PHYSICAL METAPHOR IN MILITARY THEORY AND DOCTRINE: FORCE, FRICTION, OR FOLLY?

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This study assesses the validity and general utility of selected instances of physical metaphor in tactical military theory and doctrine.

An analytical framework is built upon the curriculum of the Advanced Military Studies Program, US Army Command and General Staff College at Fort Leavenworth, KS. The advice of experts is integrated through a review of scholarly works on human communication, cognition, and complexity. A review of four historical cases is used to help scope and provide insight for the analysis. The resulting framework allows the separation of instances of metaphor, and their associated theories, into categories according to the level of complexity of the phenomena they represent. Specific evaluation criteria are developed to enable objective judgement of the justifiability and general utility of the metaphor in a 1997 military context. Individual instances of the use of physical metaphor in military theory and doctrine are treated as data. A representative sample of forty-four (44) primary sources of military theory and doctrine yields hundreds of such "data points." These are grouped by metaphor, and four of the metaphors are selected for evaluation. The selected metaphors are "center of gravity," "tempo," "phase transition," and "friction."

The study has shown that "center of gravity" is a bad metaphor because it is a degenerated term, "tempo" is a very good metaphor, "friction" is a good metaphor that has been inappropriately applied in some cases but can be saved, and "phase transition" is promising but will depend on the successful integration of complexity theory into US military doctrine.

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INTRODUCTION

Metaphor can be good, or it can be bad depending on its application. Good metaphor serves two basic purposes in explaining military theoretical concepts, but these purposes contend with one another. First, good metaphor is simple enough to provide a layperson with an intuitive understanding. Second, it is accurate and precise enough in its representation to serve as a proxy model. Bad metaphor, which results from violation of either of these rules, serves to the detriment of the military community. The body of contemporary military theory and doctrine is replete with metaphor – especially physical metaphor – and it enjoys the beauty and simplicity imparted by the good as well as the inelegance and confusion imparted by the bad. This monograph is a search for good physical metaphor – with simplicity enough for decision-makers and fidelity enough for the developers of war simulations. The target military theoretical concept is "Battlefield Dynamics."

On the field of battle, opponents try to destroy or defeat one another. To simplify their consideration, one might apply some unifying label to each of the opponents at the macroscopic level. In the closer view of the interaction of the opponents, though one finds them to be subdivided into "armed forces," "formations," and "units." In this monograph, the term "armies" will be used in a general sense to represent the highest level of aggregation in military organization. The constitution of an army's "formations" and "units" and the nature of their interaction, both within one army and between opponents, has been described by many authors throughout history. These descriptions are not all alike, and the nature of these interactions has been a matter of great debate.

Recent theories in particular claim that armies and their interactions are undergoing drastic change as a result of the emergence of new technology and concepts for its use.

Many have claimed the existence of a revolution in military affairs because of the magnitude and scope of these emerging concepts, but the authors of military theory and doctrine are still struggling to explain them. These authors face a formidable challenge: because the concepts are complex, they themselves cannot be expert at all their aspects. They are therefore *doubly* difficult to articulate to an essentially military lay-readership. In response to this challenge, writers assemble their works with the time-honored tool of metaphor.

Artists and scientists of theory use metaphor to inform or persuade. It is a powerful enabler, and it is central to the use of language. A speaker can "translate" a "meaning" to a listener of generally dissimilar background by expressing it via metaphorical reference to some specific common experience. Thus, one who articulates meaning in metaphor elicits the use of a common basis for its judgement. So metaphor is both the disembodied meaning of other words and potentially a powerful "data compression mechanism." As such it is widely used to clarify ideas in exposition and to strengthen inductive arguments of persuasion. In particular, physical metaphors have long adorned the writing of military theorists.

Physics has been a favorite source for metaphor since the dawn of the early modern age. In 1687, Newton's *Philosophiae Naturalis Principia Mathematica* (Mathematical Principles of Natural Philosophy) "established the mathematical representation of nature as the paradigm of what counted as 'science'."[1] This "natural philosophy" – later called physics – provided seventeenth and eighteenth century "Age of

Reason," "Enlightenment," and "Aufklarung" intellectuals with a common starting point. It provided an inarguably rational basis for understanding nature and thus became the template for theorists and scientists in all endeavors. Despite "counter-enlightenment" in the eighteenth and nineteenth centuries and revolutionary discoveries in physics in the nineteenth and twentieth centuries, the practice of supporting writing with physical metaphor remains commonplace. It is no surprise to find it in the works of military theorists from Clausewitz to J.F.C. Fuller and beyond.

Today's physics is vastly different from Newton's "natural philosophy." Maxwell, Einstein, Heisenberg, and many others have introduced thermodynamics, electrodynamics, relativity, quantum mechanics, and uncertainty. Similarly, the scientific method has changed. Theories still explain the nature of systems, but theoretical development is seen as a never-ending evolution of models punctuated by revolutionary shifts where whole models may be redesigned or replaced. Where theories are "different," it is usually because they are relevant, useful, or practical under different conditions. One example is the observation that special relativistic mechanics reduces to Newtonian mechanics when the system consists only of large objects in slow relative motion. Another example is the "principle of correspondence" in quantum mechanics which demands that the "quantum physics reduces to classical physics at large quantum numbers."[2]

The key word in these last sentences is "reduces." The details and dynamics of complex systems require complex theories to explain them. Therein lies the danger in the use of bad metaphor. A simple metaphor may be very convincing, but it may also be

overly reduced. On the other hand, a complicated metaphor may provide an accurate and precise proxy model, but it may be incomprehensible to decision-makers.

Clausewitz was not being reductionist when he used the Newtonian mechanical concepts of *mass, force, friction*, and *center of gravity*. These ideas were "state of the art" then – but that is not true today. Weapon systems have changed, organization has changed, and the nature of the Command and Control (C2) systems has changed most of all. Today, the application of *some* such Newtonian terms might be reductionist and inadequate to the task of providing the fidelity of an accurate and precise representation. Others might be applied *wrongly*. More modern physical theories might provide better representations.

This monograph is a critical examination of the body of theoretical and doctrinal works in which physical metaphors have played an important role. First, it lays out the theoretical foundations for discussing the linguistic role of metaphor. Then it identifies a set of evaluation criteria to judge the justifiability and general utility of metaphors used in military writing. Next, it presents several historical case studies to demonstrate its relevance and gain insight for analysis. Finally, it applies the criteria in a critical analysis of the role of a specific set of metaphors used to explain battlefield dynamics at several levels of complexity in military writing.

ISSUE STATEMENT AND METHODOLOGY

Statement of the Basic Research Question

Does contemporary theoretical/doctrinal explanation of battlefield dynamics at the tactical level of war benefit from the use of physical metaphor?

Methodology

This monograph is a search for good metaphorical explanation of battlefield dynamics at the tactical level of war. Such metaphor could be powerful literary tools for future writers of military theory and doctrine. First, the section on THEORETICAL FOUNDATIONS builds a framework for understanding the general linguistic role of metaphor. The different relevant types of military writing are classified and described in relation to one another. The role of metaphor in written communication is explained and then focused for application to military writing. A set of evaluation criteria is developed to judge the justifiability and general utility of metaphor. Then, the final part of THEORETICAL FOUNDATIONS establishes the study's relevance and gains insight for analysis by describing several cases of the historical consequences of the use of bad metaphor. It is impossible *not* to notice that the authoritative sources consulted in this section use metaphor to describe their theories. These metaphors are therefore not "data points" in this study; they are elements of the theoretical foundation. The exposition of these metaphors serves two purposes. First it demonstrates the universality of the method of metaphorical communication. Second, it illustrates the imagery actually in use by the author; therefore this monograph does not need to invent imagery probably less representative of the author's thoughts. The theoretical merits of these models are discussed so that metaphorical references to battlefield dynamics found in the study of military theory and US Army doctrine can be categorically and qualitatively judged later in the monograph.

With this framework in place, the study becomes an examination of "the military literature" to identify the instances of the use of many types of metaphor as data points.[3]

This data is then assessed qualitatively to develop an appreciation for its scope, unifying features, and the relationship between the various kinds of metaphor. This assessment becomes the analytical framework for the evaluation of specific categories of metaphor. The evaluation criteria are then applied to some of the more prominent metaphors regarding battlefield dynamics.

THEORETICAL FOUNDATIONS

Science, Theory and Doctrine

Before examining the use of metaphor by military authors, one must understand the motivation and purpose, and the relationship between the various classes or levels, of military thought and writing. "Science," "Theory," and "Doctrine" are three titles which commonly describe these classes, and the role of metaphor differs in each. The remainder of this section is an examination in moderate detail of the individual levels in the hierarchical organization of the body of military writing – in order to understand better the whole. The next section examines the role of metaphor within the context of this better understanding.

Science

It is unfortunate that many laypersons regard science with suspicion, ignorance or disdain. In their view, science inherits the general incomprehensibility of physics – the prototypical science. Science is seen by some as a waste of time that is like trying to walk to the infinity it seeks to comprehend. Others see it as the source of destructive violations of the union between man and nature. Still others see it as contradictory to their religious belief – perhaps even the work of the devil. US Army doctrine does little to correct this when it defines military science as "a systematized knowledge of the

principles of war; the systematic development, examination and dissemination of appropriate methods; and the systematic development, examination, and understanding of capabilities."[4] This description of science in terms of principles, methods, and capabilities seems mostly concerned with an end-state: the *application* of science. Science itself is really much more the process of trying to understand nature. Scientists may necessarily articulate their understanding in principles, but it is others who derive methods and capabilities.

In this way, science is really a service. In one extreme view, it serves only the individual scientist in a quest to satisfy curiosity. In another extreme, science provides the knowledge necessary for the development of technology and its application in all human activity from painting and music to warfare. In American society in general it is both – the scientific pursuit of knowledge is economically supported by the demand for applied knowledge. However, few recognize that in a very essential way, *everyone* is a "scientist." The following paragraphs place science in its proper context, hopefully with a positive image as well as an explanation of the universality of science and the applicability of the methods of science to the military.

Long ago, most "scientists" believed that Newton's natural laws were absolutely elementary – that nothing was more fundamental. Such "scientists" sought to find laws similarly fundamental in their fields; and the militaries of the world have had their fair share of such "scientists." In *The Origins of Military Thought*, Azar Gat identifies several such individuals including Guibert and Jomini who were imprisoned by the absolutist logical positivism produced by the French Enlightenment.[5] Gat believes Clausewitz was trying to escape that prison when he drafted *On War*. Physics escaped

with the development of the modern scientific method and inductive reasoning. And physicists have made tremendous progress in formulating an understanding of nature that is consistent over incredible variations in scale. Many of the basic descriptions developed by physicists apply from the subatomic to the cosmological. The more advanced descriptions include such concepts as an inherent ***uncertainty*** in some aspects of "observable" natural phenomena and an understanding that the relationships between "things" (their features ***relative*** to one another and their ***interaction***) are at least as important as the "things" themselves. Physics is a continuous search for a better understanding of nature. Though some physicists do not rule out the possibility that a single unified theory might someday explain everything in nature, all agree that there is no such theory today. Instead of looking for a complete or absolute explanation, most physicists work to develop a *better* understanding. In this effort they follow a scientific method which entails *observation*, *hypothesis*, and *experimentation*.[6] Usually, the process begins when one observes something not explained by current theories, but it could begin with any of the three phases. For most individuals, this process begins before they become aware of it, and it never really stops, though at times it seems to fade into the background as the mind focuses on the activity of the body and its relationship with others.

One's "observations" are the basis of one's inquiry into the nature of things, "hypothesis" is what reasoning gives one as a tentative answer, and "experimentation" is the way one validates these answers. It is important to understand that everyone applies this method continuously, though often not consciously. This cycle – of observation, experimentation, hypothesis, observation, etc. – is simply the way one's mind relates to

experience of the world in which one lives. It is the built-in means of preparing oneself to be better equipped to live in this world in the future. Often, in the application of this method, the demarcation of the phases of the cycle is not so clean as presented in this description. Nonetheless, this is how one formulates and justifies one's mental models.[7]

Military theorist Dr. James J. Schneider says in *The Eye of Minerva*, "it is fundamentally the role of science to provide us with an empirical method for obtaining [justified] true beliefs."[8] That method is the one described above, and its product is the mental model. However, the scientific method does not exist in each person in isolation.

When individuals communicate their hypothetical mental models to one another, they can help each other advance their understanding of the world. The result is a collective body of hypotheses that develop into something very much like what Peter M. Senge calls a shared vision.[9] This is theory.

Theory

So, a set of justified true beliefs, provided by individuals using the scientific method, is the body of knowledge that allows the formulation of theory. However, there are very few individuals who seek only to satisfy their curiosity about nature. There is also a practical "applied" side to theory. In *On War*, Carl Von Clausewitz describes the *purpose* of theory: "to clarify concepts and ideas that have become, as it were, confused and entangled."[10] In his later article, "How War Works," Schneider explains both the conceptual/cognitive view and a practical/purposive view of theory. He says theory "in-forms" the minds of those who view it, "that is, it provides a structure for clear thinking and problem solving."[11] Its practical purpose is to "lay the foundation for a rigorous system of training and education with the aim of making intelligent people war smart."[12]

Theory accomplishes this purpose in both a conceptual and a cognitive sense – it embodies the ideas and their relationship to one another, giving structure to the mind, and thinking about these ideas and their relationships to one another and other ideas is good mental (cognitive) exercise. The most important thing that theory does, however, is embody the ***collectively justified*** beliefs of the military community as a group.

Theory is too dynamic to be completely practical by itself; it changes too quickly for everyone in the military to keep up. It is a continuous expansion and reduction of problem spaces.[13] Various authors provide different sets of justified beliefs that may conflict, and each may enjoy the following of many adherents in belief. However, while these authors justify their adherents' beliefs, they typically have no authority to direct their action. Military activity in war demands an ***authoritative basis for common coherent action***. This then is doctrine.

Doctrine

Doctrine captures a coherent, holistically consistent, picture of the state of military theory at some point in time. It is published under the authority of military leadership. In the U.S. Army this process is led by the publication of *Field Manual 100-5, Operations*, (*FM 100-5*). All other doctrinal Army Field Manuals are subordinate to *FM 100-5* and are reviewed for possible revision whenever *FM 100-5* is revised.[14] This means that like science and theory, doctrine is "always dynamic, the Army's doctrine is firmly rooted in the realities of current capabilities. At the same time, it reaches out with a measure of confidence to the future."[15] Thus, doctrine strives to provide the authoritative stability required for common aim and action, not just in the present, but

also for some finite period into the future. In this way, it tries to minimize the surprise that future changes might create, so the Army is not caught too unprepared.

Therefore, the great challenge to doctrine developers is *when* to capture the snapshot. New theoretical developments are continually being given greater justification as their authors seek to gain the authoritative approval and inclusion in doctrine. How much justification is enough? How many such developments must there be before the doctrinal manual should be revised? If it is published too soon, the changes might be viewed as irrelevant or lacking in credibility (undermining the authority the changes now carry), but if it is published too late, the changes might be too grand to be implemented smoothly (undermining the common action doctrine intends to promote).

Authors of theory and doctrine can take two measures to facilitate doctrinal revision. First, authors of doctrine can remain in a perpetual process of *drafting* significant changes as they are recognized and *staffing* the draft throughout the Army (clearly noting that the draft is not doctrine). Second, both authors of theory and doctrine must carefully exercise *intellectual rigor* in their writing.

Physical Metaphor and the Importance of Intellectual Rigor

One cannot achieve clarity or a common understanding without clarity and rigor in the use of the language. On 23 February 1979, General Donn A. Starry, Commanding General, U.S. Army Training and Doctrine Command (TRADOC), began his *Commander's Notes, no. 3*, with the following paragraph:

> All professions have vocabularies of professional terms. Over time, many such terms become establishment "in-words," and are so ill-used that their original meaning is lost. Often it is only necessary to use the words to evoke affirmative head nodding; even though no meaning is conveyed, everyone professes to understand what is meant.[16]

What is Physical Metaphor?

> [According to Webster's:] **Metaphor** ... [from the Greek] *meta-* [BEYOND, TRANSCENDING] + *pherin* to bear. **1 :** a figure of speech in which a word or phrase literally denoting one kind of object or idea is used in place of another to suggest a likeness or analogy between them (as in *the ship plows the sea*) <using ~, we say that computers have senses and a memory – William Jovanovich>; *broadly* : figurative language – compare SIMILE **2** an object, activity, or idea treated as a metaphor.[17]

Physical metaphor is the set of metaphors constructed by using terms that name physical principles in place of other descriptions of phenomena. A classic example is the use of the term "momentum" in the following sentence from John L. Romjue: "Studies ... showed clearly that air and land interdiction impaired significantly the enemy's massive firepower and slowed his momentum."[18] In this example, Romjue evidently felt that "momentum" sufficiently and clearly described the phenomenon he intended readers to understand. He could have used other terms. He probably meant that the effect of interdiction was to change something "inertial" (physically or psychologically) about the enemy's advance. He probably intended to convey to the reader the idea that, because of its determined will and massive firepower, the enemy would tend to continue to advance with the same speed and in the same direction unless acted upon by some external force (such as interdiction)[19]. If it was not important to Romjue to tell the reader *which* of these changed, then he succeeded in using the metaphor to achieve brevity. He was able to present the whole idea with one word at a significantly higher level of abstraction. However, if it were important to Romjue that his reader to know, *with precision*, what the effects of interdiction were on the enemy (Were weapon systems destroyed or people killed? Did they dig in or flee? Did they slow down? Did they turn?), then the use of metaphor might be judged a failure. This information is hidden in a lower, unstated, level of abstraction. There are many other examples of physical metaphor. Some are presented and analyzed further below.

What is Intellectual Rigor?

> [According to Webster's:] **Rigor** ...[from the Latin] *rigor*, lit., stiffness, ... **1 a** (1) : harsh inflexibility in opinion, temper, or judgement : SEVERITY (2) : the quality of being unyielding or inflexible : STRICTNESS (3) : severity of life : AUSTERITY **b** : an act or instance of strictness, severity, or cruelty **2** : a tremor caused by a chill **3** : a condition that makes life difficult, challenging, or uncomfortable; *esp* : extremity of cold **4** : strict precision : EXACTNESS <logical ~> **5 a** *obs* : RIGIDITY, STIFFNESS **b** : rigidness or torpor of organs or tissue that prevents response to stimuli ***syn*** see DIFFICULTY.[20]

In this monograph the applicable definition for intellectual rigor is **4:** strict precision: EXACTNESS <logical ~>. Starry's description of "vocabularies of professional terms" illuminates the central problem of theoretical or doctrinal writing to which the application of intellectual rigor is the solution. His "in-words" are a poor choice in writing because they are ambiguous. Such careless word use results in lost meaning or, more precisely, lost clarity. Meaning is subjective; the reader determines it contextually. Only by rigorous attention to clear (precise, exact) word use can authors improve the likelihood that the meaning they intend to put in their writing is that which is found there by the reader.

Note that this places a two-fold burden on the authors of doctrine. First, they must be precise in their word choice. Second, however, and more importantly, they must be aware of the degree of precision available to them in the use of these words.[21] The precision available in a word is a feature of the community of readers.

There are several basic ways to overcome this impediment. One way would be to use only simple, clearly defined doctrinal terms. However, this is not possible when "clearly defined" to the readership and "doctrinal" are mutually exclusive, as is the case with several of the US Army's doctrinal terms.[22] Another way to overcome the burden is to define explicitly the terms in the text. However, there are problems with this method

as well. When the use of the term is quoted without the associated explicit definition, the clarity is still lost; and it is very cumbersome to attach such an explicit definition to every reference to the term. A third way to overcome the burden is to avoid the use of the term, but this would be the manifestation of what Jacques Barzun and Henry F. Graff call deterioration of language, the "carrier of meaning," in *The Modern Researcher*.[23] Barzun and Graff continue:

> ... public opinion has begun to take repeated note of the fact and some critics have gone so far as to speak of "degeneration." More than ever, the [author] who wants to report faithfully and to be understood accurately must attend to vocabulary and grammar. The pitfalls and temptations in his path multiply, for two very different reasons. One is the increasing deformation of accepted meanings; the other is the insidious influence on the mind of what we hear and read. The use of words is a social act so closely tied to communal feelings and purposes that vocables take on the coloring of the environment as they leap to our minds and come out of our lips. That is how a blunder or a smart innovation spreads and destroys. Thus *gender* has ousted *sex* with lightning speed and left *both* words indefinite, while robbing the language of a needed grammatical term.[24]

Barzun and Graff: Trafficking in Metaphor

Barzun and Graff go on to explain that "the two straight roads to meaning are, on the one hand, simple particulars and, on the other, careful generality."[25] Then, since such writing is lifeless and boring, they offer a third method:

> The road of imagery, the third, is the winding and dangerous one. Nowadays everything a writer sees and hears tempts him to take it. Advertising pelts us with images to make commonplace objects alluring; business and professional men think to enliven their work by refreshing its vocabulary with new images, and statesmen and journalists try to influence our minds with slogans and catch-words based on images. All this is an indirect tribute to poetry, of course; meantime, the residue left in the writer's mind is jargon.[26]

The purpose of this discussion has not been to whine about the state of the English language nor about the difficulties facing authors. Rather it has been to place in context the use of metaphor, and now its role should be clearer. There along Barzun and

Graff's "winding road" whereby authors use imagery to deliver meaning is the traffic of metaphor. Some of the sturdy trucks faithfully deliver their cargo (meaning), but others break down, collide, get lost, or go off the road, taking their cargo with them.

Barzun and Graff are describing communication via metaphor, with their own metaphorical image. Specifically, this model for communication treats the content of the metaphor as a "commodity." Whether the content/commodity is information or something *representing* information (like "data" or a "signal") is a matter for careful consideration, but it is beyond the scope of this monograph. Here, however, one should appreciate the idea that something, maybe "information," maybe not, is transported and distributed. This concept is embedded in all levels of information and communication theories, and therefore it is relevant to the idea of communication via metaphor.

Hayakawa: Metaphor as Affective Communication

The utility of Barzun and Graff's "winding road" is limited, however. S. I. Hayakawa also describes how language carries meaning. In *Language In Action* he describes "affective communication" involving both "informative" and "affective" uses of language.[27] Informative language is symbolic: it uses things (words) which "stand for" other things ("objects"). Says Hayakawa, "human beings... can make anything stand for anything [having agreed how to communicate verbally]. We shall call that system of agreements *language*."[28] The discussion of Barzun and Graff above illustrates that language intended as informative is not informative if the connection between the symbol and the symbolized is lost. "Affective language" is "presymbolic." It is human communication *expressing* the speaker's internal conditions rather than *reporting* them. Social interaction such as verbal greeting, flirting, arguing, or fighting often involves this

kind of language. The sounds of the words (the symbols) have little or no real meaning attached to them, but they are completely successful in the way they affect their recipient. Hayakawa describes generalized "Affective Communication" involving both the affective and the informative connotations of words. He writes,

> Metaphors are not "ornaments of discourse"; they are direct expressions of feeling and are bound to occur wherever we have strong feelings to express. They are to be found in special abundance, therefore, in all primitive speech, in folk speech, in the speech of the unlearned, in the speech of children, and in the professional argot of the theater, of gangsters and other lively occupations... No implication is intended, however, that because metaphors ... are based ultimately upon primitive habits of thought they are to be avoided. On the contrary, they ***are among the most useful communicative devices we have***, because by their quick affective power they often make unnecessary the inventing of new words for new things or new feelings. ... Metaphors, that is to say, are so useful that they often pass into the language as part of its regular vocabulary. ***Metaphor is probably the most important of all the means by which language develops, changes, grows, and adapts itself to our changing needs***. When metaphors are successful, they "die" – that is, they become so much a part of our regular language that we cease thinking of them as metaphors at all.[29]

Thus metaphor enables a speaker to "translate" meaning to a listener of generally dissimilar background by expressing it via metaphorical reference to some specific experience the speaker and listener have in common. It is an efficient and effective method because it is both informative and affective. Military authors have made much use of metaphor, and the general success of that use has produced many "dead" military metaphors. These are those that were so successful that they are not generally considered metaphors anymore, but rather a part of the regular military language. Military "force" and combat "power" are two such successful and therefore dead metaphors. These particular metaphors are in fact so dead that they are excluded from the study.[30] A danger can arise however, if "dead" metaphors become Starry "in-words" devoid of meaning.

Dörner: Cognition Through Analogy

Both of the models above for the role of metaphor deal with its role in *communication*. Dietrich Dörner discusses metaphor's *cognitive* role in his book, *The Logic of Failure,* in the context of a generalized planning process, something quite germane in the military. In Dörner's generalized planning process "we don't *do* anything; we just consider what we *might* do. The essence of planning is to think through the consequences of certain actions and see whether those actions will bring us closer to our desired goal."[31] When viewed together with the implied decision about what do, his description is similar to the Military Decision-Making Process (MDMP). US Army *Field Manual 101-5:* "Staff Organization and Operations" (*FM 101-5*) begins its chapter on the MDMP in a similar description: "Decision making is knowing *if* to decide, then *when* and *what* to decide. It includes understanding the consequence of decisions. Decisions are the means by which the commander translates his vision of the End State into action."[32] Both Dörner's planning process and the MDMP apply an "analytical approach to problem solving."[33] In Dörner's vocabulary, this analytic approach is an investigation into a sector of reality – what he calls a "problem sector." In general, he claims,

> the vastness of problem sectors prohibits us from investigating them completely, we must narrow our focus... there are many methods of narrowing our problem sectors ... [however] methods for narrowing problem sectors make methods for expanding them necessary too. Narrowing a sector lets us operate in a surveyable field, but the possibility exists that we are in the wrong one... there are several ways [to change our field]... Perhaps the most important method for expanding a problem sector *is thinking by analogy*.[34]

In thinking by analogy (metaphor or simile) one can gain insight into the dynamic complexity of a system and the inter-relationships of its critical variables. If the metaphor comes to one individual from someone else, that communication is affective in Hayakawa's words, or effective transportation of meaning in Barzun's. Even if one

achieves this understanding in isolation, the metaphor is the concept one has in mind *a priori* and from which one develops new beliefs. To the degree that one is justified in these new beliefs, they constitute new knowledge. What is unique so far in this description, however, is that the new knowledge has been *synthesized* in the mind. There has been some kind of a ***cognitive*** event.

Wittgenstein and Casti: Metaphor as the Catalyst of Emerging Knowledge

If one connects both the *communicative* models of Barzun and Graff and Hayakawa with the *cognitive* model of Dörner, the result is a communication that involves the receipt of one meaning and results in the synthesis of another. The recipient derives meaning from the linguistic symbolic (informative) and emotive presymbolic (affective) content of the metaphor.[35] Curiously, however, since the "traffic" was a metaphor rather than a direct linguistic representation, once the new meaning is realized, the metaphor may no longer be necessary to sustain it. In fact, if the inductive leap goes far enough, the metaphor may not even be *sufficient* to sustain the new knowledge. According to John Casti, this is the conclusion Ludwig Wittgenstein eventually reached.[36]

Wittgenstein is well known for his formulation of the linguistic theory of knowledge. According to this belief, one knows only what one can articulate using language. Casti references Wittgenstein's later work and claims it implies that one cannot use language to "'say' the link between the language and the real world." Rather, this link can only be "shown."[37] It is a surprise to hear this from Wittgenstein because it seems to contradict the central idea of his theory. Rephrased by a linguist it would say that it is impossible to articulate meaning, which therefore implies that one *cannot know* the meaning – of anything. But another way to put it is: Language alone is insufficient to

sustain meaning. Cognition is the faculty with which the mind derives meaning from language by contextual association with other informative symbols and emotive presymbols. So, says Casti, Wittgenstein changed his mind when he realized this. Casti quotes Wittgenstein:

> My propositions are elucidatory in this way: he who understands me finally recognizes them as senseless, when he has climbed out through them, on them, over them. (He must so to speak throw away the ladder, after he has climbed up on it.) He must surmount these propositions; then he sees the world rightly.[38]

Wittgenstein's metaphor of throwing away the ladder is a concise statement of a completely different epistemological concept.[39] It illustrates, by its own example, what happens in metaphorical communication. Once the metaphor has elucidated meaning for the reader, it is no longer needed. This clarifies Hayakawa's claim that metaphor is "among the most useful communicative devices," since it permits language to "grow and adapt to our changing needs."[40]

The counter argument is that metaphor has a "dark side." Because it produces new meanings, metaphorical communication actually causes the degeneration of language that Barzun and Graff mention. Each time someone uses a metaphor in a new way, the old word becomes attached to the new context. By its very use in the new context, the meaning of the old word is affected. In fact, the more effective the metaphor, the more likely the new context is to influence the meaning. Combat "power" and military "force" are good examples. Their meanings in military application are now quite different from the physical meanings from which they were derived.

Piattelli-Palmarini: The Dark Side of Metaphor

The danger in this production of new meanings is that it can facilitate or manifest what Massimo Piattelli-Palmarini calls "cognitive illusions" or "mind tunnels." As he

points out in *Inevitable Illusions*, "Cognitive illusion is not an ordinary blunder; it does not originate in guesswork but from the formulation of a potent although mistaken intuitive judgement that, at least at first sight, convinces us within ourselves."[41] Piattelli-Palmarini continues, explaining:

> There exists in our nervous and mental systems certain circuits and computations that are autonomous, specialized, and by and large insensible to factors we know in other ways... Angelic is a component that is able to make us reject a perceptual hypothesis that has become untenable and find another, contrary one. Diabolical, on the other hand, is ***the tenacity with which these modules hang on to a mistaken hypothesis until it becomes truly unsustainable***. Demoniacal, too, is the illusory reconstruction of a [continuity, disregarding implausibility and factual unreality].[42]

Piattelli-Palmarini describes eight kinds of "mind tunnels" associated with seven "deadly sins" of everyday irrationality or judgement under uncertainty. Metaphorical communication and metaphorical mental modeling can facilitate three of these sins. First, metaphor can generate "***magical thinking***." Piattelli-Palmarini states a psychological law "endlessly confirmed, even among professionals and experts:

> When someone is convinced of a positive correlation, however illusory that correlation can objectively be shown to be, that person will always find new confirmations and justify why it should be so.[43]

This makes metaphor dangerous because readers are likely to believe false claims based on a metaphor that seems coherent with their other beliefs – regardless of the truth.

Second, through its affective or emotive component, metaphorical communication facilitates "***ease of representation.***" Piattelli-Palmarini says that British philosopher Bertrand Russell "identified [emotion as] the force behind 'popular inductions,' which are kinds of spontaneous generalizations" such as those one might draw from a newspaper or television story:

> The easier it is to imagine an event or situation, and the more the occurrence impresses us emotionally, the more likely we are to think of it as also objectively frequent... [despite the fact that] emotional factors... do not suffice to explain these phenomena.[44]

This makes metaphor dangerous because readers are likely to believe a claim to be true *in general* when it is presented with or as an emotive metaphor – despite the actual falsity of the claim in most circumstances.

Third, metaphor can facilitate Piattelli-Palmarini's seventh "deadly sin," "***reconsideration under suitable scripts***." Piattelli-Palmarini says, "our judgement allows itself to be influenced by fictions, including... the fruit of pure invention."[45] This is a general weakness to which all humans are evidently susceptible. Inductive arguments are chains of linked premises and propositions, many of which *cannot* be *absolutely* true. These can only be shown to be *likely* or *probably* true. Probabilities are mathematically expressible as fractions (less than one) and the probability of a conjunction is the product of the probabilities of its constituents. Therefore, "the probability of an entire [chain of inductive argument] being true is *always and without exception less probable than the probability of the least likely link in the chain.*"[46] Piattelli-Palmarini calls this "the conjunction effect." Humans are evidently more likely to believe a conjunctive chain of argument, in which there are some probable links and some improbable links, than they are to believe the argument's individual improbable links.[47] This occurs despite the mathematical ***fact*** that such conjunctions of premises and propositions make it ***impossible*** for the whole argument to be more likely true than its weakest links.

This makes metaphor dangerous because it can strengthen some links of an argument, in which other links are weak. Thus, the metaphor makes the whole argument *seem* stronger, when in fact it *cannot* be.

As illustrated above, there are two general categories on the "dark side" of metaphor. One is that metaphor can support the human weakness of cognitive illusion and result in irrational judgement and decision-making. The other is that it can create new meanings for words and cause the degeneration of language.

However, the existence of a "dark side" of metaphor does not mean that metaphor must be avoided. Authors must understand how useful it is and that it is also dangerous. Therefore, they must be careful applying it. As Casti explains using Goedel's Incompleteness theorem, it is impossible to linguistically symbolize everything.[48] So, metaphor makes linguistic communication possible where formalized symbols (words) do not exist – one can say with a metaphor what cannot be said in other words. One might even argue that some communication would be impossible otherwise.

The paragraphs above have shown how metaphor can be a solution to problematic communication, or it can be part of the problem. The same linguistic tool that can support irrationality or cause degeneration of language can also catalyze growth or adaptation and facilitate rational communication.[49] This means that the basic research question in this study (Does contemporary theoretical/doctrinal explanation of battlefield dynamics at the tactical level of war benefit from the use of physical metaphor?) can only be answered on a case-by-case basis. The next section provides a method for classifying instances of metaphor by their level of complexity. This method helps to scope and frame the basic question.

Maruyama, Waldrop, and Casti: Classifying Metaphor by Level of Complexity

The double-edged feature of metaphor also means that the result of a reader's cognition is not completely determined. Two readers could be affected differently by the

same metaphor and thus receive different meanings. However, as readers share their views about what they have read, their dialogue will result in a better collective understanding. They synthesize new knowledge in two stages. First, they read it and glean their own understanding. Then they share and improve their understanding. So, the degeneration of the language is partially counteracted. The readership is a complex, adaptive, self-organizing system.

In "Information and Communication in Polyepistemological Systems," Magoroh Maruyama develops an idea of "contextual information" which helps explain the subjective nature of metaphor outlined above. He contrasts this view with the traditional Western view that he calls "classificational." The table below restates the differences between the two views.[50]

	"Classificational Information"	*"Contextual Information"*
1	Universe consists of "objects" which have "identity" and "mutual exclusion" and can be classified into a hierarchy of categories	The universe is basically heterogeneous
2	Increasing categorical Specification, implies an increase in information "value"	The universe consists of interrelations and interactions and everything occurs in a context that may vary. Therefore the value of information lies in relation to its context (interrelations)
3	A "piece" of information has an "objective" meaning which is universally understandable without reference to other pieces of information	"Objective" meaning is useless; there is no universal meaning; each piece of information must be interpreted in the context of other pieces of information and in terms of the given situation
4	Discrepancies within a message or between messages must be errors	Differences within a message or between messages convey information about the interrelations, just as in binocular vision, the differentials between two images enable the brain to compute an invisible third dimension

Maruyama's idea is relevant to the discussion of metaphorical communication because it illustrates the self-contradiction built into the traditional western view of information. A detailed discussion of this contradiction is beyond the scope of this monograph, but one can easily see that those who seek to hierarchically classify and specify everything in detail will eventually have too few words with which to do it. Thus,

they must re-use a word as a metaphor. In the hierarchical classificational view, this is the antithesis of what one should do. It amounts to a "loss of information" about the meaning of a linguistic symbol (word). However, in the contextual view, there is no loss of information because the linguistic symbol only has meaning in context – which could be infinitely varied.

Maruyama uses the human capability of binocular vision to explain "contextual information." All predators have depth perception. A predator must see in three dimensions in order to judge the distance to its prey. Predators like humans are well designed for this with two eyes at the front to the head so there is a large region of overlap between the images captured by the eyes. However each eye only provides the brain a signal that is the aggregate of the stimuli from the photoreceptors in the retina – an encoded representation of the two-dimensional image projected onto the retina. The mind processes each of these signals in the context of the other and in the context of other sensory and memory information. In this way, the mind is aware of the small differential created by the different perspective that each eye has (the eyes lateral spacing on the face causes this differential). Thus, the mind becomes cognizant of information that is not available in either signal – a third dimension. A differentially coded drawing has been included with viewing instructions at Appendix 1, so the reader may verify this ability.

Maruyama subsequently breaks these two categories down further into four categories. He calls these epistemological categories, but they also exhibit different levels of complexity. Though there is no explicit reference to any common influence, these four categories correspond exactly to the four categories of types of system behavior identified by M. Mitchell Waldrop in *Complexity*, and Casti in *Complexification*. Selected portions

of Maruyama's table are presented in Appendix 2; two rows are added to show the connection to Waldrop and Casti's categories and the order is changed to reflect the same order Waldrop uses.[51]

Maruyama's Homogenistic, Hierarchical Classificational category corresponds to Waldrop's Category I.[52] This is the lowest level of complexity. In fact, phenomena in this category demonstrate Convergent Order. They move toward a single-valued solution. This is the category he uses to describe "conventional western thought." It is somewhat ironic that Maruyama exhibits a strong tendency to hierarchical classification. The rest of his categories are Heterogenistic.

His second category is Homeostatic, which corresponds to Waldrop's Category II.[53] Phenomena in this category exhibit periodic order. They are structured around some form of equilibrium, but they oscillate about the equilibrium point rather than converge into it.

Maruyama's calls his third category Isolationist (from his epistemological perspective). This category corresponds to Waldrop's Category III (Chaos). Phenomena in this category exhibit aperiodic behavior. There are no patterns, no apparent governing rules, no order whatsoever.

Maruyama's fourth category is Morphogenic.[54] This corresponds to Waldrop's Category IV. Phenomena in this category are what Waldrop calls "complex" – those on the "edge of chaos." These phenomena involve systems that, with the help of a catalyst, will exhibit emergent behavior or evolution.

The table at Appendix 2 lists the categories in the order I, II, IV, III because category IV is the transitional category between the ordered categories (I and II) to the

chaotic category (III). Thus the table progresses from left to right in increasing degree of disorder and complexity.

The reader can use these categories to describe metaphorical instances in the works of military authors. This may help the reader discover how the author thinks about the level of complexity in the phenomenon he is describing, and it can help the reader classify the author's theory by the complexity-level of its metaphors.

The explanation of how this classification of metaphor can be applied to a critical study of military writing is presented in the ANALYSIS portion of this monograph, below. The following section examines what some respected authors of military writing have to say about the use of metaphor. It also examines the specific use of physics as a source of metaphor.

Metaphor in Military Writing

Clausewitz: On Metaphor

Carl Von Clausewitz describes in *On War*, Chapter Five, Book Two, a method of "critical analysis" in the study of war that involves the testing of theoretic truths by application to actual events. He describes this method in detail, including its aim in advancing theoretical understanding. He says, "These truths should always be allowed to become self-evident, while only the more precise and complex proofs are left to theory. We will thus avoid using an arcane and obscure language, and express ourselves in plain speech, with a sequence of clear, lucid concepts. ...Granted that while this cannot always be completely achieved, it must remain the aim of critical analysis."[55] He then describes what he feels to be the three biggest reasons critical analyses of the past had failed:

> [1] The first common error is an awkward and quite impermissible use of certain narrow systems as formal bodies of laws. It is never difficult to

> demonstrate the one-sidedness of such systems...[but] this error is the lesser of the two evils that concern us ... [2] A far more serious menace is the retinue of *jargon, technicalities, and metaphors* that attend these systems. They swarm everywhere – a lawless rabble of camp followers. Any critic who has not seen fit to adopt a system – either because he has not found one that he likes or because he has not yet got that far – will still apply an occasional scrap of one as if it were a ruler, to show the crookedness of a commander's course. Few of them can proceed without the occasional support of such scraps of scientific military theory. The most insignificant of them – mere technical expressions and metaphors – are sometimes nothing more than ornamental flourishes of the critical narrative. ... [3] third failing: showing off their erudition, and the misuse of historical examples.[56]

Despite his criticism of the use of metaphor by others, Clausewitz himself is probably the most prolific military author of metaphors. He gives us such images as "center of gravity," "culminating point," "friction," and "fog;" he describes lines of communications as "arteries;" he calls units "building blocks" for larger "structures;" and he talks about an army as a "monolith" becoming a "many-jointed entity which was pliant and flexible."[57] Some of his metaphors are discussed below; his relevance in this monograph is his role as both a critic and an author of metaphor.

In the tradition Clausewitz established (or criticized depending on one's perspective), most authors of military theory and doctrine use metaphors. John L. Romjue's comments about the authors of the 1982 version of *FM 100-5* are applicable to military authors in general. The type of success the 1982 manual writers achieve is the goal of all military writers. Romjue claims:

> ... the clear turn of phrase and apt metaphor that readers of the 1976 manual had found striking were not lost in the new version. Conscious that clear ideas turn on cogent phrase and lucid writing, the manual writers worked to avoid the pitfalls of jargon and specialty speech. Here they borrowed and invented, employing, for example, the arresting Clausewitzian image of the defense as a 'shield of blows,' along with the AirLand Battle concepts of *deep battle* and of *collapsing* the enemy's fighting structure.[58]

Brinton: Metaphor as the Theory Itself

The military use of metaphor described above exemplifies both affective and informative use of language and "meaning transport," but there is yet another way to look at metaphor. Crane Brinton, author of *The Anatomy of Revolution*, describes a scientific method that produces a "conceptual scheme" similar in definition to Senge's "mental model." He claims that "in the social sciences, at least, the distinction between a conceptual scheme and a metaphor is still an uncertain one, and there is no great harm in looking at our present problem as a search for a metaphor to hold together the details."[59]

In Brinton's view, the mental model (and thus the theory) is indistinguishable from the metaphor. The theory *is* the metaphor and the metaphor is the theory. In one sense, such metaphors, when formalized, are the foundations of new paradigms. There are many examples of this kind of metaphorical construction in the body of military writing as well. Identifying these theory-as-metaphors is not always easy, though. To do so, one must answer an important question about these theories: Is the author using the metaphor in a literary sense (to transport meaning by affective or informative communication), or is he or she using the apparent metaphor in a literal sense (as a statement of theoretical principle)?

Science, Art, or Pseudo-science – Invoking physics in military writing

Is it metaphor or is it a statement of theoretical principle? Some references to physics in military writing appear not to be metaphor at all. In Brinton's case the author clearly asserted the role of his metaphor-theory. Many other authors do not. They leave it to the reader to answer this question. In some of these cases, physical principles are quoted accurately in the expression of scientific fact pertinent to some aspect of warfare.

There are other cases where it is not entirely clear if an author intends to use physics as an artistic metaphor or as a physical first principle for his theory. In these uncertain cases, if the reader perceives that author seeks the former (metaphorical expression) and fails to convey his understanding, then the reader judges the author a poor artist. However, if the reader perceives that the author seeks the latter (physical principle) and fails to convey his understanding, then the reader tends to label the author as a pseudo-scientist. Pseudo-science is the kind of thing Clausewitz speaks of with contempt in his chapter on Critical Analysis, discussed above. J. F. C. Fuller even goes so far as to label the unscientific study of war "Alchemy" – a powerful affective image connoting evil and irresponsibility to society.[60] Fuller's disdain is actually more focused on those who adhere to the idea that there is no place for any "science" in war. However, in the context above, the term might even be applied to Fuller. His *Foundations of the Science of War* was never widely accepted and is based on pseudo-science, or more accurately an incomplete, inaccurate and imprecise science.[61]

The relevance of the classification of pseudo-science and alchemy is that since they entail arguments based on false-science or non-science the very meaning they convey is falsehood. The implication here is that authors who use physical metaphor ineffectively and authors who articulate scientific principle poorly end up in the same category as authors who intentionally engage in pseudo-science or alchemy. In one case the author fails to deliver truth, and in the other the meaning delivered is simply false. The distinction is subtle, but it is important in this critical analysis since it is a moral judgement of the author's character and not his work. Therefore, this monograph

assumes that any such work found in its analysis is ineffective metaphor since there is no *practical* difference.

The labels "pseudo-scientist" and "alchemist" are not be applied to the subjects of this investigation and all instances of the application of physics in military writing are treated equally. Therefore, henceforth they will all be labeled "metaphor" for simplicity. The evaluation criteria defined below are developed to judge positively a useful, correct statement of physical principal– just as they would a useful, accurate presentation of a physical metaphor. In order to be "good," metaphor must maintain fidelity with the phenomenon it describes (rigorous completeness and correctness in formulation) and coherence with its author and audience (simplicity and unambiguousness).

Evaluation Criteria

The following criteria are designed to evaluate instances of metaphor in military theory and doctrine in the context of 1997 reality and the analytical framework established in the Advanced Military Studies Program at the US Army Command and General Staff College, Fort Leavenworth, Kansas. The evaluation judges the justifiability and the general utility of such metaphor. Therefore applying the criteria does more than validate a hypothesis (that a particular metaphor is valid). It also judges the utility (that the metaphor is good). Note also that because the 1997 context is used for evaluation, the question is not whether the metaphor was good when the author used it; it is whether the metaphor is good for us today (and likely to remain good).

FIDELITY – The metaphor should be rigorously derived and developed. It should also accurately and precisely represent the phenomenon. Fidelity is measured via

the quality of the ***formulation*** and the rigorous ***correctness***, ***completeness,*** and ***correspondence*** of the metaphor.

Formulation – Can an image or mathematical representation be extracted from the metaphor? (Yes is good.) In order to be of utility, the metaphor must provide a compact mental model of the "form" of the phenomenon. Most often, this is a description of the way in which objects within a system interact with each other and objects in other systems. Formulation is achieved by the use of literary or artistic image or mathematical representation. A metaphor that does not generate a mental model is a bad metaphor. A good metaphor generates a mental model of the dynamic nature of the system and its critical variables.

Correctness –Are the physical principles in the metaphor cited correctly and used appropriately? (Yes is good.) A metaphor based on bad physics is a bad metaphor because even in the best case it cannot evolve with improved understanding (or more complete expression) of the physics. In the worst case it misrepresents the phenomenon in all situations. Therefore, even if it succeeds in delivering its meaning, that meaning is false.

Completeness – Has the formulation been well developed? (More is better.) A good metaphor is complete enough to represent the phenomenon in all reasonable circumstances. A metaphor based on an incomplete formulation is bad because it causes reductionism in thought and inconsistency in action. Dynamic systems cannot be completely represented by a static model. However, one should recognize that completeness might contend with simplicity.

Correspondence – Does the formulated description correspond with a proper scaling of other generally accepted models? (Yes is good.) In principle, correspondence means that the metaphorical model can be reduced to produce an agreement with other accepted models or other models can be reduced to produce an agreement with it. A good metaphor obeys this correspondence principle. A metaphor in doctrine that does not "correspond" is bad. Note that in *theory*, correspondence is not always a requirement, though it is desirable. Theory has the job of persuasion, and it is much easier to persuade others about a theory when it "corresponds" to their existing beliefs. Only accepted, corresponding theories should find a home in authoritative doctrine, however.

COMMONALITY -- The metaphor should be common enough in its expression to serve reliably as a basis of common experience for the military lay-readership. The language used to explain the metaphor should be simple but unambiguous. Only this commonality in experience makes a metaphor produce the same meaning in its reader as is intended by its author. Commonality is measured with ***reliability***, ***simplicity*** and ***ambiguity***.

Reliability – Has the metaphor been used in the same way by many independent authors over a long period?[62] (More is better.) A reliable metaphor is one that has "stood the test of time." Note that there are three important factors in reliability. First and most important, the metaphor must be used in the same way. Many physical principles (such as "mass") have become metaphors with a wide range of meanings. The second and third components of reliability are the number of authors and time. It is tempting to think that reliability could be quantified in cumulative author-years (the sum of the number of years all discovered instances have been published). However, this would falsely indicate that

a sudden appearance of a metaphor in many authors' works means that its use will continue and carry the same meaning for a long time.[63] A better quantitative measure of reliability is years since its first occurrence.

Simplicity – What level of study of physics is required to comprehend the metaphor? (Less is better). Note that simplicity is a characteristic of the *EXPRESSION* of the metaphor. It does not imply that the metaphor must represent a simple phenomenon. Many complex phenomena can be described by simple metaphorical expressions – as such they are amazingly efficient methods of translation. On the other hand, an overly complex metaphorical expression is bad because its lack of simplicity makes it incomprehensible to the layperson.

Ambiguity – Is the common experience attached to the metaphor single-valued? (Yes is good). The metaphor should unambiguously carry the same meaning to all its recipients. Ambiguity is avoided through intellectually rigorous use of language. Terms must be clearly defined, and more importantly, these definitions must be faithful to both the phenomenon and the common understanding. A good metaphor serves its purpose by clarifying and forming a basis for a common understanding. Metaphors described in imprecisely defined terms are bad. Also, metaphors described in terms that tend to have strongly different subjective meanings are bad whether or not they are precisely defined in the description.

The Historical Consequences of Bad Metaphor

The cases presented below illustrate what can happen when a bad metaphor gains authority. It is not the aim of this monograph to prove the cause and effect relationship between the metaphors and the effects. The authors cited below have taken that on as

their task, and they provide keen insight into the workings of the collective mind of the military.

Case 1: The Key to the Country – Not

Clausewitz provides an example of the danger of the blind application of scientific metaphors in his Book Six of *On War*. He may have this specific case in mind when he describes in Book Two, as outlined above, the failings of critics and their attendant "lawless rabble of camp followers."[64]

He says: "there is no theoretical subject dearer to the hearts of critics than the one under discussion here: It has been a prize exhibit of innumerable accounts of battles and campaigns, the favorite theme of all arguments – one of those ***pseudoscientific terms*** with which critics hope to show their erudition. Yet the underlying concept has neither been established, nor even clearly defined."[65] The idea of a "key to the country" is an extension of the thought that *certain* points have "*exceptional* importance" and may be decisive, as is having the right key when opening a lock. Clausewitz continues, describing the origin of the term "When a road traverses a mountain ridge, the traveler breathes a sigh of relief... this holds true of an individual, and even more so of an army. ... The country is spread out before us and appears to be at our feet, ***metaphorically*** as well as physically. Thus, the highest point of a road across the mountains has usually been considered the decisive one."[66] Clausewitz notes that this idea may have been true in some cases, but certainly not in all. He also notes that this idea merged with the related idea of defense of mountainous terrain. Here, he says, critics espoused the notion of organizing "a mass of tactical elements relevant to mountain warfare."[67] The ridiculous result, he says is the "highest *point on a road* being the key to the country was

replaced by the highest point in the mountains – in other words, the *watershed.*"[68] To compound the issue, this was coincidentally the time (end of the eighteenth century) when "new theories began to be disseminated concerning the formation of the earth's surface by erosion. Natural science, in the form of this geological system, became the ally of military history. ***This broke the dam of practical common sense; sensible discussion was swept away in a flood of illusions based on geological analogy***. [As a result, in 1814], in obedience to the theory, an army of 200,000 men was forced to make a senseless march through Switzerland to get to Langres."[69]

Case 2: The British Fiasco in the African Desert

Correlli Barnett's *The Desert Generals* is frequently quoted, albeit controversially, as evidence that leaders must be highly technically competent. Barnett's Operation CRUSADER archetype is General Alan Cunningham. The Commander-in-Chief, Sir Claude Auchinleck, made Cunningham the commander of the Eighth Army. At the time, 1941,Cunningham was famous for his great success as a commander of infantry in East Africa. His competence was quite well established, but he was unprepared for the scale and complexity of armored operations in North Africa. Barnett says:

> He knew little about armour and had never commanded it. This was true of all British officers of his rank. But whereas O'Connor had had six months of relative quiet in which to learn it, Cunningham had two [months] at a time of frantic preparation and rapid expansion. He was to control a swiftly moving armoured battle against Germans who had been practising tank warfare in the field since 1936; yet when he first reached the desert he so little understood radio-telephony that he is remembered fumbling helplessly with a radio-telephone, trying to use it like an ordinary telephone.[70]

The story above is presented as much for its affective as for its informative content. For Barnett, it set the stage for his assertion that "sureness of command depends

on professional knowledge and experience. However great the qualities of leadership in a man, he cannot make use of them unless he is a master of the technical details of his profession..."[71] There are two questions though: What was the problem? and How did it get that way in the first place? Barnett answers the first question above, but the second one is more pertinent to this monograph. He answers it twenty pages later:

> After the First World War, few officers thought there would be another major war, the concept of tank warfare, which by 1918 had progressed as far as deep break-throughs, seemed irrelevant. One or two radical theorists such as Liddell Hart and Fuller proclaimed that the future army should be based on the tank... [but the British never progressed beyond experimentation and] balked at destroying the cavalry regiment... Cavalry was too well protected by its influence in high military and political circles to give the smallest hope that a plan for its destruction would ever mature. There was also the emotional pull, the veneration that ancient regiments exercised even over the British military radicals. ***The problem was solved by sliding easily along a fallacious analogy***. A modern armoured corps performed the same function as an antique cavalry corps – reconnaissance, shock action, mobile exploitation... Therefore it was obvious that the cavalry should be converted to armor... There had been no such fundamental thinking and no such fundamental agreement about their role and organisation as Guderian had fostered in Germany; on the contrary there was the uneasy marriage of the 'tank-alone' school of the Royal Tank Corps [which had evolved from experiments], and the 'armour-is-cavalry' school of the cavalry. [Britain got a late and disorganized start to the Second World War] ... in their half-baked British way, the British were still cobbling together with empiricism and pragmatism a panzer arm. Only in 1940 was the Cavalry Division in Palestine converted (with reluctant emotions) to armour.[72]

It is no wonder that Cunningham was not qualified to command the Eighth Army. The British, as a whole, had not figured it out yet.

Case 3: Seeking Decisive Victory in World War I

The 1700's perception of armies was one of ***monolithic formations*** that could be shattered like a crystal hit with a hammer. According to Robert M. Epstein, this changed when the armies of Napoleon exhibited a new degree of "flexibility."[73] In Epstein's description, Napoleon's armies consisted of *several* corps that were large, operationally

durable, formations. These formations conducted distributed maneuver by moving along separate routes under a system of decentralized command and control. Says Epstein, "the days of armies moving as unitary blocks under the direct command and control of the Commander in Chief were gone."[74] Napoleon's battles prior to Jena/Auerstadt (1806) pitted a modern French army against "antique" opponents, and Napoleon's command system could overcome the inevitable "friction" of battle as long as this overmatch existed.[75] However, as early as 1809, Napoleon's enemies began to adopt his methods and make up the difference. The transformation of battlefield dynamics was manifest in the emergence of distributed operations on both sides. Warfare was no longer like a collision between billiard balls. Now, it became a "collision of large armies on extended fronts."[76]

There were many changes impressed atop the Napoleonic model between 1809 and 1914, but this metaphorical mental model for warfare was still the dominant feature at the onset of the First World War. Armies were not "unitary blocks" or "monoliths," but they consisted of large ***monolithic formations*** which were mobilized, moved, and maneuvered into collision with the enemy. The enemy had the same features, and one side tried to "shatter" or "smash" the other.[77] In the late eighteenth century and early twentieth century, however, a period of rapid industrialization, deployment and lethal fires played a role of elevated importance. Theorists struggled with the question of how to best use the massive armies that a nation could raise. Most ideas were unsuccessful, and the only recourse was to "hit first" – when and where the blow would not be stoppable. This problem is reflected in the pre- and early-World War I activities of all the major belligerents. As Michael Howard says in his article "Men against Fire,

> When war broke out in Europe in August 1914, every major belligerent power at once took the offensive. The Austro-Hungarian Army invaded Poland. The Russians invaded East Prussia. The Germans invaded France through Belgium; and the French tried to reconquer their lost provinces of Alsace and Lorraine. By the end of the year every one of these offensives had been checked or *repulsed* at a cost of some 900,000 missing, prisoners, wounded, or dead. The attacks continued through 1915, when Italy attacked Austria with equally disastrous results; through 1916, when the Germans assaulted Verdun and the new British armies entered the war with their great offensive on the Somme; and began to falter only in 1917, when after Nivelle's disastrous offensive in April the French troops refused to attack again and the Russian Empire collapsed under the strain of the war. These disasters, compounded by the failure of the four-month British offensive at Paschendaele from August to November 1917, have left a historical image of strategic and tactical blindness virtually unparalleled in history, an image that the successful German offensives on the eastern front have done little to redeem.[78]

But Howard goes on to explain that though the planners of such operations may appear blind to us today, they were not. They knew that they would not win without suffering heavy losses, but they thought they *could* win – based on moral superiority.[79] Many factors affected the decisions of the time including lethality of fires and the reliability of troops. As had been most strongly stated by COL Ardant du Picq in 1865 in *Battle Studies*: "Jomini speaks of charges at a trot against cavalry at a gallop... Jomini insists on the effect of shock. The trot permits that compactness which the gallop breaks up. That may be true. But the effect is moral above all."[80] Du Picq explained that the moral effect here was "resolution." While the gallop might give a combatant more speed and therefore more "energy," resolution was more important. In du Picq's own words, "R is worth more than all the MV^2 in the world."[81] He did not say Jomini's prescriptions were *completely* invalid. Rather, he felt the combat commander could use Jomini's "principles" to achieve a *physical* position from which he secured a ***moral*** advantage. If the commander won, the moral advantage, not the physical one, was the cause of victory. For du Picq, the commander had to first understand the soldier's instinct. Then the

commander had to maintain order and direct movement in harmony with that instinct.[82] This would support the soldiers' morale. This higher morale or "moral ascendancy" would make the soldiers more resolute. Remember, "R is worth more than all the MV^2 in the world."[83] Let the enemy charge at a gallop -- and run into a brick wall! While du Picq is often considered a proponent of the bayonet charge, he should really be credited with understanding the psychological (moral) contribution of resolution.[84] It is the measure of the soldiers' tendency to continue their actions despite those of the enemy. This is the moral equivalent of the physical principle of mass – the measure of an object's tendency to continue in its state of motion, i.e. to resist acceleration.

The importance of this notion of resolution was extended all the way to the national levels and eventually the war became a stalemate determined only by the collective resolution and resources of the sets of allies. Each of the belligerent nations had its several attempts at innovation to break the stalemate. Some of these innovations met with local but temporary success. In the end, though, it was sheer exhaustion that led to the collapse of the German western front. And since there was no decisive victory, the post-war settlements were not very effective and led in part to the Second World War.

The debate over the primacy of "Resolution" or "MV^2" was never settled. Instead, both concepts have evolved. "Resolution" (as "morale") is gaining the status of "principle" of war in emerging US Army Doctrine. Its main expression has been in the strength of primary group bonding. "MV^2" is either a statement about kinetic energy ($\frac{1}{2}mv^2$) or an incorrect statement about momentum (mv). In the military context, both are derived from the basic metaphor of colliding enemies. These formulae show that "mass" and "speed" are important in this metaphor. Thus, it is no surprise that both terms have

been the *names* of "principles" of war in US Army doctrine. However, "mass" has become a verb meaning "concentration" of *effects* of combat power, and "speed" has been supplanted by the more useful term "tempo," which means much more than just "speed." A detailed comparative critique of all of these terms is beyond the scope of this monograph, but some are discussed in the analysis section below. Today, the reader will easily note how obvious such terms as these continue to be in contemporary authors' works. Unfortunately, in many of these works, the use of physics is even worse – and more confusing than it is in Du Picq's.[85]

Case 4: Buna, The "Leavenworth Nightmare"

The U.S. operation against the Japanese in Buna, New Guinea, seems at first look to be a mindless application of Methodism. The "school solution" template of "*maneuver to concentrate forces*" was completely inappropriate on highly restrictive terrain and the heavily fortified defense of the Japanese on the jungle island. This brief exposition is not intended as a criticism of the doctrine or the methods of the time. It is not a suggestion that today's leaders would have fared any better or that they would not have done the same thing. Rather it is an example of what happens when such a condition exists. It could exist today as easily as it did in 1942.

Jay Luvaas writes the following text in "Buna, 19 November 1942 – 2 January 1943," which he subtitled "A Leavenworth Nightmare" –

> NEW GUINEA PINCERS CLOSE ON FOE... ALLIES IN JUNCTION
> AUSTRALIANS AND U.S. TROOPS CONVERGE FOR ATTACK ON
> BUNA JAPANESE CAUGHT IN TRAP
>
> These headlines in the late city edition of the New York Times, 16 November 1942, served notice that unidentified Australian and United States units "have joined forces and are moving in for an attack on the Japanese at Buna" and are "pressing forward in a semi-circular manoeuvre against the Japanese beachhead. . . . This week may see our troops

> besieging the Buna beachhead – if the strength of the enemy defenses and resistance necessitates a siege." The next day headlines trumpeted: "MACARTHUR AT BUNA FRONT LEADS ASSAULT ON JAPANESE." Establishing field headquarters in "a fighting zone for the first time since he was with his . . . troops in the defense at Bataan," General Douglas MacArthur was leading his forces in a rapid advance "and driving the Japanese into a trap protected by the sea and jungles." The ***nutcracker movement***. . . might finish off the fight within days or even hours," for this time "MacArthur is on the offensive – with plenty of men, weapons and food at his command to score his first victory over the Japanese."[86]

As Luvaas explains, it did not turn out as MacArthur hoped. What should have been over in "days or even hours" took a month and a half. Luvaas is careful to point out that most of the U.S. troops at Buna were from an under-manned, un-prepared and ill-equipped National Guard division. He also points out that even after extensive after action reviews, the commanders had "no great fault to find with our training doctrine or methods... generally they are sound. It is in the application of them that we fail."[87]

The two formations of the nutcracker actually were confined to very narrow strips of navigable dense jungle, and while U.S. battle casualties had not yet been as great as disease, "in Port Moresby, MacArthur received reports from the front with growing impatience. To him, light casualties meant one thing: there had been little serious fighting."[88] Eventually, GEN MacArthur relieved the Division commander, MG Edwin F. Harding, placing his superior, LTG Robert L Eichelberger in charge of the operation, saying: *"I want you to take Buna, or not come back alive."*[89] Luvaas explains that Eichelberger affected significant improvements in morale, initially. However, he was unable to sustain any sort of rapid advance. Luvaas quotes Eichelberger from a letter: " 'Someday the Leavenworth boys will get on their platform and describe a Japanese position which initially had a left flank resting on the ocean, a right flank resting on

unfordable tidal streams, a rear on the ocean and an impassable swamp across most of the front.' The proverbial school solution did not seem to fit the terrain."[90]

Luvaas goes on to explain that, still MacArthur was urging the traditional "concentration of force:"

> Where you have a company on your firing line, you should have a battalion; and where you have a battalion, you should have a regiment. And your attacks, instead of being made by two or three hundred rifles, should be made by two or three thousand... so that their firepower can beat the enemy down... Attrition will have to apply. It will be an eye for an eye and a tooth for a tooth – and a casualty on your side for a casualty on his... your battle casualties to date compared with your total strength are slight so that you have a big margin still to work with.[91]

Eventually, after great loss, the forces under Eichelberger began to act as a combined arms team like their doctrine described. First, coordinated and more importantly, observed fires supported an advance. But this only brought the battle back to the World War I standard. As Luvaas quotes an Australian newspaperman:

> "'It's the same old picture of trench fighting, or dugouts and pillboxes, of stomach-twisting bayonet charges behind lifting artillery barrages, of nerve-wracking night patrols... of deadly sniping and awful moments of suspense waiting for the zero hour' Even the nightly artillery bombardments resembled that war of attrition."[92]

It was not until mid-December that the operation was reinforced with two Australian troops of American M3 Light (General Stuart) tanks. In late December, tanks achieved some success, but in at least one case they went without infantry support and the "Japanese infantry let the tanks pass overhead and then filtered back into the first line to fight the infantry."[93]

In the end, Buna was taken, and America got its first victory over the Japanese, but only at great cost. Of the 14,646 American troops committed, 2,848 were lost to

battle, and 8,659 suffered from infectious disease. The Japanese had between 11,000 and 12,000 dead.[94]

Again, the point of this exposition is not to imply that Buna could have been taken at lesser cost. That is not relevant here. The point is that even the Army's best leaders were *surprised* that it was difficult to apply their doctrine in this situation which did not seem to fit their mental model of what war was and how to fight it. The point is that one might learn from these predecessors, that "school solutions" and their associated mental models do not necessarily work out of context.

In this particular case, one might learn about the tenacity with which old metaphors and their associated mental models retain the power to induce "magical thinking" in the collective mind – and thus held power over the actions – of an army. As Luvaas notes, the principles and methods in the 1941 doctrine were not at fault. The new problem of asymmetric jungle warfare had been anticipated and a reasonable doctrinal solution was available. However, no such solution was applied at Buna.[95] MacArthur was clinging to an idea of one-for-one attrition, but the operational design reflected a plan for "concentration of forces," and doctrine apparently had yet another view.[96] This subject is central to the contemporary debate over appropriate mathematical models for combat, which is discussed further as an endnote.[97] Evidently, the new ideas about the jungle's "natural defenses" in *Field Manual 31-20: Jungle Operations* had not yet achieved ***de facto*** authority through powerful repeated articulation and through good training. Contemporary leaders should recognize that the same fate could befall the best new ideas of *any* age if the new ideas are not exercised.

The four historical cases above show physical metaphor in military context. Some general observations are now possible. First, the Buna, World War I (WWI), and North Africa cases demonstrate the tenacity with which old ideas hold onto the collective military mind. This is particularly true of the low-complexity metaphors derived from "collision" type mental models involving monolithic formations. The WWI case introduces the evolving notion of flexibility and rhythm or tempo. These ideas are more complex in that they imply periodicity or continuous dynamics about an equilibrium. The WWI case also introduces the ideas of friction and uncertainty. These ideas represent highly complex or chaotic phenomena. This correspondence between physical metaphor in military writing and these three levels of complexity suggest that the four-level model of Maruyama, Waldrop, and Casti *will* facilitate the analysis of such metaphor in the current context.

PRELIMINARY HYPOTHESIS

The Correspondence Principle of Military Theory

A Maruyama-Casti-Waldrop ***Level-of-Complexity*** framework can be used to describe a correspondence principle for different models of battlefield dynamics. All models of battlefield dynamics rely on the existence of some fundamental "building block." Fundamentally, the basic building block is the weapon-equipped soldier. However, most models postulate the aggregation of groups of soldiers or combat vehicles together. The basic collective unit of soldiers is traditionally referred to as the "primary group" which exhibits "cohesion."[98] The activities of such primary groups is then combined in the aggregate notion of larger formations in which specialty groups also exist. These larger organizations can either exhibit monolithic order, or they can be

flexible. The degree of flexibility may vary greatly. It may vary by conscious design, or by interaction with the environment, or both. Further, it can range from *monolithic*, to *elastic*, to *morphogenic*, to *chaotic* depending on this design and interaction. In this way, the strength and nature of the bonds of cohesion determines the nature of the group, and defines the way in which the various models for battlefield dynamics correspond to one another.

The Hypothetical Framework for Analysis

Within this framework, the degree of justifiability and utility of a particular instance of metaphor can be judged by using the evaluation criteria defined above to examine the metaphor in the context of one of these categories. Various metaphorical models are applicable at different scales – more or less so depending on the state of moral and "cybernetic" cohesion and coherence.[99] Actually, cohesion, coherence, and degree of complexity can be described as a function of communication and interconnection, but that is left as an opportunity for a separate research effort.

The four categories of military metaphorical description of battlefield dynamics are: (1) ***Monolithic Cohesion*** – the phenomenon is described by classical mechanics. Outcomes are convergent and are completely determined by initial conditions (mainly numbers of troops, their weapons, and their disposition). Cohesion is not a bad thing. In fact it is the result of effective "primary group" bonding described by Anthony Kellett, S. L. A. Marshall and others."[100] (2) ***Periodic Elastic Flexibility*** – the phenomenon is described by classical mechanics. However the outcome exhibits periodic rather than convergent order. Examples are *periodic* behaviors such as repeated concentration and dispersion or repeated decision-cycles like the "Boyd Cycle." E*lastic flexibility* is

distinguished from morphogenic phenomena in that *elastic flexibility* implies a system design feature by which the system operates about a "position of stable equilibrium." Displacement from that position is corrected by the system's inherent tendency to return toward, and operate around, equilibrium. (3) ***Morphogenic Fluidity*** – described by similarity to other "emergent" or "evolving" phenomena. Formations orchestrate either their own "phase transition" (like turbulent non-periodic concentration of effects and dispersal) or that of the enemy (like "disintegration" by successive action or "freezing" through "cybernetic paralysis"). (4) ***Chaotic Disorganization*** – described by similarity to other chaotic phenomena. Formations undergo chaotic change and outcomes are completely uncertain (like the disintegration of the enemy through successive action or perhaps the completely random acts of terrorists).

A formation need not necessarily be exclusively a member of only one of these categories. During the course of an operation, the organizational behavior may vary from one category to another. However, at any given time, its behavior can be categorized in this framework.

The following description of a mobile defense is an example. Note that the "dominant mode" of the unit changes as the operation progresses. Note that the choice of unit sizes here is arbitrary. And note finally that this is a characterization of battle-as-it-is today. This is not a description of some science fiction event in the future. It is just a different way of looking at what is already happening:

First, the friendly and enemy units are seen to fit category 2 (*periodic*) behavior. The rhythmic action of the initial friendly division's main effort brigade (and the supporting activity of other parts of the division) is visible in its conduct of a DELAY to a

fixing position. This activity is marked by the regular tempo of the brigade's shoot-move-communicate cycles, by observe- orient- decide- act cycles, by the periodic rhythm of logistics activities from resupply to casualty evacuation, and by the cyclic action of the engagements of individual weapon systems. Then, suddenly, through lateral coordination a spontaneous division counterattack emerges and the division displays category III (*morphogenic*) behavior. Rapidly, many subordinate units within the division coordinate the concentration of the effects of multiple weapons systems (including rapidly concentrated aviation and indirect fires) against the enemy formation. As part of the counterattack, a new friendly main effort brigade is temporarily physically concentrated and displays category I (*monolithic*) behavior as it conducts a follow-on assault to destroy-in-detail the remnants of the enemy formation. The friendly brigade appears to be intensely cohesive and resolute throughout this action. When the action is complete, however, it rapidly disperses again and is re-integrated into the division.

The enemy on the other hand makes a different transition. The enemy begins in category I (nearly *monolithic* in its cohesion and resolve during the initial stage of its attack). When it encounters the delaying action of the friendly units, however, it transitions to category II (*periodic*) as the delaying action imposes a new tempo and decision cycle on it. Then, it rapidly transitions to category IV (*chaotic*) as it is completely disintegrated at the aggregate level and disorganized at subordinate levels by the friendly counterattack.

DATA, METHOD, AND ANALYSIS

DATA AND METHOD

The sources cited in Appendix 3 (Presentation of the Data) were reviewed for the instances of the use of metaphor. 855 such instances were cataloged in relational database. These instances were observed empirically to fall into five "super-categories" – 1) Physics, 2) Biology, 3) Music, 4) Sports, 5) Other. From these instances, only the 791 pertaining to the super-category of Physics were selected. Then, from these, only the instances describing the structure of military formations and their interactions (collectively called battlefield dynamics) were selected. These records were then assigned to four "dynamics categories": 1) Monolithic Cohesion (271 records), 2) Periodic Flexibility (247 records), 3) Morphogenic Fluidity (229 records), and 4) Chaotic Disorganization (44 records).

The process of assigning individual instances of metaphor to these categories was tedious and somewhat difficult. Often the same word was used metaphorically by different authors in different ways, and occasionally a single author used the same word in completely different ways. Two simple examples are the terms "mass" and "friction." Each has a precise physical definition. However, in military writing, "mass" could be a noun meaning the numbers of soldiers in a formation, or it could be a verb meaning the act of concentrating the effects of weapon systems. In military writing, "friction" sometimes means that an activity dissipates energy, making action difficult, but in other cases, the word means that there is an inherent uncertainty in the outcome of some events that are observable in warfare. The general descriptions of the four dynamics categories

developed in the PRELIMINARY HYPOTHESIS section above were used in these assignments to help eliminate such ambiguity

Note: the database is undoubtedly incomplete. Many sources were reviewed and instances of metaphor may have been unnoticed. However, the overall uniformity of the data indicates that such "missing data points" are probably well represented by the ones found. The review of *Field Manual 100-5-1: Operational Terms and Graphics* (1997), *Field Manual 100-15: Corps Operations* (1996), and *Field Manual 100-40: Tactics* (1997) was performed by searching through the electronic format for these documents on a home computer. As a result, that review probably produced more records than the same volume of any of the manually searched texts. Though perhaps the automated search was more likely to produce redundant instances.

ANALYSIS

Analytical Framework

The theoretical foundations established in this study suggest that theories of battlefield dynamics can be separated into the four categories above. First, the review of literature above implies that one can classify *all phenomena* in this way. Consequently, one can classify metaphor *describing* those phenomena in the same way. Second, the empirical observation of historical cases supports this implication. Even further support is offered by preliminary review of the data.

The goal of this analysis is to determine whether selected metaphor meet the evaluation criteria described above. To manage the scope of the analysis, only one metaphor is selected for evaluation from each of the four categories. These are:

For *Monolithic Cohesion*: **"center of gravity"** – In the Buna case, MacArthur's "magical thinking" demonstrates the tenacious cognitive-illusory nature of metaphor. The study reveals that this was a strong effect of the low-complexity mental models of "concentration of force" derived from physical metaphor involving "collision" of systems of monolithic formations. This effect is visible in the WWI case and the North Africa case as well. In the Key to the Country case, the geological analogy is somewhat more complex but Clausewitz's critics reduced it to a low-complexity strategy of a single point. Again, the flood of metaphorical thinking swept these critics away with cognitive illusion. They believed it because it conformed strongly to their other beliefs. In the nineteenth century, Clausewitz's "center of gravity" was a state of the art metaphor, and it was accurate. However, the military context has changed significantly in the last 165 years. The base metaphor of collision of largely monolithic formations is progressively being replaced by literary constructions describing a "flexibility," "fluidity," and "morphogenisis." "Center of gravity" is particularly tenacious, however. It should be subjected to this evaluation because it may have lost its utility in the 1997 context.

For Periodic Elastic Flexibility: **"tempo"** –The emergence of "flexibility" is apparent in the WWI case. Actually, Epstein claims that it describes Napoleon's armies. One could probably also justify an argument that the Roman Legions also exhibited "flexibility." The WWI case also introduced the debate about "resolution" versus "mass" and "speed." "Speed," replaced by "tempo," is similar to "flexibility" or "elasticity" in that both describe system dynamics of periodic order about some equilibrium condition. However, whereas the literary use of "flexibility" has evidently been around quite a while, "tempo" seems to have infiltrated military writing only relatively recently.

Actually, although everything comes down to physics at some level, and "Tempo" can be described as a frequency, or rate, "Tempo" is not technically a "physics" term. In fact it is derived from the musical arts. The important fact in this analysis, however, is that "Tempo" is assuming a place in doctrine where it describes phenomena previously described metaphorically by "speed" and "momentum." The *utility* of "speed" is limited by its physical meaning: rate of change of position, which implies movement. The *correctness* of "momentum" is questionable, given the many non-rigorous definitions for *mass*. (See appendix 4 for a more detailed discussion of the limitations of classical mechanics as a description of battlefield dynamics.) "Tempo" is far more prevalent in the 1993 version of *FM 100-5* than in the 1986 version, and there are at least two dozen separate references to "tempo" in the 1996 *FM 100-15: Corps Operations*. Such an important new term deserves the deliberately rigorous scrutiny of this evaluation.

For Morphogenic Fluidity: **"phase transition"** – Whereas the historical review of this study exposes instances of metaphor from each of the *other* categories, it did not reveal *any* metaphor from this category in any of the historical cases. For this very reason, any such contemporary metaphor are suspect and should be scrutinized rigorously. The recent appearance of a notion of "phase transition" is a perfect test case since it is the very example that Waldrop claims "is not just a metaphor" in *Complexity*.[101] It is important to determine if such descriptions are valid, *in military context*. The Key to the Country case study shows an example of a valid science producing an unsound theory in military context.

For Chaotic Disorganization: **"friction"** – In both the Napoleonic introduction to the WWI case and in the Buna case, "friction" is mentioned. Like "center of gravity,"

"friction" is traceable to Clausewitz. In the traditional sense, "friction" implies the dissipation of mechanical energy. This indicates that a military system subject to friction should exhibit convergence to a dissipated state. One might argue that this was exactly the way WWI ended. However, in the general military context, the term is more frequently used to represent "uncertainty."[102] This inevitable uncertainty implies a chaotic nature to warfare that is strongly supported by the anecdotal evidence of many commentators. The apparent discrepancy between the dynamical predictions of these two interpretations of the term "friction" makes it a good candidate for this deliberate evaluation.

The results of these four evaluations are provided below in tabular form. Each table's analysis is amplified in an endnote. Each analysis is also supported by a set of data provided at Appendix 3.

Analytical Results

Center of Gravity – In the 1997 Context of Monolithic Cohesion		
Criterion	***Measure of Criterion***	***Judgement***
Formulation	Can an image or mathematical representation be extracted from the metaphor? (Yes is good).	**No**. A formulation is possible for the original use of the term, but the 1997 use is now abstract and multi-valued. Application of the term in joint doctrine has compromised the term's meaning. The new use also causes confusion because it is no longer consistent with the associated principle of concentration. Detailed discussion is provided as an endnote.[103]
Correctness	Are the physical principles in the metaphor cited correctly and used appropriately? (Yes is good)	**No**. The 1997 definitions are no longer based on any physical principles.
Completeness	Has the formulation been well developed? (More is better)	**N/A**
Correspondence	Does the formulated description correspond with a proper scaling of other generally accepted models? (Yes is good.)	**N/A**
Reliability	Has the metaphor been used in the same way by many independent authors over a long period? (More is better)	**No**. Clausewitz used the term as an extension of his mental model of formations as rigid bodies the dynamics of which were governed by solid mechanics. The 1997 uses of the term are abstract concepts with two groups of camp-followings: The King and Queen theories (critical vulnerabilities or critical strengths)[104] Note also that "centers of gravity" is now a *plural* concept.
Simplicity	What level of study of physics is required to comprehend the metaphor? (Less is better)	High school
Ambiguity	Is the common experience attached to the metaphor single-valued? (Yes is good)	**No**. Not any more.
Overall Judgement: "Center of Gravity" is a degenerated term. Now an amorphous abstract idea as well as a physical concept, the term's meaning is so sensitive to subjective factors that is has little utility in facilitating common action. US Army and joint doctrine should refer to it only as an obsolete term from history. US Army and joint doctrine should replace all contemporary reference to "centers of gravity" with more appropriate individual terms. "Critical vulnerabilities" should be called "critical vulnerabilities," and "critical strengths" should be called "critical strengths." Terms derived from "center of gravity" such as "decisive point," "critical point," "decisive terrain," and "key terrain," must also be reassessed. They have done to "center of gravity" what Barzun says *gender* has done to *sex* – all these terms are now left indefinite.		

Tempo – In the 1997 Context of Periodic Elastic Flexibility		
Criterion	***Measure of Criterion***	***Judgement***
Formulation	Can an image or mathematical representation be extracted from the metaphor? (Yes is good).	**Yes**. Rigorously defined, *tempo* is the rate of an activity, with dimensions of "something" over time (rounds per second, miles per hour, decision cycles per shift, meals per day, etc.). *Tempo* is replacing instances of the physical metaphor *speed* and *momentum*. Detailed discussion is provided as an endnote.[105]
Correctness	Are the physical principles in the metaphor cited correctly and used appropriately? (Yes is good)	**Yes**, *Tempo* is a better description of the basic measure of the time domain. In current doctrinal manuals, it is generally correctly defined and used. The single exception noted by this author is on p. 2-9 of *FM 100-5*, where the manual says, "Tempo is a combination of speed and mass that creates pressure on the enemy." Some other authors are more thoroughly confused about tempo. For example, Pickar claims that *tempo **is** combat power*. This comment devalues both terms.
Completeness	Has the formulation been well developed? (More is better)	**Yes** in general, and in doctrine in particular.
Correspondence	Does the formulated description correspond with a proper scaling of other generally accepted models? (Yes is good.)	**Yes**, when rigorously defined. In the *monolithic convergent order* category, Tempo corresponds to the speed of movement. In the *periodic elastic* category, it corresponds to rates like decision-making. In the *morphogenic* category, it corresponds to the purposefully variable rates of decision cycles and movements used to cause desired effects. Tempo also integrates more naturally with the terms "synchronization" and "orchestration." The collective effect of common or synchronized or orchestrated tempos is coherent action.
Reliability	Has the metaphor been used in the same way by many independent authors over a long period? (More is better)	**Unknown**. Tempo appears to be a relatively new term. However, most authors seem to understand and use the term in the same way that current doctrine does. Also, current doctrine appears to be very consistent in its use of the term.
Simplicity	What level of study of physics is required to comprehend the metaphor? (Less is better)	**No physics required**. While everything comes down to physics at some level, tempo is derived from the musical arts. There it is the cadence or rhythm to which the activities of instruments conform (implying synchronization or orchestration).
Ambiguity	Is the common experience attached to the metaphor single-valued? (Yes is good)	**Yes**, it is single-valued as the rate of some activity. However, the activity must be specified.
Overall Judgement:Tempo is a very good term. It is an important word in modern doctrine. It is more rigorously correct than the terms *speed* and *momentum* it appears to be replacing. It also helps to develop a uniformity in understanding the importance of "quickness," "synchronization," or "orchestration" in activities other than just movement. Authors of doctrine should continue to exercise rigor in its literary application.		

Phase Transition – In the 1997 Context of Morphogenic Fluidity		
Criterion	***Measure of Criterion***	***Judgement***
Formulation	Can an image or mathematical representation be extracted from the metaphor? (Yes is good).	**Yes**, it is easy to imagine phase transitions in substances like water. Mathematical models are also available in physics and chemistry texts. Formal description of a general phase transition for things other than materials is complicated but also possible. Waldrop claims that Chris Langton has done so. Detailed discussion is provided as an endnote.[106]
Correctness	Are the physical principles in the metaphor cited correctly and used appropriately? (Yes is good)	**Yes**, the descriptions are consistent with the physics of phase transition.
Completeness	Has the formulation been well developed? (More is better)	**Somewhat,** development of the term in military context only goes as far as literary description of first order transitions. Morphogenic behavior is more accurately modeled by second-order phase transitions in physical substances.[107]
Correspondence	Does the formulated description correspond with a proper scaling of other generally accepted models? (Yes is good.)	**Yes**. Transition, as the name suggests, is transient. Formations subject to it end up in one of the other categories of complexity.
Reliability	Has the metaphor been used in the same way by many independent authors over a long period? (More is better)	**No**. It is a new term, and while many authors have decribed the mechanics of phase transition, very few have actually called it that in their writing.
Simplicity	What level of study of physics is required to comprehend the metaphor? (Less is better)	High school physics is sufficient to understand the general sense, but detailed study would require graduate level work.
Ambiguity	Is the common experience attached to the metaphor single-valued? (Yes is good)	**Yes**. The term is still single-valued.
Overall Judgement: Phase Transition is an immature but promising metaphor. It is particularly effective in describing the orchestrated transition of a formation from one "form" to another. Its success will depend on the successful integration of complexity theory in military doctrine. Indications of early success have emerged in publications such as TRADOC Pam 525-5 – Force XXI Operations (See Appendix 3).		

Friction – In the 1997 Context of Chaotic Disorganization		
Criterion	***Measure of Criterion***	***Judgement***
Formulation	Can an image or mathematical representation be extracted from the metaphor? (Yes is good).	**Yes.** There are two abstract formulations of military frictional imagery. One is the physical impediment to motion. The other is uncertainty. Detailed discussion is provided as an endnote.[108]
Correctness	Are the physical principles in the metaphor cited correctly and used appropriately? (Yes is good)	**Yes/No.** In its strict physical application as impediment to motion it is correct. However, use of the term *friction* to mean *uncertainty* (another precise physics term) is not correct. Only in the sense of "moral impediment to action" can *friction* and *uncertainty* be connected. However, the instances of metaphor discovered by this author indicate that current doctrine tends to use the term *uncertainty* rigorously rather than cover it with *friction.* Another instance in the 1993 *fm 100-5* uses the meteorological metaphor *fog.* To mean uncertainty, thus discriminating and not misusing *friciton.* (See Appendix 3)
Completeness	Has the formulation been well developed? (More is better)	**No.** In general the fomulations remain abstract and the imagery is somewhat vague.
Correspondence	Does the formulated description correspond with a proper scaling of other generally accepted models? (Yes is good.)	**Yes.** If friction is uniformly applied to periodic elastic formations, it tends to dissipate their "energy" and turn them into monolithic formations. I.e. it paralyzes them. If it is spatially and temporally varied, it tends to disorganize and disorder the formation.
Reliability	Has the metaphor been used in the same way by many independent authors over a long period? (More is better)	**Yes**, since Clausewitz at least.
Simplicity	What level of study of physics is required to comprehend the metaphor? (Less is better)	High school physics is sufficient to understand the general sense, but detailed study would require graduate level research. (*Friction* is not a well-described phenomenon.)
Ambiguity	Is the common experience attached to the metaphor single-valued? (Yes is good)	**No** there are two uses.
Overall Judgement: Friction is a good metaphor that can be saved. It is a complicated phenomenon, but the term is very efficient at describing the general concept of impediment to action (both physical and moral). Doctrinal publications have tended to use the word *uncertainty* rigorously rather than try to cover the idea with the word *friction*. This is good. If the authors of doctrine continue to exercise such rigor, this term can be saved.		

CONCLUSIONS AND IMPLICATIONS

Conclusions

A level-of complexity framework has been developed through a synthesis of the ideas of Maruyama, Waldrop, and Casti. This framework has been used as the context for the evaluation of four physical metaphors found in military writing and indicated as

"suspect" upon review of historical case studies. Evaluation criteria have been developed to judge the justifiability and general utility of the metaphor as the basis for a mental model for some phenomenon in military action. The study has evaluated "center of gravity," "tempo," "phase transition," and "friction." The following paragraphs are a restatement of the results of this evaluation.

"Center of gravity" is a degenerated term. Now an amorphous abstract idea as well as a physical concept, the term's meaning is so sensitive to subjective factors that is has little utility in facilitating common action. US Army and joint doctrine should refer to it only as an obsolete term from history. US Army and joint doctrine should replace all contemporary reference to "centers of gravity" with more appropriate individual terms. "Critical vulnerabilities" should be called "critical vulnerabilities," and "critical strengths" should be called "critical strengths." Terms derived from "center of gravity" such as "decisive point," "critical point," "decisive terrain," and "key terrain," must also be reassessed. They have done to "center of gravity" what Barzun says *gender* has done to *sex* – all these terms are now left indefinite.

Tempo is a very good term. It is an important word in modern doctrine. It is more rigorously correct than the terms *speed* and *momentum* it appears to be replacing. It also helps to develop a uniformity in understanding the importance of "quickness," "synchronization," or "orchestration" in activities other than just movement. Authors of doctrine should continue to exercise rigor in its literary application

Phase Transition is an immature but promising metaphor. It is particularly effective in describing the orchestrated transition of a formation from one "form" to another. Its success will depend on the successful integration of complexity theory in

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Implications

The set of evaluation criteria developed for this study, or something like them, could be institutionalized for use by doctrine authors. A major theme of this monograph has been an articulation of the role of doctrine in establishing common understanding. The focus, however, has been on the linguistic role of metaphor in theory and doctrine. Given the volume of such use found in this study, it is reasonable to believe that authors of the future will use metaphor as well. This study and its evaluation criteria could serve as a guide.

In the review of military theoretical writing, many authors were found to use physics with little or no rigor. Fortunately, this is not generally the case with military doctrine. This is probably because of the intense staffing process that doctrine must survive before it can gain the authority of approval. Two implications are apparent here. First, the staffing process seems to be working and it should continue. Second, however, there are many authors who evidently do not ask competent individuals to review their work (and they did not learn correct physics themselves). The implication here is for the Physics Instructors of our officers: if they do not learn to apply the vocabulary of physics

rigorously in college, they probably never will. Authors will probably continue to be irresponsible in this regard. At least the future *audience* can be prepared for the challenge. Thus, they will be able to tell the difference between good and bad writing involving the use of physical metaphor.

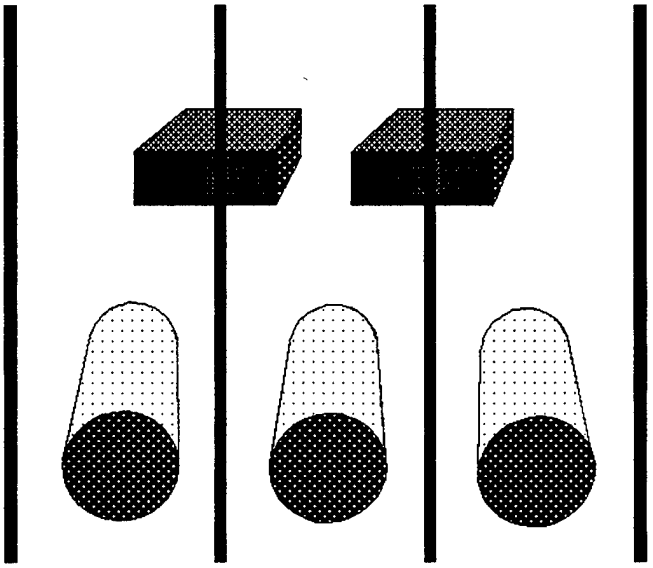
Further Research

One of the most intriguing aspects of this study that deserves further investigation is the connection between cohesion and coherence. What is the difference? These two seem to be the high on the list of critical variables characterizing any complex, adaptive, self-organizing military unit. What is the mechanism responsible for achieving these two effects? There is strong anecdotal evidence from Marshall, Kellett, McPherson, Sledge, and others, that formal (informative) and informal (affective) communication is responsible for moral cohesion. Can this be more rigorously determined? And what are the implications of this line of reasoning on the design of future communications systems? What are the critical limitations of the communications systems of the future? And what are the implications of these limitations on the design of military organizations?

Another intriguing aspect of this study that deserves further rigorous investigation is the connection between recent discoveries of the complexity of turbulent fluid dynamics and the intuitive appeal of fluid metaphor in military context. Such study could produce new and better models of combat – particularly if done with reactive fluids in turbulent modes of flow. How do two reactive fluids interact with each other in turbulent and laminar modes of flow? How does a reactive fluid (gaseous or liquid) interact with a solid object? Could one identify parameters like viscosity and Reynolds number for

different military designs? Would these parameters be useful in simulation of combat? Would they accurately describe combat between peer and asymmetric enemies?

Appendix 1: Binocular Vision



The drawing above has been created using a differentially encoded signal. To experience it, hold this page near your face and focus on some point beyond (like a wall). The drawing should appear as a double-image and out of focus. There will probably be four fuzzy blocks on the top row. Slowly move the page away from your face while continuing to focus on the distant point. Notice that the lines, blocks, and cylinders in the drawing will shift relative to one another. As the paper moves away, the center two of the four blocks on the top row will appear to merge. There will three blocks on the top row. At the same time there will be four cylinders and five vertical lines. At this point stop moving the paper and concentrate on the center block on the top row. As your mind decodes the differntial pattern in the drawing, the blocks and cylinders will appear to be three dimensional. The vertical lines will appear to be in front of the blocks, and the cylinders will appear to lie between and in front of these vertical lines.

Appendix 2: Maruyama's levels of complexity

	Homogenistic	***Heterogenistic***		
	Hierarchical Classificational	***Reciprocally Causal***		***Isolationistic independent event***
		Homeostatic	*Morphogenic*	
Waldrop Category	Category I (Convergent Order)	Category II (Periodic Order)	Category IV (Complexity)	Category III (Chaos)
Casti Attractor	Classical Attractor: Fixed Point	Classical Attractor: Limit Cycle	Strange Attractor: Unstable orbit	Strange Attractor: Aperiodic Path
Philosophy	*Universalism*: Abstraction has higher reality than concrete things *Organismic*: The parts are subordinated to the whole	*Equilibrium or Cycle:* Elements interact in such a way as to maintain a pattern of heterogeneous elements, or they go in cycles	*Heterogenization, Symbiotization, and Evolution*: Symbiosis thanks to diversity. Generate new diversity and patterns of symbiosis.	*Nominalism*: Only the individual elements are real. Society is merely an aggregate of individuals.
Perception	Rank ordering, classifying and categorizing into neat scheme. Find Regularity.	Contextual: Look for meaning in context. Look for mutual balance, seek stability.	Contextual: Look for new interactions and new patterns. Things change and relations change. Therefore meanings change and new meanings arise.	Isolating. Each is unique and unrelated to others.
Knowledge	Belief in existence of one truth. If people are informed, they will agree. There is a "best" way for all persons. Objectivity exists independent of perceiver. Quantitative measurement is basic to knowledge.	Poly-ocular: binocular vision enables us to see three-dimensionally, because the differential between two images enables the brain to compute the invisible dimension. Cross-subjective analysis enables us to compute invisible dimensions. Diversity in perception enriches our understanding		Why bother to learn beyond my interrest?
Information	The more specified, the more information. Past and future inferable from present probabilistically or deterministically	Loss of information can be measured by means of redundancy or by means of feed-back devices.	Complex patterns can be generated by means of simple rules of interaction. The amount of information needed to describe the generated pattern may be greater than the amount of information needed to describe the rules of interaction. Thus amount of information can increase.	Information decays and gets lost. Blueprint must contain more information than the finished product. Embryo must contain more information than adult.

Appendix 3 - Instances of Physical Metaphor by Name, Author, Title, and Date

Notes:

1. The enclosed instances of metaphor are only those necessary to support the analysis portion of this study. The database of instances contains 855 records. Only the enclosed 319 instances are for one of the analyzed metaphors: (1) Center of Gravity, (2) Tempo, (3) Phase Transition, or (4) Friction.

2. The complete database is available from the author .

3. For comparison, some references derived from, or related to, metaphors are included. Examples are "decisive point," "critical point," and the principle of concentration (with center of gravity); "speed" or "quickness" (with tempo); "fluidity" and dynamic distribution of "mass" (with phase transition); and "uncertainty" (with friction).

4. The abbreviated citations in this appendix include Author, Title, Date, Page(s), and either a quotation or a paraphrased summary of the information cited. For the full citations for these works, refer to the alphbetical listing of the author's full citations in the bibliography.

Center of Gravity

Doctrinal Publications

Army Vision 2010, Army Vision 2010 (1997)

pp. 13	Describes "Shaping the Battlespace" as the integration of all combat multipliers to "overcome the enemy's center of gravity and result in the total takedown of an opponent."

Field Manual 100-15, Corps Operations (1996)

pp. 2-5	"Attacking, either directly or indirectly, enemy CENTERS OF GRAVITY and critical functions to destroy the cohesion of the enemy plan, such as the ability to generate and sustain combat power."
pp. 3-15	"The assault force's main advantage derives from achieving operational and tactical surprise and the generation of overwhelming combat power at DECISIVE POINTS by the application of all means"
pp. 4-5	"The commander must be where he can effectively concentrate combat power at the point of decision"
pp. 5-13	"Deep operations might even be the decisive operation against enemy forces. As such, the corps might only conduct close operations to facilitate cross-FLOT operations and to attack the enemy's center of gravity. "
pp. 5-16	"Information required may include-- Enemy centers of gravity or decisive point"
pp. 6-6	"A force-oriented objective or engagement area usually indicates a decisive point"

Field Manual 100-40, Tactics (1997)

pp. 1-23	Maneuver: No mention of COG, but describes DECISIVE point which CDR determines and then moves forces to the right place at the right time, facilitating precise fires. . . All designed to mass the effects of overwhelming combat power at the decisive point.
pp. 1-30	Still no mention of COG, however on CSS: "The commander and his staff must continuously look toward the decisive point, determine where the forces must be to mass effects, . . . "
pp. 10-21 line 27	"This decisive point can be a geographical objective or an enemy force."
pp. 10-7 line 24	"The degree of dispersal adopted by defending forces is first a function of the enemy's capabilities and then a function of the friendly force's capability to rapidly concentrate overwhelming combat power at the decisive point."
pp. 2-33 line 10	Not COG: "there is usually only one decisive point for an operation."
pp. 5-16	Still no COG: Talks about key terrain [advantageous to either side], decisive terrain: "key terrain that has an extraordinary impact on the mission"

Field Manual 100-5, Operations (1986)

pp. 12	"the generation of combat power requires the conversion of the potential of forces, resources, and tactical opportunity into actual capability through violent and coordinated action concentrated at the decisive time and place."
pp. 12	"Maneuver. . . is the dynamic element of combat -- the means of concentrating forces at the critical point to achieve surprise, psychological shock, physical momentum, and moral dominance which enables smaller forces to defeat larger ones."

pp. 14	"operational planning must orient on decisive objectives. . . stress flexibility, the creation of opportunities to fight on favorable terms by capitalizing on enemy vulnerabilities, concentration against enemy centers fo gravity. . ."
pp. 174	Economy of force = (principle of war) "Allocate minimum essential combat power to secondary efforts. -- a reciprocal of the principle of mass. . ." Still means concentrate on the main effort.
pp. 174 (App A)	Mass = (principle of war) "Concentrate combat power at the decisive place and time." Note however, last sentence says "massing of forces"
pp. 179	"effective operation depends not merely on the performance of each [component] but also on the smoothness with which these components interact. . . As with any complex organism, some components are more vital than others."
pp. 179	COG of armed force = source of strength or balance. Described like CVC's Hub. Tactical formations have COGs - a key CP, piece of terrain. Then COG like a vulnerability: eg. Boundary between formations, LOG, LOCs, alliance cohesion, CDR mental state.
pp. 179	"If these are damaged or destroyed, their loss unbalances the entire structure, producing a cascading deterioration in cohesion."
pp. 179	Strategic level: "the center of gravity may be a key economic resource or locality, the strategic transport capabilities, . . . But it may also be a wholly intangible thing."
pp. 179	Operational level: "the center of gravity may also be more abstract - the cohesion among allied forces, for example, or the mental and psychological balance of a key commander."
pp. 179	"The center of gravity of an armed force refers to those sources of strength or balance. . . [Clausewitz's] The hub of all power and movement."
pp. 179	Operational level: "the center of gravity may well be a component of the field force - the mass of the enemy force, the boundary between two formations, a vital command and control center, or perhaps its logistical base of lines of communication."
pp. 179	The enemy will protect his COG: "Identification of the enemy's center of gravity and the design of actions which will ultimately expose it to attack and destruction while protecting our own, are the essence of the operational art."
pp. 179	"Tactical formations have centers of gravity - a key command post. .. a piece of terrain. But the concept is more usually and usefully applied . . . at the operational level."
pp. 179	"The concept of centers of gravity is key to all operational design. It derives from the fact that [a combattant is] a complex organism."
pp. 23	On Main Effort: "Concentrating combat power against enemy vulnerabilities is also fundamental to AirLand Battle operations. . ." Commanders and their units must be flexible enough to shift their main effort to create or exploit new enemy vulnerabilities.
pp. 23	ALB Imperative - concentrate against enemy vulnerabilities
pp. 3	"The more fluid the battlefield, the more important and difficult it will be to identify decisive points and to focus combat power there."
pp. 30	"Once he has determined the enemy's center of gravity, . . . the commander . . . selects a course of action."
pp. 47	"Without control [of air] tactical flexibility is lost. . . The success of both offensive and defensive operations can depend greatly on massing airpower at decisive points. . . [Also,] interdict an enemy [to] limit the flexibility of his forces. . ."

pp. 5, 9, 125, 132, 133	CONCENTRATION (also equated to "mass") is a principle of defense and a ALB imperitive. P 23 says concentrate against the enemy's vulnerabilities.
pp. 80	"Key terrain . . . affords a marked advantage."

Field Manual 100-5, Operations (1993)

pp. 2-4	MASS = mass the EFFECTS of combat power at the decisive place and time (properly synchronized)
pp. 2-6	Initiative requires commanders to concentrate forces and execute with speed, audacity, and violence, continually seeking soft spots and shifting the main effort when required
pp. 6-7	"Several traditional examples of a potential center of gravity include the mass of the enemy army, the enemy's battle command structure, public opinion, national will, and an liance or coalition structure."
pp. 6-7	"The center of gravity is the hub of all power and movement upon which everything depends. It is that characteristic, capability, or location from which the enemy and friendly forces derive their freedom of action, physical strength, or will to fight."
pp. 6-7	"The essence of operational art. . . " is in massing effects against the enemy center of gravity.
pp. 6-7	"The concept of a center of gravity is useful as an analytical tool to cause the joint commander and his staff to think about their own and the enemy's sources of strength. . ."
pp. 6-7	"the center of gravity may be abstract, such as the enemy's national will or an alliance structure, or concrete, such as strategic reserves, C2, or industrial bases and LOCs."
pp. 6-8	"Decisive points are not centers of gravity; they are the keys to getting at centers of gravity."
pp. 6-8	"Decisive points include transportation nets or terrain features that are critical for the continued momentum of operations or the rapid shifting of direction."
pp. 6-8	Usually, theaters contain more decisive points than we can attack, so we have to figure out "which enable eventual attack of the enemy's center of gravity."
pp. 7-0	On offense: "At times more direct attacks are possible. However, such attacks are nearly always costly in lives and materiel. Commanders should undertake them only when no other approach will accomplish the mission."
pp. 7-0	On offense: "At the point of their attack, commanders aviod the enemy's main strength. . . The main feature of an offensive battle is the out-flanking or bypassing of the defender -- that is taking the initiative."
pp. 8-5	"To maintain . . . momentum, commanders conduct an offensive relief to pass fresh troops . . . The ability to continually mass at key times and places, while maintaining momentum of the attack at a tempo the enemy cannot handle is essential."
pp. 9-2, 12-9	Identify key enemy nodes - important stuff in enemy "structure". Examples: limited ports, airfields, inland transportation networks, LOCs

Field Manual 101-5-1, Operational Terms and Graphics (1997)

pp. 1-24	Center of Gravity (JP 1-02) Those characteristics, capabilities, or localities from which a military force derives its freedom of action, physical strength, or will to fight. (Army) The hub of all power and movement, on which everything depends.
pp. passim	Also derived "Points" Critical Point (1-41) Decisive Point (1-45) Dominant Terrain (1-55)

Fleet Marine Field Manual 1, Warfighting (1989)

pp. 35, 60, 66 — Doesn't name it "center of gravity," but says: "To win, we must concentrate combat power toward a decisive aim - against weaknesses rather than against strength. - Therefore, we should focus our efforts against a critical enemy vulnerability."

Joint Pub 3-0, Doctrine for Joint Operations (1995)

pp. III-20 — Centers of gravity are the sources of the enemy's strengths as well as weaknesses.

TRADOC Pamphlet 525-5, Force XXI Operations (1994)

pp. 3-10,11 — Describes "Depth and Simultaneous Attack" to "reduce, if not entirely eliminate, the time and need to shape the battlespace; to facilitate the full-dimensional attack of an enemy center of gravity [abstract & amorphous] & accelerate his defeat."

Theoretical Works

Clausewitz, On War (Howard & Paret) (1989)

pp. 163 (Book 2 Theory) — "Even though Bluecher was weaker than Schwartzenberg, his enterprising spirit made him more important. The CENTER OF GRAVITY lay with him, and he pulled the other forces in his direction."

pp. 391 (Book 6 Defense) — using every element of attack-assault, surprise, and flanking movements. All these pressures will be brought to bear on the battle's CENTER OF GRAVITY.

pp. 485 (Book 6 Defense) — "an analogy will illustrate it more clearly - that is, the nature and effect of a CENTER OF GRAVITY." -- "is always found where the mass is concentrated most" - good place to hit, or to hit with. From which the idea COG = Main Effort comes.

pp. 486 — "where there is cohesion, a center of gravity may be found"

pp. 595 (Book 8 War Plans) — "Out of these characteristics a certain CENTER OF GRAVITY develops, the hub of all power and movement, on which everything depends. That is the point against which all of our energies should be directed."

Epstein, Napoleon's Last Victory (1992)

pp. 145, 146 — Italy (1809): "Perceiving disruption. . . Eugene ordered Macdonald to charge. . . The French smashed through the front line . . . [the Austrian counter] was hurled back. . .Grenier's advance. . . captured the town. . .John's Army was broken by this. . ."

pp. 19 — On Bourcet's new method (~1770): "These divisions could then be maneuvered to turn enemy defenses as well as concentrate against detachments, creating force superiority at the decisive point."

pp. 69 — (1809): "the French center of gravity shifted to Iberia. The defeats inflicted on French forces there meant that a further strategic commitment was needed."

Geyer, German Strategy in the Age of Machine Warfare (1986)

pp. 532 — Says the Schlieffen Plan was designed to counter the fluidity of war by using a massive forward thrust to create a center of gravity and escalate into the annihilation of the enemy forces.

Leonhard, The Art of Maneuver (1991)

pp. 20,21 — COG and the chess metaphor: Leonhard is an advocate of the King Theory - COG = vulnerability. The other is the Queen Theory (enemy strength).

Lind, Maneuver Warfare Handbook (1985)

pp. 17 — Says the second GLUE that holds the force together is the "filter" of "Schwerpunkt" - here it applies to own forces main point of effort against an enemy weakness. It is shifted by the CDR as his subordinate units discover weakness.

pp. 24 Talking about operational art: "the small force wins only by using battle sparingly . . . When a victory will strike directly at the enemy's strategic center of gravity."

Schneider, The Theory of Operational Art (1988)

pp. 27 Combat mass is the fire density of a deployed force (including its indirect fires). CONCENTRATING it creates a center of gravity.

Schneider, Vulcan's Anvil (1991)

pp. 25 Describes a conflict of interest between possession of territory which requires dispersal and stroke at center of gravity which requires concentration.

pp. 26 Describes the dynamics of massing to strike a COG (and forming your own in so-doing). . . Described by both Clausewitz and Jomini and calculated by Lanchester Square Law.

Warden, The Air Campaign (1988)

pp. 9, 10, 53, 138 CENTER OF GRAVITY = Vulnerability. "Command is the true center of gravity" - three spheres: Information, Decision, Communication

Student Monographs

LeGare, Mass: Evolving Tool of the U.S. Operational Artis (1983)

pp. 10 Center of gravity is the location of concentration of "mass"

pp. 14 position and concentrate mass to direct energy at the decisive point

Pickar, Blitzkrieg (1992)

pp. 33 Defines COG as main effort (COG in Causasus in Operation Barbarosa).

Tempo

Doctrinal Publications

Field Manual 100-15, Corps Operations (1996)

pp. 2-18	"The effects of nuclear weapons can-- . . . Change the battle tempo and the courses of campaigns and battles. "
pp. 2-2	"The first aspect in the commander's visualization is gaining an understanding of the current state of his unit and that of the enemy. This includes . . . tempo of operations"
pp. 2-20	"Passive defense operations reduce force vulnerability, minimize the effects of attack on the tempo of operations,"
pp. 2-24	"Air Force and Army delivery of critical supplies to forces conducting deep operations enhances those operations and helps maintain their tempo."
pp. 2-4	"A commander's battle space expands and contracts in relation to the ability to acquire and engage the enemy . . .is influenced by time, tempo, depth, and synchronization. "
pp. 2-5	"Commanders determine the best sequence of operations that will maintain the initiative and achieve a tempo of operations to reach the desired objective. In deciding on the required tempo, commanders consider many factors "
pp. 2-5	"- Seizing and retaining the initiative while controlling the tempo of operations. A key aspect of simultaneous operations in depth is tempo. Commanders control their tempo and strive to control the enemy's tempo."
pp. 2-5	"By design, deep operations dominate the enemy by--. . . Disrupting the tempo of his operations. . . Goals of deep operations include--. . . Altering the tempo of operations in favor of the corps. "
pp. 3-14	"Ideally, there should be spare systems and crews available to provide airlift and sealift to accommodate maintenance failures, provide necessary crew rest, and replace estimated casualties without disrupting the tempo of the operation."
pp. 4-1	"Battle command is the natural expansion of C2 brought on by changes in the scope, intensity, and tempo of current and future operations"
pp. 4-13	"The Army is currently facing the need to consider alternative approaches to CP structuring because of-- . . . The fast-paced operational tempos."
pp. 4-5	"Tempo is the rate of speed of military action. Tempo is not synonymous with speed. At times, the commander may wish to slow operations and induce the enemy to hasten his operations."
pp. 4-5	"The increased tempo of future operations will be manifested through requirements to move forces rapidly, destroy the enemy quickly, and reset for subsequent operations before the enemy can recover or respond."
pp. 5-1	"A sudden or unexpected change, which catches the enemy off guard, in the tempo of operations is another way the corps can achieve surprise"
pp. 5-1	"Surprise, concentration, tempo, and audacity are the critical characteristics of offensive action."
pp. 5-12	"The boundaries between what is deep, close, or rear are not well-defined lines; they shift over time as the corps concentrates and varies the tempo of the attack to keep the enemy off balance. "

pp. 5-15	"The fluidity and quick tempo of corps offensive operations pose challenges to corps rear operations planning"
pp. 5-17	"Corps units should vary the tempo of operations, concentrate rapidly to strike the enemy, then disperse and move to subsequent objectives."
pp. 5-2	"By controlling and changing the tempo of the attack, the corps can keep the enemy in a reaction mode, off balance, yet still retain the initiative."
pp. 5-2	"The tempo of offensive operations is the effect the combination of speed of military action and combat power creates. The more rapidly a force can apply combat power throughout the depth of enemy defenses, the greater the tempo will appear."
pp. 5-48	On Fire Support: "Synchronization also helps the corps control the tempo of the attack."
pp. 6-2	"The corps disrupts the attacker's tempo and synchronization to prevent him from massing his combat power at the point of attack"
pp. 6-8	"Ideally, units launch local counterattacks immediately after attacking forces enter the position and have not had time to reorganize and establish themselves or maintain the operational tempo that allowed them to penetrate."

Field Manual 100-40, Tactics (1997)

pp. 11-20 line 22	"deep operations typically destroy high payoff targets, such as C2 nodes, fire support, and air defense assets. They destroy the enemy's cohesion and disrupt the TEMPO of his approach to the main battle area."
pp. 12-10 line 20	"The intensity of deep operations increases dramatically upon commitment of the striking force to generate a TEMPO that temporarily paralyzes enemy C2."
pp. 12-13 line 15	"Dismounted assaults reduce the TEMPO of the operation but provide a greater degree of security."
pp. 2-6 line 29	"Rear operations underwrite the tempo of tactical operations. . ."
pp. 5-1 line 5	"the execution of that attack must mass the effects of overwhelming combat power against a portion of the enemy force with a tempo and intensity that cannot be matched by the enemy."
pp. 7-1 line 12	"A successful pursuit requires flexible forces, initiative by commanders at all levels, and the maintenance of a high tempo during execution."

Field Manual 100-5, Operations (1986)

pp. 128	"An offensive relief is conducted to pass fresh troops into the attack in order to maintain offensive momentum. . . May be conducted as reliefs in place, but ideally are conducted without a significant pause in offensive tempo."
pp. 15	"On initiative: "Planning anticipates likely enemy course of action so no time is lost in shaping the battle -- setting the tempo and conditions of enemy operations -- and in making adjustments."
pp. 20	"Command posts and communications networks must be deployed where they can continue the fight without a break in the operating tempo."
pp. 22	"The ultimate measure of command and control effectiveness is whether the force functions more effectively and quicker than the enemy.

Field Manual 100-5, Operations (1993)

pp. 10-5	"Commanders slow the enemy's movement in some areas or separate their formations to deny the enemy the ability to mass or establish a tempo that will make defense impossible."
pp. 2-11	"Sustained, high-tempo operations can put soldiers at risk." (safety)
pp. 2-5	Surprize can be in tempo, size of force, direction or location of main effort, and timing"
pp. 2-6	In defense, commanders "act rapidly to negate the attackers initial advantage - they set the tempo
pp. 3-11	On Early Entry Decisions: "Sustaining the tempo is especially important."
pp. 6-13	"Battle space also includes the operational dimensions of combat, including time, tempo, depth, and synchronization."
pp. 6-8	"Tactical overextension is less a matter of culmination than a temporary exhaustion or depletion of resources." Also, outrunning current intelligence can influence culmination. (Note: both of these result from support tempo not matched with the op tempo)
pp. 6-9	"Synchronization of logistics with combat operations can forestall culmination and help the commander control the tempo of his operations." (In reality, logistics has a tempo and the ops have a tempo - and these must be "tuned" to match one another).
pp. 6-9	On Sequencing Operations: "Army commanders determine the best sequence of major operations that achieve a tempo of operations to reach the desired objective."
pp. 7-0	"The attacker presses successful operations relentlessly to prevent the enemy from recovering from the initial shock . . ., regaining his equilibrium [dynamic like tempo], forming a cohesive defense [static], or attacking in turn [morphogenic]."
pp. 7-1	"Surprise, concentration, tempo, and audacity characterize offensive operations and are components of initiative."
pp. 7-11	On frontal attack: "it is often the best form of nameuver for a hasty attack or meeting engagement in which speed and simplicity are paramount to maintaining battle tempo."
pp. 7-12	On operations in depth: "the payoff is high-tempo operations that present the enemy with one continuous operation."
pp. 7-2 - 7-3	Tempo is the rate of speed of military action. Demands ability to decide quickly. Is adjusted to ensure synchronization.
pp. 7-3	"Speed, moreover is not a substitute for the mass produced by sound tactics."
pp. 7-3	[Badly confused string of metaphors]. Tempo provides the necessary momentum. "Tempo is a combination of speed and mass [but mass not defined] that creates pressure on the enemy"
pp. 7-3	"While speed is often preferred, commanders adjust tempo to ensure synchronization. At times, tempo may be slowed to ensure conditions are set before accelerating again to gain the advantages that come with speed."
pp. 7-3	"An attack tempo that puts sufficient pressure on the defender is essential to success. . . Properly exploited, tempo can confuse and imobilize the defender until the attack becomes unstoppable."
pp. 7-4	On approach march: "Commanders adjust their tempo appropriately as they anticipate closing with enemy forces."

pp. 8-5 "To maintain . . . momentum, commanders conduct an offensive relief to pass fresh troops . . . The ability to continually mass at key times and places, while maintaining momentum of the attack at a tempo the enemy cannot handle is essential."

pp. 9-1 disruption of the attacker's tempo and synchronization - separating the enemy forces, isolating units, and breaking up his formations so they cannot fight as an integrated whole.

pp. 9-4 On defense in depth: "As deep operations succeed, they upset the attacker's tempo and synchronization of effects. . ."

Field Manual 101-5-1, Operational Terms and Graphics (1997)

pp. 1-151 (Tempo) The rate of military action; controlling or altering that rate is a necessary means to initiative. All military operations alternate between action and pauses as forces do battle and fight friction

pp. 1-151 (OPTEMPO) 1. The pace of an operation or operations. The OPTEMPO includes all of the activities the unit is conducting. OPTEMPO can be a single activity or a series of operations.

pp. 1-151 OPTEMPO 2. The mileage allowed to be put on a vehicle or aircraft during a fiscal year based on budgetary guidance. See FMs 1-111, 6-20, 7-20, 7-30, 17-95, 71-100, 71-123, 100-15, and 101-5.

Fleet Marine Field Manual 1, Warfighting (1989)

pp. 32 "Speed is rapidity of action. . . Speed over time is tempo, speed over distance is velocity."

pp. 55 Quotes Sun Tzu: "Speed is of the essence - strike him where he has no precautions."

pp. 60 "Through the use of greater tempo, and velocity, we seek to establish a pace that the enemy cannot maintain --"

pp. 62 "In order to generate tempo of operations we desire and to cope with uncertainty, disorder, and fluidity of combat, command must be decentralized.

TRADOC Pamphlet 525-5, Force XXI Operations (1994)

pp. 3-17 Describes dynamic interplay between strategy and doctrine. Describes 100-5 (82) as for Fighting outnumbered but no longer technically inferior. . . ALB controlled the tempo of ops" Next 100-5 will "organize battlefield and control operational tempo."

pp. 3-19 "Improved logistic asset visibility will also affect tempo." "Timing pulses of maneuver, pulses of logistics, pulses of fire-and-speed will achieve maneuver, and if necessary, firepower dominance." - controlled by shared information.

pp. 3-19 "Tempo is more than speed; it is adjustment in rate of operations relative to battle circumstance and assessment relative to enemy capability to sense and react."

Theoretical Works

Epstein, Napoleon's Last Victory (1992)

pp. 98, 99 (Italy 1809] The Austrian "plan placed a premium on speed and rapid command and control. . . However, the command and staff were untried which tended to slow the pace. If the tempo of operations could not be maintained, then the campaign would be lost."

Leonhard, The Art of Maneuver (1991)

pp. 58 Tempo derives from momentum. Differentiates between "mounting" tempo and "execution" tempo. (Insight into tempo as a decision rate, cycle frequency)

Lind, Maneuver Warfare Handbook (1985)

pp. 6 "Maneuver means Boyd cycling the enemy, being consistently faster through however many OODA loops it takes until the enemy loses his cohesion. . . "

pp. 78 "We keep our tempo by moving faster than the enemy's. We are moving quickly. The enemy is always off balance. . . The result of faster tempo on our side will be fewer casualties."

Schneider, Vulcan's Anvil (1991)

pp. 45 "Formations conducting a distributed campaign are analogous to gases undergoing similar force dynamics. . . " hard to maintain their density. The army "percolates distributively . . . Projects force by virtue of its rate of flow: its tempo and density."

pp. 46 "Not only does logistics sutain the movement tempo, it also sustains its force density."

Simpkin, Race to the Swift (1985)

pp. 112 "Paucity or inaccuracy in INFORMATION impacts maily on the TEMPO of C2"

Student Monographs

LeGare, Mass: Evolving Tool of the U.S. Operational Artis (1983)

pp. 27 Good definition for Tempo: Rhythm, cadence

Pickar, Blitzkrieg (1992)

pp. 11 Bad physics: "Tempo is a measurement of speed and direction." on p. 12: (dist. From concentration area to OBJ) / (time from rcpt orders to accomplish mission)

pp. 12 "Tempo not only determines combat power, it IS combat power" (conveys that it's an advantage, but completely invalid otherwise).

Phase Transition

Doctrinal Publications

Field Manual 100-15, Corps Operations (1996)

pp. 10-1	On Future: "dispersion effectively neutralizes the threat of enemy artillery concentrations. The movement is rapid and "in step," . . . converging momentarily to slip through pinpointed passages in restricted terrain, then dispersing again."
pp. 2-18	" The corps could use nuclear weapons to-- . . . Force dispersal of enemy units."
pp. 4-3	"Physical agility is inculcated at lower levels by stressing the ability to move, concentrate, strike, and sustain the momentum of operations."
pp. 4-8	"Because of the unique signature of massed CPs and their greater vulnerability to acquisition and attack, the corps should disperse the cells of the command posts whenever feasible."
pp. 5-11	"The corps conducts spoiling attacks to disrupt an expected enemy attack or to disrupt the enemy's concentration and timing."
pp. 5-2	"Commanders must balance force-protection activities, such as dispersion, concealment, deception, and security, against the requirement to concentrate effects. "
pp. 5-2	"Because of the fluid nature of offensive operations, corps units might simultaneously employ different forms of the offense throughout the depth of the battlefield."
pp. 5-2	"Concentration of forces can make the corps vulnerable to enemy action. Commanders must balance force-protection activities, such as dispersion, concealment, deception, and security, against the requirement to concentrate effects"
pp. 5-2	"Operations must be flexible enough to allow the main effort to shift without losing the effects of mass and momentum."
pp. 5-5	"Spoiling attacks enhance deception operations and prevent the enemy from concentrating reserves"
pp. 6-12	"The signal support system will be challenged to meet the demands of a fluid mobile defense."
pp. 7-2	"The complexity and fluidity of retrograde operations and the absolute need to synchronize the entire corps operation dictates the need for detailed, centralized planning and coordination with decentralized execution."
pp. 8-9	"In theaters where long-range sensors can expose dispositions at great distance and where self-directing antiarmor munitions and air maneuver can alter circumstances rapidly, fluid movement is crucial, the real essence of "agility." "

Field Manual 100-40, Tactics (1997)

pp. 10-30 line 28	Fire Support in the MBA: "target enemy units, force them to deploy, inflict casualties, disrupt the cohesion of the enemy's attack and his ability to MASS combat power."
pp. 11-17 line 15	"Generating MASS is expecially critical to the commander tasked to defend a large area against an enemy with a significant advantage in combat power."
pp. 17-21 line 13	On Movement: "Multiple routes provide the commander with the FLEXIBILITY to react to unexpected situations and permits more rapid CONCENTRATION of combat power."

Field Manual 100-5, Operations (1986)

pp. 100	Must sustain the "momentum of the attack." Attack may be hasty or follow "the unintended collision . . The battle of Gettysburg resulted from just such an unintended collision. . . Finally, phases may run into each other with no abrupt . . . break."
pp. 109	"The ideal attack should rsemble what Liddell Hart called the 'expanding torrent' It should move fast and follow reconnaissance . . shift its strength quickly to widen penetrations. . . carrying the battle deep into the enemy rear."
pp. 11	"More commonly, tactical success by the attacker leads to a fluid operational interlude which lasts until the defender reestablishes a tenable resistance or the attacker overextends himself."
pp. 129, 130	"The defense can greatly damage the enemy only when early counterstrokes accompany the reactive PHASE of the battle. Gettysburg exemplifies a defensive battle of pure reaction. The outcome depended on the errors of the attacker."
pp. 130	"A closer parallel to the fluid conditions, rapid maneuver, and calculated risks of contemporary operations can be found in the Battle of Tannenberg. . ."
pp. 137	"Defensive operations . . Will require [the enemy] to designate a main effort, concentrate in support of it, then shift it to concentrate against another threat, and to do so repeatedly."
pp. 14	"operational planning must orient on decisive objectives. . . stress flexibility, the creation of opportunities to fight on favorable terms by capitalizing on enemy vulnerabilities, concentration against enemy centers fo gravity. . ."
pp. 15	"On initiative: "Planning anticipates likely enemy course of action so no time is lost in shaping the battle -- setting the tempo and conditions of enemy operations -- and in making adjustments."
pp. 16	"Agility -- . . . act faster than the enemy. . . permits the rapid concentration of friendly strength against enemy weakness. . . repeatedly. . . against [local weakness] enables smaller forces to disorient, fragment, and . . . defeat much larger [ones]."
pp. 16	"Elasticity in the defense is achieved and maintained when resources and forces are deployed in depth. . .and defending forces aggressively concentrate combat power in critical areas."
pp. 17	"In the chaos of battle, when communications fail and face-to-face coordination is impossible, . . . implicit coordination may make the difference between victory and defeat."
pp. 175	Maneuver = (principle of war) "Place the enemy in a position of disadvantage through the flexible application of combat power." Mentions flexibility three more times in two descriptive paragraphs.
pp. 19, 20	WWII, Korea, and Vietnam show examples of techniques to "isolate the battlefield, paralyze the enemy's support and command and control systems and to prevent, delay, or disrupt . . . uncommitted enemy formations. . ." [and means are more available now].
pp. 2	"The high- and mid-intensity battlefields are likely to be chaotic, intese and highly destructive. . . Even in conventional combat, operations will rarely [be] linear." Concentration speed and volume of fire make "intermingling" inevitable.
pp. 22	"Wargaming, rehearsals, and realistic training promote initiative and flexibility by preparing units and their leaders for cooperation in the chaos of combat without time-consuming coordination."

pp. 27	"AirLand battle doctrine recognizes that modern warfare is likely to be fluid and nonlinear. . . [emphasizes] initiative, agility, depth, and synchronization . . "
pp. 3	"The more fluid the battlefield, the more important and difficult it will be to identify decisive points and to focus combat power there."
pp. 3	"Fluidity will also characterize operations in the rear of forward deployed committed forces. Guerrillas, SOF, and terrorists will seek to avoid set-piece battles and to strike at scattered points of vulnerability."
pp. 35	"Commanders must . . .minimize overall risk by dispersing their commands into small units. . . Yet they must concentrate sufficient combat power to accomplish the mission. . . This dilemma is dynamic [must disperse - concentrate - disperse]."
pp. 4	"Combat in built-up areas will be unavoidable in most theaters of war. Divisions and larger units will have to plan for attack and defense in urban areas and for fluid battles around them."
pp. 59	ability to maneuver or mass fires extensively depends on flexibility
pp. 7	"The complexities of combat make it increasingly important to concentrate on training programs for leaders and teams."
pp. 70	on fluid battlefield, lines of operations may change with startling rapidity
pp. 78	fluid battles may develop rapidly on high speed avenues of approach
pp. 96	sudden concentration followed by deep exploitatoin, to shatter enemy def in depth

Field Manual 100-5, Operations (1993)

pp. 10-1	"IPB is more difficult if friendly units are fighting irregular forces that have no doctrine and adapt their methods rapidly when fighting conventional forces."
pp. 12-4 & 12-5	"Logistics commanders and staffs must adapt units to requirements, often on short notice. . . [on improvisation] Successful logistics operations adapt to changing situations. The American soldier is a master at this."
pp. 12-9	"On a FLUID battlefield, LOCs may change orientation rapidly."
pp. 2-4	MASS must also be sustained so the effects have staying power. Mass thus seeks to SMASH the enemy, not sting him.
pp. 2-4	To MASS is to hit the enemy with a closed fist, not poke him with fingers of an open hand (here the closed fist is the combined arms team the fingers single arms)
pp. 2-6	The goal is to create a fluid situation where the enemy loses the coherence of the defense. (like a Schneider phase change)
pp. 2-7	In the defense, depth creates elasticity
pp. 2-7	On agility - greater quickness permits rapid concentration of strength against enemy vulnerabilities - repeatedly, successively
pp. 7-13	On close operations in the offense: "Commanders pick a combination of the forms of offensive operations and movement to use at the critical time and place . . . dispersed formations that mass to fight . . . Disperse again to protect the force."
pp. 7-3	"Different forms of attack -- occuring throughout the depth of the battlefield simultaneously and in closely aligned phases that shift back and forth -- take new forms and offer increasing options for development."

pp. 7-3	On 4 forms of offense: "movement to contact, attack, exploitation, and pursuit. . . Different forms flow readily from one to another. Operations are increasingly fluid."
pp. 7-3	"In force projection operations, the transition from offense to defense is another critical ebb and flow."
pp. 7-3	"The ebb and flow of battle opens up many avenues for attack; victory goes to the bold."
pp. 7-9	"Pursuit, like other operations, can give way to other forms of the offense." Example: Huertgen forest, WW II.
pp. 9-1	separating the enemy forces, isolating units, and breaking up his formations so they cannot fight as an integrated whole.

Field Manual 101-5-1, Operational Terms and Graphics (1997)

pp. 1-53	dispersion - 3. The spreading or separating of troops, materiel, establishments, or activities which are usually concentrated in limited areas to reduce vulnerability
pp. 1-98	Mass (JP 1-02, NATO) 1. The concentration of combat power. 2. The military formation in which units are spaced at less than the normal distances and intervals. (Army) To concentrate or bring together fires, as to mass fires of multiple weapons or units

Fleet Marine Field Manual 1, Warfighting (1989)

pp. 55	Quotes Sun Tzu: "Now an army can be likened to water"
pp. 7	"Like friction and uncertainty, fluidity is an integral attribute of the nature of war." Should try to adapt to a constantly changing situation. But beware changing tempo to high for too long - there are limits.

TRADOC Pamphlet 525-5, Force XXI Operations (1994)

pp. 2-5, 2-8	Describes categories of future army types, including "Complex, Adaptive Armies"
pp. 2-8	Projects the empty battlefield phenomenon into the future as a result of dispersal of key nodes in an internetted rather than heirarchial structure.
pp. 2-9	"Maneuver forces may be Physically massed for shorter periods of time."

Theoretical Works

Bacevich, The Pentomic Era (1986)

pp. 105-116	Gavin: The problem - was to "dissolve the [existing] units down to the size of units you are not afraid of losing in one [nuclear] blast." Conceptually to deploy on a widely dispersed non-linear battlefield.
pp. 135	Army not optimistic about "Flexible Response" on Nuclear Battlefield. COL Henry E. Kelly article: Only a "Verbal solution" - "virtuous words" of dispersion, flexibility, and mobility - no "Army could aquire merely by repeating the words over and over."

Booz, Allen & Hamilton, Decisive Ops, Mass. Eff., & Entropy Based Warfare (1997)

pp. Slides	41 Network Centric Chaotic Model. 31 dynamic systems/swarm. 34 described as beyond linear and fluid battlefield. 19 - 21 Force, Temporal and Spatial values computed. 9 concentrates on the linkage

Epstein, Napoleon's Last Victory (1992)

pp. 120	Italy (1809): "Eugene would rely on interior lines to crush one opponent, then the next. The Viceroy planned to fall back only until had gathered enough forces to turn and crush John's army."

pp. 154	(1809): "A see-saw fight raged for the [Ebelsberg] castle. . . Finally the French stormed the castle."
pp. 19	On Bourcet's new method (~1770): "The method by which these divisions would alternately be dispersed and concentrated and dispersed again emphasized flexibility. . ."
pp. 19	Bourcet's new method (~1770): "The unitary field armies of the past could be broken into their separate divisions and dispersed on broad fronts."
pp. 21	On Guibert's contribution (1770s): "This approach differed significantly from pas practice in that the dispersed but mutually supporting [assembled] divisions . . . could be flexibly used to attack or defend depending on the circumstances."
pp. 22	"Guibert's writings included a description of a flexible tactical system, based on the infantry battalion organized in a column of maneuver. The battalion would be trained to easily deploy into a linear formation and back into column. . ."
pp. 25	On the French levee: "The army was flooded with untrained recruits. . . unable to execute the more intricate maneuvers of [1791]. These enthusiastic but untrained troops fought in battalion column or were dispersed into great clouds of skirmishers."
pp. 279	"Neither Napoleon, the Allied commanders who fought against him, nor the theorists Clausewitz and Jomini were able to articulate the way warfare had changed since 1809. For them, the Napoleonic wars formed a unitary block rather than two separate periods.
pp. 279	"Neither Napoleon, the Allied commanders who fought against him, nor the theorists Clausewitz and Jomini were able to articulate the way warfare had changed since 1809. For them, the Napoleonic wars formed a unitary block rather than two separate periods.
pp. 45	On the Grand Armee (1804): "separate corps [with] organic units, staffs and flexible tactics, could fight a combined arms action with great advantage against an opponent of the same size but without the necessary structure, cohesion, and flexibility."
pp. 45, 66	On the Grand Armee (1804): "The collective effect of the staff system, corps structure, experienced citizen soldiers at all levels, and flexible tactics produced the first truly nineteenth century army."
pp. 48	On the battle of Austerlitz (Dec 1805): "The allies were completely outclassed in respect to generalship, command, control, tactical flexibility, and intelligence."
pp. 48	On the Grand Armee (1804): "The days of armies moving as unitary blocks under the direct command of the commander in chief were gone. . . [enter] distributed maneuver . . . Napoleon practiced what later became known as decentralized command and control."
pp. 54, 55	On Jena (Oct 1806): The Prussians "collided with the French . . . Napoleon successively smashed the armies of Hohenlohe, [and Ruchel]. . . The prussian command became paralyzed [Duke killed]. . . Davout was able to smash the piecemeal Prussian attacks."
pp. 55,56	"Jena-Auerstadt. . .The collision of large armies on extended fronts. . . longer fall under the eyes of [CINCs]. . .mistakes ([later called] friction) were bound to occur." (Decentralized C2 overcame friction [adapted] if battle was one-sided like this).
pp. 69	(1809): "the French center of gravity shifted to Iberia. The defeats inflicted on French forces there meant that a further strategic commitment was needed."
pp. passim.	More general characterizations of Napoleon and the 1809 Austrians as "flexible" See pp. 58, 66, 79, 80, 82.

Geyer, German Strategy in the Age of Machine Warfare (1986)

pp. 532 Says that the Schleifen plan was actually an example of an "expanding torrents" plan designed to force a fluid situation with many possible points of concentration toward a decision - "a concept abandoned by the younger Moeltke."

pp. 532 Says the Schlieffen Plan was designed to counter the fluidity of war by using a massive forward thrust to create a center of gravity and escalate into the annihilation of the enemy forces.

Leonhard, The Art of Maneuver (1991)

pp. 50 Comments on the Liddel Hart's "EXPANDING TORRENT" - says it's ultimately due to Sun Tzu.

Lind, Maneuver Warfare Handbook (1985)

pp. 9 Quotes B.H. Liddel Hart on the EXPANDING TORRENT system of attack (Hart's article from JRUSI, Feb 1921).

Mao, Selected Military Writings (1991)

pp. 137-142 Plans must be fluid within limits (practical flexibility)

pp. 138 "As [the Red Army's] operational direction often shifts, its battle lines are fluid."

pp. 138 "The exponents of 'regular warfare' . . .denied this fluidity and opposed what they called 'guerrilla-ism. . . comrades who oppose fluidity managed affairs [like] a big state, and the result was extraordinary and immense fluidity -- the 25,000 li [march]"

pp. 138 "Fluidity of battle lines leads to fluidity in the size of our base areas. Our base areas are constantly expanding and contracting, and often as one base area falls another rises. This fluidity of . . . is entirely a result of the fluidity of the war."

pp. 138 "Fluidity in the war and our territory produces fluidity in . . .construction in our base areas. . . We must not have illusions [of] advance without any retreats, take alarm at any temporary fluidity . . .or attempt to draw up detailed long-term plans."

pp. 138 "It is only by exerting ourselves in today's fluid way of life that tomorrow we can secure relative stability, and eventually full stability."

pp. 138 "The difference between the Soviet Army and ours is that its battle lines were not so fluid as ours."

pp. 139 "In the future this guerrilla character will definitely become something to be ashamed of and to be discarded, but today it is invaluable and we must stick to it."

pp. 139 always keep moving so as to be able to give battle only when you can win.

pp. 140 "In the second stage. . . Both the guerrilla character and the fluidity were considerably reduced"

pp. 140 "In the third stage, . . . The guerrilla character and the fluidity were further reduced, and a central government and a revolutionary military commission had already been set up."

pp. 140 "The fourth stage was the Long March. The mistaken rejection of guerrilla warfare and fluidity on a small scale had led to guerrilla warfare and fluidity on a great scale."

pp. 140 "Now we are in the fifth stage. Because of our failure to smash the fifth "encirclement and suppression" campaign and because of this great fluidity, the Red Army and the base areas have been greatly reduced."

pp. 140 "have there been no changes whatsoever in the guerrilla character of the Red Army, its lack of fixed battle lines, the fluidity of its base areas, or the fluidity of construction work in its base areas? Yes there have been changes."

pp. 140	"In Kiansi. . . [the first] stage in which guerrilla character and fluidity were very pronounced."
pp. 141	"guerrilla-ism consists of the principle of mobile warfare, . . . Which is still necessary at present, the inevitable fluidity of or base areas, flexibility in planning the development of base areas. . ."
pp. 184	sacrifice cohesion at lower (tactical) levels to gain it at higher political and strategic levels. Strategic centralization produces, over the long run, moral cohesion
pp. 193	Extended fluid front - swift advances and withdrawals, swift concentration and dispersals -
pp. 228-229	Extends fluid metaphor to extreme - "a FLUID society" - mobilization of the common people throughout the country will create a "vast SEA in which to DROWN the enemy."
pp. 84	"The Important Thing Is To Be Good At Learning"
pp. 84, 138	(related to "fluidity") Must understand RELATIONSHIPS between concentration and dispersion, attack and defense, advance and retreat, concealment and exposure, assault and containment, regular and guerilla, fighting and resisting, and others

Pitt, The Crucible of War 2 (1986)

pp. 119	On observations in N. Africa: "Gradually during the night, groups sorted themselves out, formations COALESCED"

Schneider, Black Lights (1996)

pp. 12	"Armies rush together like great rivers along broad turbulent fronts. Destroy that fluid medium and you have effectively frozen and paralyzed the enemy."
pp. 13	"It would be a serious error, however, to believe that one could defeat an opponent by paralysis alone. . . Complex military systems [will] spontaneously self-[reorganize and adapt]. . . Armies in battle [are] distributed . . . swarm or hive-like"
pp. 13	Quotes Sun Tzu: ". . . Apparent confusion is the product of good order."
pp. 8	"the continuous, fluid and wavelike nature of lightning-fast information is able to control and regulate all aspects of Full Spectrum Dominance."
pp. 8	"dense solid pre-industrial military forces began to disaggregate and distribute themselves to accommodate the new physical characteristics of the modern nation-state. Fundamentally, armies began to melt or-better- liquify and flow"
pp. 9	"flow of armies. . . Manifested a state of turbulence, eddies of disorganization and disorder that for the first time . . . transformed the simple dense monolithic tactical structures into distributed complex . . . Fighting at the edge of chaos."

Schneider, The Theory of Operational Art (1988)

pp. 6-7	compares a disorganized enemy to liquified
pp. 6-7	compares a disintegrated enemy to gaseous

Schneider, The Theory of the Empty Battlefield (1987)

pp. passim.	describes dispersal as decreasing battlefield troop density. Formulates a target density factor as well. . . inversly proportional to the rate of fire. Also unity of will proportional to troop density. Relates to DuPiq and Marshall. . . moral cohesion.

Schneider, Vulcan's Anvil (1991)

pp. 11 "In a very fundamental way, the battlefield had become liquified. The application of concentration of force would have to be achieved with new methods. Now the physical analogy of mechanical Force would be replaced by the analogy of Pressure."

pp. 15 "Fundamentally troops of the 19th century were confronted with a curel dilemma: maintain a concentrated morrally cohesive formation and die or maintain a dispersed fragile unit and survive."

pp. 15 Quotes SLA Marshall and indicates that "the use of massed formations provided a singular psychological benefit as well: the hardening of moral cohesion."

pp. 17 "From now on battle itself would become atomized and consist of a cloud of engagements. These . . . Would flow through the theater of operations creating great military pressure."

pp. 21 Discusses a requirement to COMPRESS the enemy . . . cause him to concentrate mass . . . so that he could be destroyed efficiently.

pp. 26 Describes the dynamics of massing to strike a COG (and forming your own in so-doing). . . Described by both Clausewitz and Jomini and calculated by Lanchester Square Law.

pp. 45 "Formations conducting a distributed campaign are analogous to gases undergoing similar force dynamics. . . " had to maintain their density. The army "percolates distributively . . . Projects force by virtue of its rate of flow: its tempo and density."

Schneider, What if We Fight Tonight (1995)

pp. 5 Cites Mao's "great river of absolute fluidity" metaphor for the future, regarding the challenge of precise planning.

Sun Tzu, The Art of War (Griffith) (1971)

pp. 101 (Also 193 in Sawyer's trans.) Now an army may be likened to water, for just as flowing water avoids . . . strengths and strikes . . . weakness. Water shapes its flow - with the ground. Water has no constant form, there are in war no constant conditions.

pp. 89 (Also 184 in Sawyer's trans.) "his people fight with the effect of pent-up waters which, suddenly relaesed, plunge intoi a bottomless abyss. (Chang Yu comment: avoid strength, strike emptiness).

pp. 92 (Also 187 in Sawyer's translation.) When water tosses boulders, it is because of its momentum

Student Monographs

LeGare, Mass: Evolving Tool of the U.S. Operational Artis (1983)

pp. 13 Commenting on CVC and Napoleon. Suggests a method of deliberate increase or decrease in DENSITY.

Pickar, Blitzkrieg (1992)

pp. 14 describes the effects in terms of Liddel Hart's EXPANDING TORRENT Model: essentially the erosion of the mud bank under the action of a swolen river.

pp. 17 depth allows momentum and elasticity to develop.

Friction

Doctrinal Publications

Field Manual 100-15, Corps Operations (1996)

pp. 2-7	"Reserves give a commander options and flexibility and provide an edge against uncertainty."
pp. 2-9	"Intelligence preparation of the battlefield is the commander's responsibility and helps reduce the uncertainty about the effects of the enemy, weather, and terrain on operations. "
pp. 4-4	"The friction of battle will be tremendous. Loss of communications, inaccurate reporting, use of weapons of mass destruction, loss of a command post, attacks within the corps rear area, and so forth, will work against the commander's will"

Field Manual 100-40, Tactics (1997)

pp. 1-14, 1-15	plan and organize to provide FLEXIBILITY to compensate for lack of information about the enemy. Use bigger reserve, more security forces, slower ops, less distributed. . .
pp. 1-30 line 14	Commanders "must allow enough time to take into account the inevitable friction that accompanies moves during operations."
pp. 2-35 line 16	"Other factors such as the uncertainty regarding enemy intentions and the impact of leadership, belong to the art of war."
pp. 2-7 line 23	"The reserve gives the commander flexibility by providing him a force to react to unforseen contingencies and act as a hedge against uncertainty."

Field Manual 100-5, Operations (1986)

pp. 109	A "culminating point is achieved when a force on the offensive expends so much of its strength that it ceases to hold a significant advantage. . .occurs because the attacker must consume resources and commit forces. . .[and] friction [slows the attacker]"
pp. 16	"the accumulation of chance errors, unexpected difficulties and confusion of battle will impede both sides"
pp. 172	"A lack of adequate communications and intelligence may hamper the initial phase of contigency force operations."
pp. 7	"logistical readiness -- the availability and proper functioning of materiel, resources, and systems to maintain and sustain operations on a fluid, destructive, and resource-hungry battlefield." [connotes dissipation like friction produces]
pp. 97	Flexibility is a characteristic of Offensive operations: "The attack must be flexible. . . [commander] must expect uncertainties . . . [must initially plan in detail to] preserve synchronization on a fluid battlefield."

Field Manual 100-5, Operations (1993)

pp. 14-2	phsychological factors increase FOG
pp. 2-7	Good definition: Friction is the accumulation of chance errors, unexpected difficulties, and confusion of battle that impede both sides. It can never be completely eliminated.

Field Manual 101-5-1, Operational Terms and Graphics (1997)

pp. 1-151	All military operations alternate between action and pauses as forces do battle and fight friction

Fleet Marine Field Manual 1, Warfighting (1989)

pp. 4 — From Clausewitz: "the force that makes the apparently easy so difficult." - and complex. (physical, external, internal) should minimize ours and raise the enemy's. should train that way.

pp. 6 — Cites Fog of war. Connected to risk, danger, initiative, friction.

pp. 62 — "In order to generate tempo of operations we desire and to cope with uncertainty, disorder, and fluidity of combat, command must be decentralized.

pp. 7 — "Like friction and uncertainty, fluidity is an integral attribute of the nature of war." Should try to adapt to a constantly changing situation. But beware changing tempo to high for too long - there are limits.

TRADOC Pamphlet 525-5, Force XXI Operations (1994)

pp. 2-2 — Information proliferation may prove to be a double-edged sword. . . Manipulation of the media to control public opinion . . . Access to information involving other cultures. . . May prove to be a significant source of FRICTION.

pp. 3-4 — "Despite information technology, . . . Never have perfect knowledge of the operational situation. . . Yet due to the pace and complexity of future battle, commanders, more so than in the past, must accept uncertainty."

Theoretical Works

Clausewitz, On War (Howard & Paret) (1989)

pp. 101, 108 — Concept of fog as obscuration (101)
Psychological fog of degraded judgement (108)

pp. 119 - 122 — "Everything in war is simple, but the simplest thing is difficult." Many minor unpredictable incidents . . . reduces will. Rooted in pshych. Of danger, exertion, uncertainty. (see also resistance, mass/inertia 580).

De Landa, War in the Age of Intelligent Machines (1994)

pp. 23 — Describes "friction" as delays, bottlenecks, and noisy data.

pp. 60 — Says "friction" has several military meanings: "On the one hand it referes . . . to the physical friction responsible for delays, bottlenecks and machine breakdowns. But more generally, it is used..." to describe uncertainty.

Epstein, Napoleon's Last Victory (1992)

pp. 111 — On the Danube (1809): "there was no single battle and neither commander physically could view the entire operational front [averaging 70 miles in length]. This type of war breeds confusion [and friction]."

pp. 118 — "Not all contingencies can be expected or planned. Information is imperfect, and the whereabouts and intentions of the enemy, as well as the location of one's own troops. . . are uncertain. . . A commander must act on uncertainty. . . take risks. . ."

pp. 55,56 — "Jena-Auerstadt. . .The collision of large armies on extended fronts. . . longer fall under the eyes of [CINCs]. . .mistakes ([later called] friction) were bound to occur." (Decentralized C2 overcame friction [adapted] if battle was one-sided like this).

Lind, Maneuver Warfare Handbook (1985)

pp. 46 — "Units must get plenty of time in the field as units if they are to learn how to accomplish their misssions despite friction." commanders should "inject" friction into exercises.

pp. 6 — maneuver warfare means creating disorder and operating within it successfully by decentralized command.

pp. 6 Quotes Van Creveld on assessment that command in war has been an endless search for certainty

Luvaas, Buna 19 November 1942 - 2 January 1943 (1986)

pp. 376 Describes lots of general friction making US operations at Buna very difficult.

Mao, Selected Military Writings (1991)

pp. 241 "Flexibility . . . is the concrete realization of the initiative in military operations . . . requires the overcoming of confusion, obscurity, and uncertainty peculiar to war and the discovery of order, clarity and certainty in it."

Simpkin, Race to the Swift (1985)

pp. 112 "Paucity or inaccuracy in INFORMATION impacts maily on the TEMPO of C2"

Watts, Clausewitzian Friction and Future War (1996)

pp. 131 & note 12 Discusses Friction as complex. Says COL John Boyd connected Clausewitzian friction to 2nd law of thermodynamics. Endnote 12 regards increase in entropy -- easier understood as friction guarntees a mechanism that dissipates energy.

pp. 15 Says Friction is actually attributable to Scharnhorst (Clausewitz's mentor) from his idea of what war actually is: "Eigentliche Krieg"

pp. 34 Friction, like CVC's notion of COG was undoubtedly borrowed from Newton"via Kantian concerns about how that physics was possible."

pp. 69-78 Info: 1) temporally dispersed 2) irreducible tacit knowledge: unavailable info -> friction which wont be reduced with new technology. Commodity model extended to self organizing market (complexity).

pp. 86 Id's 4 principles regarding unpredictable future war: 1) Violence 2) 2d order effects of unknowables 3) Differential Friction 4) Finite Human Limitation. 5-days confirmed in DS/DS. Evolutionary biology is a better model for future warfare than prediction

Annex 1 (Metaphor Use By Metaphor) to Appendix 3: Presentation of the Data

Count of Physical Metaphor by Metaphor Then Author

Center of Gravity

1 Army Vision 2010: Army Vision 2010 (1997)
5 Clausewitz: On War (Howard & Paret) (1989)
3 Epstein: Napoleon's Last Victory (1992)
6 Field Manual 100-15: Corps Operations (1996)
6 Field Manual 100-40: Tactics (1997)
22 Field Manual 100-5: Operations (1986)
14 Field Manual 100-5: Operations (1993)
2 Field Manual 101-5-1: Operational Terms and Graphics (1997)
1 Fleet Marine Field Manual 1: Warfighting (1989)
1 Geyer: German Strategy in the Age of Machine Warfare (1986)
1 Joint Pub 3-0: Doctrine for Joint Operations (1995)
2 LeGare: Mass: Evolving Tool of the U.S. Operational Artis (1983)
1 Leonhard: The Art of Maneuver (1991)
2 Lind: Maneuver Warfare Handbook (1985)
1 Pickar: Blitzkrieg (1992)
1 Schneider: The Theory of Operational Art (1988)
2 Schneider: Vulcan's Anvil (1991)
1 TRADOC Pamphlet 525-5: Force XXI Operations (1994)
1 Warden: The Air Campaign (1988)

Cohesion

1 Bellamy: The Evolution of Modern Land Warfare (1990)
1 Booz, Allen & Hamilton: Decisive Ops, Mass. Eff., & Entropy Based Warfare (1997)
3 Clausewitz: On War (Howard & Paret) (1989)
1 Corbett: Some Principles of Maritime Strategy (1988)
1 Davis: Aggregation, Disaggregation, and the 3:1 Rule (1995)
1 De Landa: War in the Age of Intelligent Machines (1994)
1 Du Picq: Battle Studies (1987)
9 Epstein: Napoleon's Last Victory (1992)
8 Field Manual 100-15: Corps Operations (1996)
6 Field Manual 100-40: Tactics (1997)
5 Field Manual 100-5: Operations (1986)
5 Field Manual 100-5: Operations (1993)
1 Fleet Marine Field Manual 1: Warfighting (1989)
3 Howard: Men against Fire (1986)
2 Leonhard: The Art of Maneuver (1991)
6 Lind: Maneuver Warfare Handbook (1985)
1 Romjue: From Active Defense to AirLand Battle (1984)

1 Schneider: Black Lights (1996)

3 Schneider: The Theory of Operational Art (1988)

2 Schneider: Vulcan's Anvil (1991)

1 Schneider: What if We Fight Tonight (1995)

1 TRADOC Pamphlet 525-5: Force XXI Operations (1994)

Coherence

1 Dubik: Decentralized Command (1992)

1 Field Manual 100-40: Tactics (1997)

2 Field Manual 100-5: Operations (1986)

2 Field Manual 100-5: Operations (1993)

1 LeGare: Mass: Evolving Tool of the U.S. Operational Artis (1983)

1 Leonhard: The Art of Maneuver (1991)

1 Lind: Maneuver Warfare Handbook (1985)

1 Pickar: Blitzkrieg (1992)

1 Schneider: Vulcan's Anvil (1991)

2 Schneider: What if We Fight Tonight (1995)

1 TRADOC Pamphlet 525-5: Force XXI Operations (1994)

1 Warden: The Air Campaign (1988)

Collision

4 Epstein: Napoleon's Last Victory (1992)

1 Field Manual 100-40: Tactics (1997)

5 Field Manual 100-5: Operations (1986)

2 Field Manual 100-5: Operations (1993)

2 Fleet Marine Field Manual 1: Warfighting (1989)

1 Jomini: The Art of War (1987)

1 LeGare: Mass: Evolving Tool of the U.S. Operational Artis (1983)

1 Lind: Maneuver Warfare Handbook (1985)

1 Pitt: The Crucible of War 2 (1986)

1 Schneider: Black Lights (1996)

1 Schneider: The Theory of Operational Art (1988)

1 Simpkin: Race to the Swift (1985)

Force

1 Field Manual 100-40: Tactics (1997)

1 Field Manual 100-5: Operations (1986)

3 Field Manual 100-5: Operations (1993)

1 Howard: Men against Fire (1986)

1 Leonhard: The Art of Maneuver (1991)

2 Schneider: Vulcan's Anvil (1991)

1 Schneider: What if We Fight Tonight (1995)

2 Tata: Sustaining the Tempo (1993)

Inertia

1 Schneider: The Theory of Operational Art (1988)

Momentum

6 Field Manual 100-15: Corps Operations (1996)

13 Field Manual 100-40: Tactics (1997)

6 Field Manual 100-5: Operations (1986)

7 Field Manual 100-5: Operations (1993)

1 Fleet Marine Field Manual 1: Warfighting (1989)

1 Hogarth: Dynamic Density (1987)

1 LeGare: Mass: Evolving Tool of the U.S. Operational Artis (1983)

3 Leonhard: The Art of Maneuver (1991)

1 Lind: Maneuver Warfare Handbook (1985)

1 Pickar: Blitzkrieg (1992)

1 Simpkin: Race to the Swift (1985)

1 Sun Tzu: The Art of War (Griffith) (1971)

Torque

2 Epstein: Napoleon's Last Victory (1992)

1 Joint Pub 3-0: Doctrine for Joint Operations (1995)

1 Leonhard: The Art of Maneuver (1991)

1 Simpkin: Race to the Swift (1985)

Acceleration

2 Field Manual 100-15: Corps Operations (1996)

1 Field Manual 100-40: Tactics (1997)

1 Fleet Marine Field Manual 1: Warfighting (1989)

1 Leonhard: The Art of Maneuver (1991)

1 TRADOC Pamphlet 525-5: Force XXI Operations (1994)

Tempo

1 Epstein: Napoleon's Last Victory (1992)

23 Field Manual 100-15: Corps Operations (1996)

6 Field Manual 100-40: Tactics (1997)

4 Field Manual 100-5: Operations (1986)

22 Field Manual 100-5: Operations (1993)

3 Field Manual 101-5-1: Operational Terms and Graphics (1997)

4 Fleet Marine Field Manual 1: Warfighting (1989)

1 LeGare: Mass: Evolving Tool of the U.S. Operational Artis (1983)

1 Leonhard: The Art of Maneuver (1991)

2 Lind: Maneuver Warfare Handbook (1985)

2 Pickar: Blitzkrieg (1992)

2 Schneider: Vulcan's Anvil (1991)

1 Simpkin: Race to the Swift (1985)

3 TRADOC Pamphlet 525-5: Force XXI Operations (1994)

Flexibility or Elasticity

1 Bacevich: The Pentomic Era (1986)

1 Clausewitz: On War (Howard & Paret) (1989)

1 Corbett: Some Principles of Maritime Strategy (1988)

1 De Landa: War in the Age of Intelligent Machines (1994)

9 Epstein: Napoleon's Last Victory (1992)

29 Field Manual 100-15: Corps Operations (1996)

11 Field Manual 100-40: Tactics (1997)

18 Field Manual 100-5: Operations (1986)

2 Field Manual 100-5: Operations (1993)

1 Field Manual 101-5: Staff Organization and Operations (1997)

1 Hogarth: Dynamic Density (1987)

1 Howard: Men against Fire (1986)

1 Lind: Maneuver Warfare Handbook (1985)

1 Starry: The Principles of War (1981)

1 TRADOC Pamphlet 525-5: Force XXI Operations (1994)

Mass Distribution

1 Army Vision 2010: Army Vision 2010 (1997)

1 Blackwell, Mazarr, and Snider: Race to the Swift (1985)

1 Clausewitz: On War (Howard & Paret) (1989)

1 Corbett: Some Principles of Maritime Strategy (1988)

17 Epstein: Napoleon's Last Victory (1992)

39 Field Manual 100-15: Corps Operations (1996)

15 Field Manual 100-40: Tactics (1997)

15 Field Manual 100-5: Operations (1986)

1 Field Manual 100-5: Operations (1993)

2 Field Manual 101-5-1: Operational Terms and Graphics (1997)

2 Fleet Marine Field Manual 1: Warfighting (1989)

1 Hogarth: Dynamic Density (1987)

1 Jomini: The Art of War (1987)

4 LeGare: Mass: Evolving Tool of the U.S. Operational Artis (1983)

2 Leonhard: The Art of Maneuver (1991)

2 Luvaas: Buna 19 November 1942 - 2 January 1943 (1986)

1 Mao: Selected Military Writings (1991)

1 Romjue: From Active Defense to AirLand Battle (1984)

2 Schneider: Black Lights (1996)

1 Schneider: The Loose Marble (1989)

3 Schneider: The Theory of Operational Art (1988)

9 Schneider: Vulcan's Anvil (1991)

2 Simpkin: Race to the Swift (1985)

1 Starry: The Principles of War (1981)

1 Warden: The Air Campaign (1988)

Phase Transition

2 Bacevich: The Pentomic Era (1986)

1 Booz, Allen & Hamilton: Decisive Ops, Mass. Eff., & Entropy Based Warfare (1997)

17 Epstein: Napoleon's Last Victory (1992)

13 Field Manual 100-15: Corps Operations (1996)

3 Field Manual 100-40: Tactics (1997)

25 Field Manual 100-5: Operations (1986)

15 Field Manual 100-5: Operations (1993)

2 Field Manual 101-5-1: Operational Terms and Graphics (1997)

2 Fleet Marine Field Manual 1: Warfighting (1989)

2 Geyer: German Strategy in the Age of Machine Warfare (1986)

1 LeGare: Mass: Evolving Tool of the U.S. Operational Artis (1983)

1 Leonhard: The Art of Maneuver (1991)

1 Lind: Maneuver Warfare Handbook (1985)

21 Mao: Selected Military Writings (1991)

2 Pickar: Blitzkrieg (1992)

1 Pitt: The Crucible of War 2 (1986)

6 Schneider: Black Lights (1996)

2 Schneider: The Theory of Operational Art (1988)

1 Schneider: The Theory of the Empty Battlefield (1987)

7 Schneider: Vulcan's Anvil (1991)

1 Schneider: What if We Fight Tonight (1995)

3 Sun Tzu: The Art of War (Griffith) (1971)

3 TRADOC Pamphlet 525-5: Force XXI Operations (1994)

Fluid

1 Bacevich: The Pentomic Era (1986)

2 Epstein: Napoleon's Last Victory (1992)

2 Field Manual 100-15: Corps Operations (1996)

11 Field Manual 100-5: Operations (1986)

2 Field Manual 100-5: Operations (1993)

2 Fleet Marine Field Manual 1: Warfighting (1989)

1 Hogarth: Dynamic Density (1987)

1 Jablonsky: The Owl of Minerva Flies at Twilight (1994)

2 Lind: Maneuver Warfare Handbook (1985)

1 Luvaas: Buna 19 November 1942 - 2 January 1943 (1986)

19 Mao: Selected Military Writings (1991)

1 Romjue: From Active Defense to AirLand Battle (1984)

1 Schneider: Black Lights (1996)

Pressure

1 Davis: Aggregation, Disaggregation, and the 3:1 Rule (1995)

5 Field Manual 100-15: Corps Operations (1996)

5 Field Manual 100-40: Tactics (1997)

2 Field Manual 100-5: Operations (1986)

4 Field Manual 100-5: Operations (1993)

1 LeGare: Mass: Evolving Tool of the U.S. Operational Artis (1983)

2 Lind: Maneuver Warfare Handbook (1985)

2 Luvaas: Buna 19 November 1942 - 2 January 1943 (1986)

1 Pickar: Blitzkrieg (1992)

5 Schneider: Vulcan's Anvil (1991)

1 Simpkin: Race to the Swift (1985)

Friction

2 Clausewitz: On War (Howard & Paret) (1989)

2 De Landa: War in the Age of Intelligent Machines (1994)

3 Epstein: Napoleon's Last Victory (1992)

3 Field Manual 100-15: Corps Operations (1996)

4 Field Manual 100-40: Tactics (1997)

5 Field Manual 100-5: Operations (1986)

2 Field Manual 100-5: Operations (1993)

1 Field Manual 101-5-1: Operational Terms and Graphics (1997)

4 Fleet Marine Field Manual 1: Warfighting (1989)

3 Lind: Maneuver Warfare Handbook (1985)

1 Luvaas: Buna 19 November 1942 - 2 January 1943 (1986)

1 Mao: Selected Military Writings (1991)

1 Simpkin: Race to the Swift (1985)

2 TRADOC Pamphlet 525-5: Force XXI Operations (1994)

5 Watts: Clausewitzian Friction and Future War (1996)

Culmination

1 Clausewitz: On War (Howard & Paret) (1989)

2 Field Manual 100-15: Corps Operations (1996)

8 Field Manual 100-40: Tactics (1997)

4 Field Manual 100-5: Operations (1986)

3 Field Manual 100-5: Operations (1993)

2 Field Manual 101-5-1: Operational Terms and Graphics (1997)

1 Joint Pub 3-0: Doctrine for Joint Operations (1995)

Energy

1 Du Picq: Battle Studies (1987)

1 Field Manual 100-5: Operations (1986)

1 LeGare: Mass: Evolving Tool of the U.S. Operational Artis (1983)

1 Leonhard: The Art of Maneuver (1991)

1 Schneider: The Theory of Operational Art (1988)

Entropy

1 Booz, Allen & Hamilton: Decisive Ops, Mass. Eff., & Entropy Based Warfare (1997)

Annex 2 (Metaphor Use By Author) to Appendix 3: Presentation of the Data

Count of Physical Metaphor by Author Then Metaphor

Army Vision 2010: Army Vision 2010 (1997)

Count	Metaphor Name
1	Center of Gravity
1	Mass Distribution

Bacevich: The Pentomic Era (1986)

Count	Metaphor Name
1	Flexibility or Elasticity
2	Phase Transition
1	Fluid

Bellamy: The Evolution of Modern Land Warfare (1990)

Count	Metaphor Name
1	Cohesion

Blackwell, Mazarr, and Snider: Race to the Swift (1985)

Count	Metaphor Name
1	Mass Distribution

Booz, Allen & Hamilton: Decisive Ops, Mass. Eff., & Entropy Based Warfare (1997)

Count	Metaphor Name
1	Cohesion
1	Phase Transition
1	Entropy

Clausewitz: On War (Howard & Paret) (1989)

Count	Metaphor Name
5	Center of Gravity
3	Cohesion
1	Flexibility or Elasticity
1	Mass Distribution
2	Friction
1	Culmination

Corbett: Some Principles of Maritime Strategy (1988)

Count	Metaphor Name
1	Cohesion
1	Flexibility or Elasticity
1	Mass Distribution

Davis: Aggregation, Disaggregation, and the 3:1 Rule (1995)

Count	Metaphor Name
1	Cohesion
1	Pressure

De Landa: War in the Age of Intelligent Machines (1994)

Count	Metaphor Name
1	Cohesion
1	Flexibility or Elasticity
2	Friction

Du Picq: Battle Studies (1987)

Count	Metaphor Name
1	Cohesion
1	Energy

Dubik: Decentralized Command (1992)

Count	Metaphor Name
1	Coherence

Epstein: Napoleon's Last Victory (1992)

Count	Metaphor Name
3	Center of Gravity
9	Cohesion
4	Collision
2	Torque
1	Tempo
9	Flexibility or Elasticity
17	Mass Distribution
17	Phase Transition
2	Fluid
3	Friction

Field Manual 100-15: Corps Operations (1996)

Count	Metaphor Name
6	Center of Gravity
8	Cohesion
6	Momentum
2	Acceleration
23	Tempo
29	Flexibility or Elasticity
39	Mass Distribution

13	Phase Transition
2	Fluid
5	Pressure
3	Friction
2	Culmination

Field Manual 100-40: Tactics (1997)

Count	Metaphor Name
6	Center of Gravity
6	Cohesion
1	Coherence
1	Collision
1	Force
13	Momentum
1	Acceleration
6	Tempo
11	Flexibility or Elasticity
15	Mass Distribution
3	Phase Transition
5	Pressure
4	Friction
8	Culmination

Field Manual 100-5: Operations (1986)

Count	Metaphor Name
22	Center of Gravity
5	Cohesion
2	Coherence
5	Collision
1	Force
6	Momentum
4	Tempo
18	Flexibility or Elasticity
15	Mass Distribution
25	Phase Transition
11	Fluid
2	Pressure
5	Friction
4	Culmination
1	Energy

Field Manual 100-5: Operations (1993)

Count	Metaphor Name
14	Center of Gravity
5	Cohesion
2	Coherence
2	Collision
3	Force
7	Momentum
22	Tempo
2	Flexibility or Elasticity
1	Mass Distribution
15	Phase Transition
2	Fluid
4	Pressure
2	Friction
3	Culmination

Field Manual 101-5-1: Operational Terms and Graphics (1997)

Count	Metaphor Name
2	Center of Gravity
3	Tempo
2	Mass Distribution
2	Phase Transition
1	Friction
2	Culmination

Field Manual 101-5: Staff Organization and Operations (1997)

Count	Metaphor Name
1	Flexibility or Elasticity

Fleet Marine Field Manual 1: Warfighting (1989)

Count	Metaphor Name
1	Center of Gravity
1	Cohesion
2	Collision
1	Momentum
1	Velocity
4	Tempo
2	Mass Distribution
2	Phase Transition
2	Fluid
4	Friction

Geyer: German Strategy in the Age of Machine Warfare (1986)

Count	Metaphor Name
1	Center of Gravity
2	Phase Transition

Hogarth: Dynamic Density (1987)

Count	Metaphor Name
1	Momentum
1	Flexibility or Elasticity
1	Mass Distribution
1	Fluid

Howard: Men against Fire (1986)

Count	Metaphor Name
3	Cohesion
1	Force
1	Flexibility or Elasticity

Jablonsky: The Owl of Minerva Flies at Twilight (1994)

Count	Metaphor Name
1	Fluid

Joint Pub 3-0: Doctrine for Joint Operations (1995)

Count	Metaphor Name
1	Center of Gravity
1	Torque
1	Culmination

Jomini: The Art of War (1987)

Count	Metaphor Name
1	Collision
1	Mass Distribution

LeGare: Mass: Evolving Tool of the U.S. Operational Artis (1983)

Count	Metaphor Name
2	Center of Gravity
1	Coherence
1	Collision
1	Momentum
1	Tempo
4	Mass Distribution
1	Phase Transition
1	Pressure

1	Energy

Leonhard: The Art of Maneuver (1991)

Count	Metaphor Name
1	Center of Gravity
2	Cohesion
1	Coherence
1	Force
3	Momentum
1	Torque
1	Acceleration
1	Tempo
2	Mass Distribution
1	Phase Transition
1	Energy

Lind: Maneuver Warfare Handbook (1985)

Count	Metaphor Name
2	Center of Gravity
6	Cohesion
1	Coherence
1	Collision
1	Momentum
2	Tempo
1	Flexibility or Elasticity
1	Phase Transition
2	Fluid
2	Pressure
3	Friction

Luvaas: Buna 19 November 1942 - 2 January 1943 (1986)

Count	Metaphor Name
2	Mass Distribution
1	Fluid
2	Pressure
1	Friction

Mao: Selected Military Writings (1991)

Count	Metaphor Name
1	Mass Distribution
21	Phase Transition
19	Fluid
1	Friction

Pickar: Blitzkrieg (1992)

Count	Metaphor Name
1	Center of Gravity
1	Coherence
1	Momentum
2	Tempo
2	Phase Transition
1	Pressure

Pitt: The Crucible of War 2 (1986)

Count	Metaphor Name
1	Collision
1	Phase Transition

Romjue: From Active Defense to AirLand Battle (1984)

Count	Metaphor Name
1	Cohesion
1	Mass Distribution
1	Fluid

Schneider: Black Lights (1996)

Count	Metaphor Name
1	Cohesion
1	Collision
2	Mass Distribution
6	Phase Transition
1	Fluid

Schneider: The Loose Marble (1989)

Count	Metaphor Name
1	Mass Distribution

Schneider: The Theory of Operational Art (1988)

Count	Metaphor Name
1	Center of Gravity
3	Cohesion
1	Collision
1	Inertia
3	Mass Distribution
2	Phase Transition
1	Energy

Schneider: The Theory of the Empty Battlefield (1987)

Count	Metaphor Name
1	Phase Transition

Schneider: Vulcan's Anvil (1991)

Count	Metaphor Name
2	Center of Gravity
2	Cohesion
1	Coherence
2	Force
2	Tempo
9	Mass Distribution
7	Phase Transition
5	Pressure

Schneider: What if We Fight Tonight (1995)

Count	Metaphor Name
1	Cohesion
2	Coherence
1	Force
1	Phase Transition

Simpkin: Race to the Swift (1985)

Count	Metaphor Name
1	Collision
1	Momentum
1	Torque
1	Tempo
2	Mass Distribution
1	Pressure
1	Friction

Starry: The Principles of War (1981)

Count	Metaphor Name
1	Flexibility or Elasticity
1	Mass Distribution

Sun Tzu: The Art of War (Griffith) (1971)

Count	Metaphor Name
1	Momentum
3	Phase Transition

Tata: Sustaining the Tempo (1993)

Count	Metaphor Name
2	Force

TRADOC Pamphlet 525-5: Force XXI Operations (1994)

Count	Metaphor Name
1	Center of Gravity
1	Cohesion
1	Coherence
1	Acceleration
3	Tempo
1	Flexibility or Elasticity
3	Phase Transition
2	Friction

Warden: The Air Campaign (1988)

Count	Metaphor Name
1	Center of Gravity
1	Coherence
1	Mass Distribution

Watts: Clausewitzian Friction and Future War (1996)

Count	Metaphor Name
5	Friction

Appendix 4: The Limitations of Classical Mechanics

This appendix presents a review of classical physics and clarifies several limitations in the application of classical mechanics as a system describing "armies in combat." This should not imply that the application of physics to the science of warfare is inappropriate. It is entirely appropriate. It must, however, be applied properly, and if it is applied metaphorically, then its vocabulary should be applied rigorously. The following is extracted from lecture notes used by this author in academic years 1994 and 1995 to provide instruction of PH201 (Classical Mechanics) to cadets at the United States Military Academy (USMA), West Point New York.[109]

The basis of classical mechanics is Sir Isaac Newton's famous three "laws of motion" and the concepts of *energy* and *momentum*. Newton's first law (N1) describes "inertia" – the tendency of an object to resist a change in motion. Rotational and vibrational motion will not be considered here, only translational. *Mass* (*m*) is a measure of translational inertia. Translational motion is measured by *velocity* ($\vec{v}$), a vector describing both *speed* and *direction*. Speed is the rate of change of the object's *position* or its *displacement* relative to some reference point. Linear *momentum* is a vector equal to the product of an object's *mass* and its *velocity:* ($\vec{p} = m\vec{v}$). Kinetic energy is a scalar quantity equal to half the product of the objects *mass* and the square of its *velocity* ($K=1/2mv^2$). By N1, a body will remain at constant *velocity* unless a *net external force* acts upon the body.

Newton's second law (N2) is usually expressed by the well-known simplification $\sum \vec{F} = m\vec{a}$. N2 describes the relationship between such a *net external force* (the vector sum of external forces, $\sum \vec{F}$) and the change in motion. Change in motion is measured

by *acceleration* ($\vec{a}$), which is a vector describing the rate of change, and the direction of change, of either the object's *speed* (tangential acceleration) or *direction* (radial or centripetal acceleration). According to N2, The vector sum of the external forces acting on a body is equal to the product of its mass and its acceleration.

Newton's third law (N3) describes the *interaction* of objects; object 1 cannot act on object 2 without experiencing these consequences. If body 1 exerts a force of some type on body 2, then body 2 must exert a force of the same type on body 1 that is equal in magnitude, and opposite in direction.

Newton's laws of motion are apparently simple, but the experience of most students in physics classrooms is evidence that they are also frequently misunderstood. These laws, along with the concepts of *momentum* and *kinetic energy* or energy of motion, are the basis of the physics used in the analysis of *force* and ***collisions***. *Momentum* and *energy* are *conserved quantities*. This means that the physicist must be able to account for any differences in these quantities between the "before" and "after" states of events such as collisions. Sometimes, the changes may be very difficult to trace. That is why physics students do collision experiments on an "air-hockey" type apparatus (approximately closed systems), where momentum is approximately conserved because dissipative forces like friction are approximately eliminated. This means that, within an experimental amount of uncertainty, the student can account for all the "before" *momentum* in the "after" state. Any *momentum* "lost" by one object is "gained" by another. If the collision is perfectly elastic (no sticking together), then the *kinetic energy* is conserved in the same way. If the collision is inelastic, then the *momentum* is conserved, but the *kinetic energy* is not, any difference in *kinetic energy* is accounted for

as work done on the objects such as observable deformation of the objects, or the production of heat, sound, etc. This is consistent with the work-energy theorem, which states that the net work done on the objects in a closed system must equal the change in kinetic energy of the objects. This is why it is preferable for a sabot to interact with the tank in such a way as to remain in the tank, converting all its kinetic energy into damage. In our ordinary experience, however, there are *many* ways that energy is dissipated. The battlefield is NOT a closed system.

The physics above, if rigorously applied, can provide good insight into battlefield dynamics. The age-old notion of a collision between military "forces" makes this analysis particularly relevant. However, in this author's opinion, there are several problems with these metaphors. Authors ought to consider these limitations before applying these terms in military context.

First, regarding the classical system in general, how does one define and measure military *mass*? One must keep in mind that military *mass* must measure the formation's inertia. A detailed comparison of the use of the term *mass* by the various authors reviewed in this study is beyond the scope of the immediate effort. However, it is easy to recognize that there are several. To Clausewitz, mass means numbers of soldiers, to others it is synonymous with "combat power," to others, it is a verb meaning to concentrate "combat power," and most recently, it has been used as a verb meaning to concentrate only the *effects* of combat power.

Second, The *collision* metaphor conveys a good sense of the military value of *momentum* and *energy*, but it can only be used in a gross metaphorical sense. The fundamental physical concept in the metaphor (conservation of *momentum*) is based on

an assumption that is not true under most battlefield conditions. In modern combat, there may not even be any physical contact between opponents – i.e. no actual *collision* at all. The action might be an exchange of fires – an exchange of many projectiles (many of which miss their targets and actually only transfer momentum to, or do work in damaging the ground or trees).

Third, the concept of *force* is frequently misused. Many laypersons try to connect classical idea of *force* with their idea of collisions using N2. They want to apply "greater force" to the enemy, and they forget about N3. If one side is applying force, then the other is applying it back. It is not possible to rigorously apply the metaphor of *force* to a firefight if *force* means the thing that causes the enemy's retreat or destruction.

Fourth, in all of the simple physics described above, *mass* is treated as a constant. It is not a constant in *any* of the military definitions. Even where it means numbers of soldiers, mass is decreased by attrition and increased by replacement. Actually, when Newton wrote *Principia*, he expressed N2 differently that the simplification above. Originally, N2 reads: The net external force equals the rate of change of momentum. Newton invented differential calculus to deal with this rate of change and those discussed

above: $\sum \vec{F} = d\vec{p}/dt$. Substituting for *momentum* gives $\sum \vec{F} = d(m\vec{v})/dt$. The derivative on the right side of this equation must be evaluated using the product rule $\sum \vec{F} = m(d\vec{v}/dt) + \vec{v}(dm/dt)$ The first term in the expanded product is the product of *mass* and the rate of change of *velocity (acceleration).* Only if *mass* is constant, where its rate of change is zero, it the right term in the expanded product zero. Thus even the

familiar formulation of N2 cannot be rigorously applied using a military definition of *mass*.

As a result of the review of the material above, one should be able to understand better the limits of applicability of classical mechanics to the phenomena of battlefield dynamics. The terms from classical mechanics provide a good sense of certain physical properties like inertia. Concepts like collision apply in the case of things like the strike of a round on a target – that is a collision, but the same concept is only roughly applicable to the interaction of enemy formations on the battlefield. Classical mechanics can be extended to improve its approximations, but two effects will counteract the improvement. First, the improvement normally comes at a cost of mathematical difficulty (which reduces utility to the layperson). And second, one cannot just extract one term from the framework of mechanics. The use of these terms necessitates rigorous use of associated terms as well – and in the Army, we have many definitions of terms like *mass* and *force* that are not generally physically correct or useable in the framework of mechanics.

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1. *The Concord Desk Encyclopedia*, vol. 2: F-N, (New York: Concord Reference Books, 1982), 874.

2. David Halliday and Robert Resnick, *Fundamentals of Physics*, Revised Printing, (New York, New York: John Wiley and Sons, 1976), 776.

3. In this study, "the military literature" is subset of the various military theoretical and doctrinal works. The study is therefor not an exhaustive search in the sense that the author did not consult ALL possible sources. It isn't likely that any one person could actually read ALL the possible sources though. Instead, the author consulted the several notable works in the bibliography. Also the study is not an exhaustive search in the sense that the author does not report ALL potential data points. The subset of the literature examined was so replete with the use of metaphor that the author reported only what really stood out to him as a critical reader of other people's work.

4. *Field Manual 101-5-1, Operational Terms and Graphics,* (Fort Leavenworth, Kansas: USACGSC, 1997) (found at http://www-cgsc.army.mil/cdd/f545.htm), 1-100.

5. Azar, Gat, *The Origins of Military Thought: From the Enlightenment to Clausewitz*. (Oxford, England: Clarendon Press, 1989) 1 – 249, especially 43 – 52 (Guibert), 111- 123 (Jomini), 143 – 149 (Herder, Fichte, Schelling, Kant, and Hegel), and 157 – 250 (Clausewitz). Gat argues that the method of critical inquiry and dialectical reasoning introduced by Kant; popularized by Herder, Fichte, Schelling, and others; and perfected by Hegel allowed Prussia to escape the absolute deductive rationalism of the "Enlightenment." Gat claims that Clausewitz's theoretical work was developed in – and reflects the influence of – this environment. Gat believes Clausewitz rewrote major portions of *On War* using dialectic reasoning. While Kant (Immanuel Kant, *Critique of Pure Reason*. Unabridged ed., trans Smith, Norman Kemp. (New York, New York: St. Martin's Press, 1965) intended the "Transcendental Dialectic" as a means to remain rational and answer questions that rational thought previously could not, his method of Thesis – Antithesis – Synthesis demands an ***inductive*** leap (*a priori* synthetic judgement). In fact, Kant described his central idea as a "Copernican Revolution in Metaphysics" (the "objective reality" of the object of our senses arises only when the object conforms to concepts which are constructed *a priori* by our "faculty of intuition" [p. 22 of *Critique*]) One must synthesize a new categorical concept to reconcile a contradiction between two things known to be true in separate circumstances – a unifying concept in which both are true. Kant postulated (p. 52 of *Critique*) "In all theoretical sciences of reason synthetic *a priori* judgements are contained as principles." Gat claims that Clausewitz derived his trinity through such a dialectic.

6. John L. Casti, *Complexification: Explaining a Paradoxical World Through the Science of Surprise*. (New York, New York: HarperCollins, 1994), 14.

7. Peter M. Senge, *The Fifth Discipline: The Art and Practice of the Learning Organization*. (New York, New York: Doubleday, 1990) pp 139 – 269, especially pp. 174 and 175.

8. James J. Schneider, Ph. D. "The Eye of Minerva: The Origins, Nature, and Purpose of Military Theory," *Theoretical Paper No. 5*, (Fort Leavenworth, Kansas: School of Advanced Military Studies, Command and General Staff College, 1995, 2nd edition), 11. The word [justified] is used because, epistemologically, the justification of belief is as important a component of a belief as truth. Whereas rules of inference for deductive argumentation require statements to be true in order to for a valid argument to be judged sound, this is not the case in inductive reasoning. It was inductive reasoning which allowed man to progress beyond what Schneider calls the "Wall of Positivism" in *How War Works: The Origins, Nature, and Purpose of Military Theory*, (Fort Leavenworth, KS: SAMS, USACGSC, 1995), 6. Here Schneider uses "justified true belief" as the rationalist definition of knowledge, but here he relates that knowledge directly to theory whereas he relates it to science in "The Eye of Minerva." In the modern scientific method, it is inductive reasoning which allows man to complete the cycle with a testable hypothesis. Here, it is often not possible to show that an argument is deductively sound. Instead, the scientist argues inductively by persuading the reader that the statement or claim is justified. That justification is usually documented verification by experiment and coherence with other theoretical work. According to the 1982/83 lectures notes of Professors Shoemaker and Boyd of the Cornell University Department of Philosophy, there are six basic definitions of knowledge – each labeled by its own "ism": *Empiricists* claim that all our knowledge is derived from experience. *Phenomenalists* (a specific version of empiricists) say that an idea only has meaning (is knowledge) if it can be defined directly in terms of experience or possible experiences. *Foundationalists* claim knowledge is justified true belief – knowledge results when one's beliefs are either self-justified by immediate experience or via a "reliable" inference (either deduction or reliable induction). *Coherentists* are foundationalists who claim we are justified in belief that coheres with all our other beliefs. *Reliablists* are define knowledge as reliably produced, true, beliefs. of Professors Shoemaker and Boyd taught Philosophy 101 *Classical Philosophy*, and Philosophy 131 *Logic: Evidence and Argument*, respectively. Their main references for the material cited above were David Hume, *An Inquiry Concerning Human Understanding*, ed . Hackett, and Giere, *Understanding Scientific Reasoning*.

9. Senge, 139 – 269, also 274 and 275. Senge's discussion of individual visions built on mental models enables him to explain how groups can "dialogue" – openly share information about mental models and personal visions – to develop his idea of "shared vision" which then becomes the basis of cohesion in the learning organization.

10. Carl Von. Clausewitz, *On War*, edited and translated by Michael Howard and Peter Paret, (Princeton: Princeton University Press, 1989) 132.

11. James J. Schneider, Ph. D., "How War Works: The origins, Nature, and Purpose of Military Theory," (Fort Leavenworth, KS: SAMS, USACGSC, 1995), 8.

12. Ibid., 8.

13. Dietrich Dörner, *The Logic of Failure: Why Things Go Wrong and What We Can Do to Make Them Right*, Translated by Rita and Robert Kimber, (New York, New York: Metropolitan Books, 1996), 153,154. The term "problem space" is Dörner's. It is explained further in the next section of this monograph.

14. *Field Manual 100-5, Operations.* (Washington, D.C.: USGPO, 1993), says in its Introduction on p. v, "[Doctrine] is the authoritative guide to how Army forces fight wars and conduct operations..."

15. Ibid., v.

16. Donn A. Starry "Commander's Notes, no. 3" in John L. Romjue, *From Active Defense to AirLand Battle: The Development of Army Doctrine 1973 – 1982.* (Fort Monroe, Virginia: US Army Training and Doctrine Command, Historical Office, June 1984), 87.

17. *Webster's New Collegiate Dictionary*, (Springfield, Massachusetts: G. & C. Merriam Co., 1981), 716.

18. John L. Romjue, *From Active Defense to AirLand Battle: The Development of Army Doctrine 1973 – 1982.* (Fort Monroe, Virginia: US Army Training and Doctrine Command, Historical Office, June 1984), 48.

19. *Momentum* is a term from classical (Newtonian) mechanics. See Appendix 4 for a brief discussion of the limitations of classical mechanics.

20. *Webster's*, 990.

21. Colin Cherry, *On Human Communication: a Review, a Survey, and a Criticism*, 2nd edition. (Cambridge, Massachusetts: The MIT Press 1966), 71. Cherry, who was the Henry Mark Pease Professor of Telecommunication, Imperial College, University of London at the time, says "If words do not name things... with precision, then language itself must be a source of imprecision in communication... and the degree of imprecision depends largely on the choice of words by the writer or speaker."

22. The author can support the claim of the mutual exclusivity of "clearly defined" and "doctrinal" terms only anecdotally via personal experience in brigade level Operations Centers and Tactics classes at the US Army Command and General Staff College (CGSC). In these cases, terms such as "center of gravity," "decisive point," "decisive terrain," "key terrain," "fire support coordination line," and "battle hand over" were the subject of hot debate until the group decided that time was precious and no clear

understanding would be gained in the current forum. So the discussion was dropped, the meaning was lost, and the terms were avoided. However, after *successfully* achieving clarity in some of the same topics of discussion in the Advanced Military Studies Program (AMSP), the author has concluded the difference was the greater propensity or duty of AMSP students to attempt a rigorous examination of available resources. Joint Pub 1-02, Joint Pub 3-0, FM 100-5, FM 101-5-1, and FM 100-40 were not always completely consistent with one another. Individual efforts to understand them were not always productive. However, by entering a dialogue regarding the doctrinal meaning, the group of AMSP students usually achieved a clearer understanding that was consistent with the overall body of US Army doctrine. This anecdote invokes two conclusions: First, it shouldn't be that hard to understand the meaning of the terms in our doctrine, and second clarity in doctrinal meaning (which is a mandate for collective action) is best achieved by dialogue (a process for developing collective understanding). However, the unfortunate reality is that there is not usually enough time for dialogue.

23. Jacques Barzun and Henry F. Graff, *The Modern Researcher*, 4th ed. (Orlando, Florida: Harcourt Brace Jovanovich, 1977) 295.

24. Ibid., 295 - 297. Barzun and Graff identify ten "types of trouble." They are (1) Jargon, (2) Vogue words, (3) Neologisms, (4) Misused or misplaced technicalities, (5) Failure to make distinctions, (6) Malaprops, (7) Twisted idioms, (8) Wrong prepositions, (9) Misdirected verbs, and (10) Faulty Constructions.

25. Ibid., 304.

26. Ibid., 304. Barzun and Graff note that "jargon" originally was not derogatory. It simply meant "the special tongue of a trade or art – what we now call technical terms – those of music or carpentry or sailing. Such terms are indispensable, there being usually no others to mean the same things." Then they distinguish a form they say should be called "pseudo-jargon." These terms "purport to be special and indispensible even though they are not technical words. They are pretentious imitations of technicality... they are not definite and fixed in meaning, and they can readily be dispensed with."

27. Hayakawa, S. I. *Language In Action.* (New York, New York: Harcourt, Brace and Company, 1941) 74 – 88 and 186 – 218.

28. Ibid., 32.

29. Ibid., 192 – 197. Emphasis added. Also Cherry, 74, 75 says "metaphor plays most forceful role, by incorporating ideas through a vehicle language, setting up a linguistic association... Metaphors arise because we continually need to strech the range of words as we accumulate new concepts and abstract relationships." Cherry goes on to quote Ogden and Richards' *Meaning of Meaning*, describing the linguistic view of communication as both "symbolic" and "emotive." These categories correspond well to Hayakawa's informative (symbolic) and affective (presymbolic) communication.

30. The terms combat power and military force are so frequently used that their military meaning probably supercedes the physical meaning from which it was derived. The sense in which they are applied militarily is very consistent with their use by the general population. Originally, ***force*** was a term Newton used to describe something intangible which could describe the way objects interact with one another at a distance – without having any real contact. Today, it is possible to completely describe the interactions of objects (using system energy states for example) without any requirement for such a thing as a "force." ***Power***, in physics, is the rate of transfer of energy. Household appliances have a power rating because the parts are designed to support only a finite rate of delivery of energy to the consuming elements. Most often, people apply the term to describe a potential to do work or to influence others. That is really more consistent with the physical term *energy*.

31. Dörner,153 – 154.

32. *Field Manual 101-5, Staff Organization and Operations*, (Washington, D.C.: USGPO, 1997) 5-1.

33. Ibid., 5-1.

34. Dörner, 157 – 160. Dörner says there are many techniques for narrowing a problem sector. He lists "hill climbing," "efficiency diversity," and "past success." "hill climbing" is associating a measureable variable [analogous to height] with your goal [analogous to a particular mountain peak] and acting in the "direction" of the goal as determined by that variable [analogous to going up – though the inherent danger here is that you could climb the wrong peak]. "Efficiency diversity" results from the selection of intermediate goals which will produce situations "favorable" in that from them there are more choices for future actions. "Past Success" is doing what worked before, but Dörner specifically warns planners against what he says Clausewitz called "methodism" – doing something only on the basis of its past success. In On War, Book 2, Ch. 4 "Method and Routine" (Methodismus in German), 152 – 155, Clausewitz discusses the pros and cons of blindly following what ammount to Standing Operating Procedures (SOPs). Dörner identifies several techniques of expanding the problem sector. He lists "free experimentation" (trial and error), "culling unsuccessful strategies" (not doing what failed in the past), and "thinking by analogy" (gaining understanding of the problem by relating it systematically to an analogous problem). However, Dörner also recognizes the practical limitations of various situations. On p. 161 he says, "In very complex and changing situations the most reasonable strategy is to plan only in rough outline and to delegate as many decisions as possible to subordinates."

35. Cherry, 74,75. Cherry quotes Ogden and Richards' Meaning of Meaning, describing the linguistic view of communication as both "symbolic" and "emotive." These categories correspond well with Hayakawa's informative (symbolic) and affective (presymbolic) communication.

36. Casti, 6-7; also Jagjit Singh,. *Great Ideas in Information Theory, Language and Cybernetics*. (New York, New York: Dover Publications, Inc., 1966), 4. Singh claims there are two "antipodal evaluations of the influence of language on ones' world view." The first is the Linguistic Philosophy in which "language is activity that is all but coterminous with life." The second is a Symbolic Philosophy such as that espoused by Sartre's hero Antoine Roquentin of La Nausée – in which language is merely a largely insufficient set of symbols used to represent objects. Says Singh, the truth is somewhere between the extremes of this dichotomy. In this light, Wittgenstein's later version falls nearer to the middle than to what Singh has called the Linguistic Philosophy.

37. Ibid. 6-7.

38. Ibid. 6-7.

39. According to *American Heritage® Dictionary of the English Language, Third Edition* by Houghton Mifflin Company.), Electronic version licensed from INSO Corporation. 1992): **e·pis·te·mol·o·gy** (î-pîs´te-mòl'e-jê) noun. The branch of philosophy that studies the nature of knowledge, its presuppositions and foundations, and its extent and validity.

40. Hayakawa,.192 – 197.

41. Massimo Piattelli-Palmarini,. *Inevitable Illusions: How Mistakes of Reason Rule our Minds*, Translated by Massimo Piattelli-Palmarini and Keith Botsford, (New York, New York: John Wiley and Sons) 1994) 32. Piattelli-Palmarini is a Principal Research Associate at the Massachusetts Institute of Technology and the Director of Cognitive Science at the Institute of San Raffaele in Milan, Italy.

42. Ibid. 36 –37. Emphasis added.

43. Ibid., 122. Piattelli-Palmarini describes his own version of the idea that everyone uses a scientific method. He says people are "naturally spontaneous verifiers rather than falsifiers or debunkers" (p. 123). He also says that Karl Popper found fame in philosophy "with his hypothesis that the hypotheses of science can be falsified, but not verified." Piattelli-Palmarini uses this as a basis for an argument that people should "learn to distrust our magical thinking," and follow a scientific method of "refutation rather than confirmation." However, in this author's experience teaching physics, students are taught that experiment *cannot prove* a hypothesis, only *validate* it within an experimental amount of uncertainty, for the specific circumstances of the experiment only. So Piattelli-Palmarini's description may fit the "everyone's" scientific method of everyday life, but it is not an accurate description of the modern, formal, scientific method.

44. Ibid. 127 – 128.

45. Ibid., 134.

46. Ibid., 136.

47. Ibid., 64 – 72. Most inductive arguments require multiple propositions to be true. For example: If and only if A and B, then C. If there is a ¼ probability that A is true, and a ½ probability that B is true, it is not mathematically possible for (A and B) and hence C to more likely than a 1/8 probability (the product of the probabilities of A and B). However, Piattelli-Palmarini demonstrates in several convincing examples that it is a general human weakness to believe that (A and B) is more likely than A.

48. Casti, 139.

49. The health of the military doctrinal language is the responsibility of both writers and readers. The staffing and approval process for doctrine revision helps maintain the health of the language by providing a way to periodically revitalize the meanings of its words. One function of new doctrine should be to "tighten up" the distribution-about-the-mean[ing] of important doctrinal terms.

50. Magoroh Maruyama, "Information and Communications in Poly-Epistemological Systems," in Kathleen Woodward, The Myths of Information: Technology and Postindustrial Culture, (Madison, Wisconsin: Coda Press, Inc., 1980), 29. Maruyama's paper is primarily an exposition of the cultural difference between the west, of which he is highly critical, and Asia, which he praises. Viewing his information in the context of the other papers in Woodward's book as he indicates one should, the paper supports the understated political message of the book that American society is far from most desireable. Nonetheless, the paper has some very appealing features.

51. M. Mitchell Waldrop, *Complexity: The Emerging Science at the Edge of Chaos*, (New York, New York: Touchstone, 1992). 225-235, esp 228, 230, and 234. Also Maruyama, 34 – 39, Also types of attractors for the four categories in Casti, 25 – 42, esp 26.

52. American Heritage® Dictionary of the English Language: **ho·mog·e·nize** (he-mòj'e-nìz', ho-) verb, transitive... 1. To make homogeneous. 2. a. To reduce to particles and disperse throughout a fluid. b. To make uniform in consistency, especially to render (milk) uniform in consistency by emulsifying the fat content.

53. *American Heritage® Dictionary of the English Language*: **ho·me·o·sta·sis** (ho'mê-o-stâ'sîs) noun. The ability or tendency of an organism or a cell to maintain internal equilibrium by adjusting its physiological processes. — **ho'me·o·stat'ic** (-stàt'îk) *adjective.*

54. *American Heritage® Dictionary of the English Language*: **mor·pho·gen·e·sis** (môr'fo-jèn'î-sîs) noun. Formation of the structure of an organism or part; differentiation and growth of tissues and organs during development. — mor'pho·ge·net'ic (-je-nèt'îk) or mor'pho·gen'ic adjective.

55. Clausewitz, 168.

56. Ibid., 168 – 169.

57. Ibid. Page references for several of Clausewitz's metaphor: Center of Gravity: 391; Culminating Point: 383; Friction: 119; Fog: 101; Arteries: 345; Building Blocks, Earthworm, Bondage of Coherence: 292; Monolith and Pliant, Flexible, Many-jointed entity: 293.

58. Romjue, 50.

59. Crane Brinton, The Anatomy of Revolution, (New York, New York: Vantage Books, 1965), 6 - 14.

60. J. F. C. Fuller, *The Foundations of the Science of War*, (London: Hutchinson & Co. 1925. Reprint, Fort Leavenworth, Kansas: U.S. Army command and General Staff College Press (page references are to the reprint edition)) 19 - 32.

61. Ibid. 1 – 335. Drawing from the philosophical ultimacy of the relationships between the extremes of duality, Fuller described war fighting with one law of Economy of Force – controlling the exertion of, and resistance to, pressure in the mental, moral, and physical spheres. His result was a set of nine general principles. Fuller claimed to have deduced his original sets of principles from his study of Napoleon. He also claimed to be responsible for their indoctrination in *Field Service Regulations* in 1920 – before he wrote *Foundations*. Fuller's method and conclusions are not perfect, but he only intended *Foundations* to be, as the name implies, a foundation for further consideration of the subject. Thus it could have lasting value as a point of departure for future work. Fuller's philosophical method is ingenious, but it is hard to understand, and in parts it is inaccurate. His use of common, ill-defined vocabulary clouds his meaning, but this is not a problem unique to him. The fact that most military writers are considered "misinterpreted" is testament to the subjective nature of meaning. Fuller compared himself, as a scientist, to Isaac Newton, and Newton considered himself to be a "natural philosopher." Thus, it is no surprise to see that Fuller's metaphysical introduction culminates in an expression of Newtonian Mechanics. He claimed that the extremities of the prototypical duality (inertia and activity) and their relationship (motion) formed a "tri-unity" or "threefold order" describing the realm of Force. He expanded from this idea, describing all aspects of war with threefold order. The imprecise definitions of Fuller's terminology made much of his work hard to follow. So did the way he inconsistently ordered the relationship of his terms. In all of his tri-unities, there was a term that provided "inertia" or "stable base," a term that provided "activity" or "power of action," and a term that provided the relationship like "motion" or "cooperation." Where this was not true, Fuller's threefold order was not a triunity – it was an arbitrary group of three aspects. An example of this is the types of military organizations (Army, Navy, and Air Force).

62. Casti, 12. Casti defines four criteria that a scientific hypothesis must meet before it can be considered a "rule." He says it must be *explicit*, *objective*, *public*, and *reliable*. Our hypothesis is explicit if it is unambiguously stated. It is objective if it is free of investigator bias. It is public if it is testable by anyone. Finally, if our hypothesis is repeatedly validated by many independent efforts – over a long period, we say it is reliable. It has stood the test of time, and we are justified in believing it as a "rule" or an element of our body of knowledge about the world. The criteria this monograph uses are designed to measure not only the justifiability of the metaphor, but also its general utility. In this monograph *public* and *objective* are incorporated by *commonality*, *explicit* by *ambiguity*, and *reliability* by itself. The other criteria used in this monograph serve to measure utility.

63. David Jablonsky, Professor of National Security Affairs at the U.S. Army War College, addresses change and trends in "The Owl of Minerva Flies at Twilight: Doctrinal Change and Continuity and the Revolution in Military Affairs", (Carlisle, Pennsylvania: US Army War College, May 1994), also at http://carlisle-www.army.mil/usassi/ssipubs/pubs94/owl.txt. Jablonski borrows from Robert Heilbroner, The Future as History, (New York: Harper & Row, 1960), pp. 193-197. "with change, there is usually continuity due to what Robert Heilbroner calls the 'inertia of history.' Inertia in this sense does not just mean resistance to change, but also what Heilbroner refers to as the 'viscosity' of history–the tendency of people to repeat and continue their way of doing things as long as possible." To clarify the Jablonsky-Heilbroner notion, one must understand that, in its essence, the statement means that the current trends (and the current changes in the current trends (and maybe even the changes in those changes)) will tend to continue in the future. Therefore, if the use of a particular metaphor grows suddenly, it is just as likely to continue to continue to grow rapidly as it is to suddenly wither. Things do not tend to suddenly appear and then continue steadily.

64. Clausewitz, 168 - 169.

65. Ibid., 456.

66. Ibid., 457.

67. Ibid., 457..

68. Ibid., 457..

69. Ibid., 456. Emphasis added.

70. Correlli Barnett, *The Desert Generals*, (Bloomington, Indiana: Indiana University Press, 1986), 85.

71. Ibid., 85.

72. Ibid., 105 – 107. Emphasis added.

73. Robert M. Epstein, *Napoleon's Last Victory: 1809 and the Emergence of Modern War,* (Fort Leavenworth, Kansas: USACGSC, 1992), throughout, esp. 19, 21, 35, 45, 51, 59, 66, 79, 80, and 82. In fairness to Napoleon's predecessors, Epstein describes the mass armies as not-always monolithic. They were formed from untrained troops that in some instances showed particulate granularity at the level of the "battalion column" and in others "dispersed into great clouds of skirmishers." (p. 25).

74. Ibid., 48.

75. Ibid., 57.

76. Ibid., 55 and 111.

77. Ibid., 55. Epstein describes the action of "smashing" the enemy on several occasions. However, he points out that the separately articulated, self sustaining corps were more durable. Frequently, they could not be destroyed before they could be reinforced. Also, even if a corps was destroyed, the army could still survive. So, while "smashing" was still the goal, it was infrequently decisive. (p. 113).

78. , Michael Howard, "Men against Fire: The Doctrine of the Offensive in 1914," In *Makers of Modern Strategy: From Machiavelli to the Nuclear Age*, Edited by Peter Paret. (Princeton, New Jersey: Princeton University Press, 1986) 510. Emphasis added: "repulsed" is a reaction to the metaphorical description of offense as "impulse," delivered by virtue of the attacker's momentum.

79. Ibid., 510..

80. Ardant du Picq, *Battle Studies - Ancient and Modern Battle*, Translated by COL John N. Greeley and MAJ Robert C. Cotton, Edited by BG T. R. Phillips, *Roots of Strategy*, (Harrisburg, Pennsylvania: Stackpole Books, 1987), 213.

81. Ibid. p. 218.

82. Ibid. p. 253. In du Picq's words "adopt the soldier's way, and bring some order to it."

83. Ibid. p. 218.

84. Howard, 515. Du Picq is considered a proponent of moral action, and often this equated with the infantry bayonet charge. Howard indicates that du Picq actually had a practical view,however, and that du Picq advocated using fires first, then moral action, otherwise no attack could succeed against high rates of fire.

85. See appendix C for metaphorical instances evaluated in the analysis section. This author's personal assessment has been that the works of authors who call themselves proponents of pure "maneuver" warfare are the heaviest "users" (actually "***ab***users") of

physics. Most notable are the works of Lind, Simpkin, and Leonhard. (See bibliography for complete citations.)

86. Jay Luvaas, "Buna 19 November 1942 - 2 January 1943: A Leavenworth Nightmare,'" From *America's First Battles*, Edited by Charles Heller and William A. Stofft, (Lawrence, Kansas: University Press of Kansas, 1986). (Reprinted by Combat Studies Institute, USACGSC, Fort Leavenworth, Kansas, 1996. Page references are to the reprint), 367. Emphasis added.

87. Ibid. 386.

88. Ibid., 379.

89. Ibid., 379.

90. Ibid., 381.

91. Ibid., 381. Note, however, that the "concentration of forces" that MacArthur was urging is a technique significantly different from what he described in his words, "a casualty on your side for a casualty on his."

92. Ibid., 382.

93. Ibid., 384.

94. Ibid., 384.

95. Ibid., 386. Also p. 368. Luvaas claims the December 1941 *Field Manual 31-20: Jungle Warfare* was fairly good, though it did not anticipate the existence of "pillbox" style defensive fortifications. He goes on to claim that "Had more careful attention been paid to the manual's advice on the jungle's natural defenses, many American lives might have been spared at Buna."

96. *Field Service Regulations 100-5: Operations*, (Washington, D.C.: USGPO, 1941), 23 and 93. *FSR 100-5* said "the mass of available means of combat is concentrated in a main effort and applied in a decisive direction," (p. 93) and it considered such concentration to be a "Doctrine of Combat... [concentrate] at the decisive place and time." (p. 23). One might argue that this doctrine must share some culpability, but one should not evaluate individual doctrinal publications outside the context of its companion manuals. *FM 31-20: Jungle Warfare* should be viewed in context with *FSR 100-5.*

97. The principle of concentration is ***not*** applicable in *all* land-combat situations, and this issue is central to the debate over appropriate mathematical models for combat. According to Martin Braun, *Differential Equations and Their Applications,* 2nd edition, 3rd printing, (New York, New York: Springer-Verlag, 1979), 381 – 389: The

"concentration" doctrine was supported mathematically by Frederick William Lanchester's *Aircraft in Warfare, the Dawn of the Fourth Arm,* (Tiptree, Constable and Co., Ltd., 1916). Braun describes Lanchester's technique of modeling combat with differential equations and explains models for conventional and guerilla combat. Braun points out that the special case of the conventional-model where there are no reinforcements is called the "square law." Braun says this "law" is set apart from the models of Lanchester's predecessors which are called "linear laws" – but this is a misnomer since the "square law" system is described by ***linear*** differential equations (attrition rate is linearly proportional to troop strengths). Braun, whose first edition was published in 1941, claims, (in his 1979 second edition) to validate the square law for the conditions of battle at Iwo Jima in World War Two. In *Theoretical Paper No. 1:* "The Exponential Decay of Armies in Battle," Dr. James J. Schneider discusses the ***linear laws*** ([pp. 22 – 26] constant ["linear time dependence"] attrition rates, concentration is not an advantage, and the bigger opponent wins). He also discusses ***square laws*** ([pp. 26 - 37][one for *fire action* where attrition rate is proportional to enemy strength as in Braun above{named for the "exponent of 2" in the characteristic equation}] and one for *shock action* [an inelastic-collision/impulse model in which kinetic energy is dissipated in the deformation of the enemy – through reduction of his cohesion {named for the v^2 in the equation balancing kinetic energy]) and Peterson's ***logarithmic law*** ([pp. 109 – 126] attrition rate is proportional to *own* strength – logarithmic (or exponential depending on the formulation) time-dependence). Schneider also discusses an ***exponential law*** (attrition rate still proportional to *own* strength so this law has the exponential time-dependence of the logarithmic law but Schneider adds a constant to account for a rate of "deployment" [or reinforcement]). RAND's Paul K. Davis combines all three laws in a generalized "Lanchester Equation" in "Aggregation, Disaggregation, and the 3:1 Rule in Ground Combat." RAND publication MR-638-AF/A/OSD. Santa Monica, California: RAND, 1995. (also at http://www.rand.org/publications/MR/MR638). Davis says that almost everyone who has written about Lanchester's equations has commented on their limitations. He claims they "have a place in explaining simple points," but the use to which he puts them in his paper is far from simple. He puts his generalized equations in an appendix: $dA/dt = -k_a A^r D^s$ and $dD/dt = -k_a D^t A^u$. A is the "attacker" strength, D is the "defender" strength. Manipulation of the exponents (which can either be 1 or 0) allows the generation of the "special case" laws described above. *s=u=1 and r=t=0* corresponds to the square law. s=u=0 and r=t=1 corresponds to the logarithmic law. If a "deployment constant" is added, Schneider's exponential law is the result. Davis claims that r=s=t=u=0 corresponds to the "linear law," however, this claim is inconsistent with what Schneider calls the "linear law" instead, Davis's result resembles Braun's "guerilla law." Common sense indicates to this author that "linear" describes "time-dependence." Therefore, the "linear law" corresponds to r=s=t=u=0; attrition rates become negative constants (linear). Davis's result of r=s=t=u=1 produces equations of the form: $dD/dt = -\tilde{K}_a DA$. Davis's expertise is in the application of these types of equations to computer simulations of combat. He says that good computer models use these kinds of equations "locally" to estimate attrition within time-steps, "but the coefficients [and

exponents] of those equations change from time-step to time-step [and vary over terrain and other conditions]."

98. Anthony Kellett, *Combat Motivation: The Behavior of Soldiers In Battle*, (Boston, Massachusetts: Kluwer Boston, Inc., 1982), 46.

99. The term "cybernetic domain" comes from the 1997 curriculum of the Advanced Military Studies Program, USACGSC, Fort Leavenworth. Cybernetics connotes the control of "human" phenomena with the assistance of non-human means. Its main components are the command and control and logistics systems and orgainzation.

100.Idem. Kellett validates the World War II observation of Field Marshall Montgomery: "there is a difference between cohesion and esprit, as was not infrequently made evident in Vietnam. Cohesion denotes the feelings of belonging and solidarity that occur mostly at the primary group level and result from sustained interactions, both formal and informal, among group members on the basis of common experiences, and shared goals and values... Esprit denotes feelings of pride, unity of purpose, and adherence to an ideal represented by the unit, and it generally applies to larger units with more formal boundaries than those of the primary group. The seed of a unifying thought is here. The effect of what Montgomery and Kellett have called Esprit is ***coherence*** At the primary group level, the effect is actual ***cohesion*** The distinction may be semantically subtle, but while cohesion does litterally mean the act of cohering, both terms also inherit meanings from classical physics which have come into popular use, and in which the terms differ in their magnitude of effect.***Coherence*** is the term applied to the wave nature of laser light. It consists of a single *wavelength* – it is monochromatic, and its contributing sources maintain a constant *phase*.relationship – if there is any change in wavelength, all contributing sources make the same change together. Note that reciprocally, if there is a change in frequency (cycle rate, tempo), then all contributing sources make the change together and maintain their coherence. By strict application, that is all that physics allows coherence, however the laser is a household item today, and the other properties of laser light may be improperly affiliated with a popular use of "coherence." Laser light is *monochromatic, unidirectional, high intensity, and coherent.* As an ensemble this concept implies ***unity of purpose, intent, and action***. Note that intent is established in a heirarchialy nested fashion, and it is primarily by ***vertical*** informative communication. ***Cohesion***, on the other hand is a term from materials science. It is a measure of the attraction which binds the basic units of the body in a state called condensed matter such as or solids and incompressible liquids. This implies an actual "block-like" ***physical integrity*** and ***unity of action.*** The difference is that this has been established primarily by ***lateral*** affective as well as informative communication.Kellett discusses the factors which determine cohesion and coherent action. In particular he provides the best description (among the sources referenced here) of the role of leaders in "giving" leadership through "fatherly" affective communication with their soldiers (Kellett, 153). Another unique observation by Kellett is that unit traditions inform soldiers that incredible personal sacrifice for the unit is expected – it is

the behavior modeled by the hero figures found in the *symbols of tradition* and ceremony. (Kellett, 49 –51).

101.Waldrop, 230. See also discussion of phase transition in general pp. 227 – 234, esp 227, 228 and 234,235.

102.Manuel De Landa,. *War in the Age of Intelligent Machines*. Edited by Jonathan Crary, Sanford Kwinter and Bruce Mau. Third Printing. (New York, New York: Swerve Editions, 1994), 60. (See "De Landa" under "friction" at Appendix C for the quotation)

103.Raymond A. Serway, *Principles of Physics*, (Fort Worth, Texas: Saunders College Publishing, Harcourt Brace, 1994). (This was the text used by the monograph author as a physics instructor at the U.S. Military Academy, West Point, NY from 1994 to1996), 239. "Center of Gravity" is a mutated metaphor that bears little resemblance to the physical concept from which it was derived. ***In the early 1800s***, Clausewitz, the originator of the metaphor, used it as a physical characteristic of a military formation. His mental model for the formation was generally that of a monolithic rigid body the dynamics of which are governed by classical solid mechanics. His use of the term "cohesion" on page 486 of *On War* supports this, and so does his use of the terms "mass" on page 485 and "friction" on pages 119 - 122. These terms are also physical characteristics of rigid bodies in classical solid mechanics. "Cohesion" describes the degree of rigidity or hardness, as determined by the structure of a formation. "Mass" is the measurement of an object's inertia – its inherent tendency to resist changes in its state of motion. In Clausewitz's view, the mass of a formation is determined by the number of soldiers. So Clausewitz's "Center of Gravity" can be formulated by extension of his metaphors from solid mechanics. In solid mechanics, if the acceleration of gravity is a constant over an entire body, then its center of gravity is the same as its center of mass (Serway, 239). And the center of mass is the average position of the formation's mass. For an equally spaced formation, this would be the center of the formation. For a formation with one flank "weighted" more "heavily" than the other, the center of mass/gravity would be toward the "weighted" flank. One property of the center of mass/gravity is that any force acting along a line passing through it produces only translational motion – no rotational motion because it produces no torque. This means the formation would "back up" but not be forced to "turn." If a formation is struck along a line of action that does not pass through the center of mass, the force produces a torque. The defending formation turns. However, this may produce (depending on the relative sizes of the attacker and defender) an envelopment of the attacker with the majority of the defenders mass – a consequence of the attacker's own action. Ancient monolithic formation-designers tried to overcome this first by attacking in line (longer than that of the enemy) rather than in column. Later, they developed composite structures for their formations in which specialty troop-types were given the mission of protecting the flanks or attacking those of the enemy. ***In 1997***, however, the monolithic rigid body metaphor rarely applies at the level of large formations, and the term "center of gravity" has become ambiguous. This study has discovered seventeen authors who have used the

term. As can be seen at APPENDIX C, their use of the term is quite varied. Six of the publications are doctrinal manuals. As the theoretical foundations section of this monograph points out, one of the roles of doctrine is to promote a common understanding of important terms. However, the use of the term in these publications is varied as well.

104.Robert Leonhard, *The Art of Maneuver*, (Novato, California: Presidio Press, 1991), 20,21. Most of Leonhard is not very rigorous in his use of physics; however, he has many insightful observations. One such observation is his statement of the perception of the Center of Gravity as a "King" or "Queen" metaphor from the game of chess.

105.*American Heritage® Dictionary of the English Language*: **tem·po** (tèm'po) *noun plural* **tem·pos** or **tem·pi** (-pê) **1.** *Abbr.* **t.** *Music.* The relative speed at which music is or ought to be played, often indicated on written compositions by a descriptive or metronomic direction to the performer. **2.** A characteristic rate or rhythm of activity; a pace: *"the tempo and the feeling of modern life"* (Robert L. Heilbroner). [Italian, from Latin *tempus*, time.] ***In military application***, the second of these definitions is closest to the use of the term in doctrine. See APPENDIX C. If the activity is motion, then the physical meaning of speed is proportional to the tempo, and the activity has dimensions of L/T (such as meters per second for muzzle velocity, or kilometers per hour for vehicular movement). Another activity characterizing the tempo of military operations is decision-making. Here the rate or tempo is like a frequency and the activity is measured in decision-cycles per hour (or day, or shift).

106.*The American Heritage® Dictionary of the English Language*: **"phase** (fâz) *noun. Abbr.* **ph.** .... **5.** *Physics.* **a.** A particular stage in a periodic process or phenomenon. **b.** The fraction of a complete cycle elapsed as measured from a specified reference point and often expressed as an angle. **6.** *Chemistry.* **a.** Any of the forms or states, solid, liquid, gas, or plasma, in which matter can exist, depending on temperature and pressure. **b.** A discrete homogeneous part of a material system that is mechanically separable from the rest, as is ice from water." ***In this monograph***, it is the *chemistry* definition that applies to the concept of *phase transition.*(However, the Physics definition is relevant to the meaning of coherence. This is the *phase* that must be constant in coherent light. Phase transition in military formations is a relatively new idea. Formally introduced by Schneider in "The Theory of Operational Art" in 1988. However, there have been other references to such effects. For Example, Gavin spoke of "dissolving" units down to the size expendable against a single nuclear blast. (See quotes from Bacevich in APPENDIX C). Other authors, including those of doctrinal publications have described the mechanics of orchestrated phase change. These descriptions are included in APPENDIX C. According to Serway, "phase changes in a substance occur when the physical characteristics of the substance change from one form to another. Some common phase changes are solid to liquid (melting), liquid to gas (boiling [or evaporating]), and a change in crystalline structure of a solid." (Serway, 385). Note that a military contextual connection is possible here in that the properties of matter that describe these phases are the bonding strength of its ***cohesion*** and the geometry of its ***organization***. For instance, the properties of solids depend on the crystalline structure. The classic example is carbon:

The only difference between graphite and diamond is the crystalline structure. ***Graphite*** exhibits high anisotropy because it is made up of carbon atoms that are, "strongly bonded to three other carbons in a layer, the bonding angles being 120 degrees (the bonds are sp^2 hybrids [covalent, metallic bonds].)... Layers, however, are bonded to each other by weak van der Waals' forces [like the weak forces that "attract" water molecules to one another in liquid water]... Moreover, it is a useful dry lubricant because the layers easily slip over each other." (Arthur L. Ruoff, *Introduction to Materials Science*, (Huntington, New York: Robert E. Krieger Publishing Co., 1979), 265. ***Diamond***, on the other hand, is isotropic because its carbon atoms are strongly bonded to other carbons in each of the four tetrahedral directions. Diamond structure has regular crystalline faces, but these are not like the layers of graphite because these faces (or lattices) in diamond are strongly bonded to one another. (Ruoff, 210 – 212). The differences in these crystalline structures can also be described in terms of the energy state of the bonds. "All phase changes involve a change in internal energy." (Serway, 385). The energy describes how strongly or weakly the atoms are bound together; i.e. it describes the strength of their ***cohesion***. Metaphorically speaking, the same sorts of phase changes take place in military formations. Again, these changes involve dependence on the strength of ***cohesion***. It is not easy to quantify the strength of this cohesion, but according to strong anecdotal evidence from Marshall, Kellett, McPherson, and Sledge, cohesion apparently depends on communication – both formal (informative) and informal (affective). This is intriguing, but further investigation would be well beyond the scope of this monograph. "Phase transition" is one of the ways Waldrop describes the complexity at "the edge of chaos"; this is Waldrop's category IV. (See Waldrop, especially page 230 in the context of pp. 228 – 237, where he discusses both first and second order phase transitions). It also corresponds to Maruyama's "Morphogenic" category and thus to complex adaptive systems in general. In "The Theory of Operational Art," Schneider describes action against the enemy which first produces disorganization (liquefied) and then disintegration (gaseous). (Schneider, p. 6-7). In his 1996 article, "Black Lights," he describes action against a fluid enemy that freezes him. This is cybernetic paralysis. These descriptions obey the "correspondence principle" in that the morphogenic activity is transient. It leaves the enemy in one of the three other states. Many other authors works are consistent as well. Several of the authors at Appendix 3 refer to B. H. Liddell Hart's "expanding torrents" model in which turbulent eddies erode the riverbank until the river breaks through. (See Appendix 3.) Another possible future military metaphor is *resistivity* or *conductivity*. Most readers should recognize this physical phenomenon. Classically, electrical *resistance* is proportional to the temperature (*heat* content = kinetic activity) of the substance. *Conductance* is the reciprocal of *resistance*. In the military, one might postulate that, as in physics, *resistance* [fundamentally related to *friction*] is eliminated as a substance is *chilled*. In physics, *resistance* impedes electrical current – the flow of an "electrically charged fluid." [See Richard P. Feynman, Robert B. Leighton, and Mathew Sands. "The Dynamics of Superconductivity," Lecture 21-8 in *The Feynman Lectures on Physics*. Commemorative Issue. Redwood City, California: Addison-Wesley Publishing Company, 1989]. One might postulate a military ***ideal*** whereby a military formation is brought to *superconductivity* by phase transition below a *critical temperature*. In the

military context, however, the *conductors* are "cybernetic" systems. *Resistance* is manifest through military *friction* proportional to the kinetic activity of these systems. And the *current* is flow of an "informationally charged fluid" of command information. Note the inherent duality between the activity and effectiveness of the command system: it is not likely that a military formation can exhibit *both dynamic fluidity* as required on a dispersed battlefield *and* remain below the *critical temperature* for *superconductivity*. The command system will always have to overcome significant *resistance*.

107. Waldrop, 230.

108."Friction" is used two ways in military writing. (See De Landa at Appendix 3). The first is in a sense consistent with the solid mechanics definition of friction – a force which impedes motion and dissipates energy. However, that is not the application in the context of Chaotic Disorder. Here, the meaning is "uncertainty." The unstated connection between the two definitions is that the ***moral*** effect of uncertainty – indecision – can be described as a form of moral ***inertia***. This moral inertia of indecision and inaction is at the opposite end of the same spectrum as the moral resolution that du Picq talks about. (See discussion in main text at "Seeking Decisive Victory.") Upon investigation in depth, one finds physical inertia to be very important in mechanical friction as well. In simple solid mechanics for example, friction is an empirically quantified phenomenon. The force of static or kinetic friction between two surfaces equals the product of an empirically approximated constant called the coefficient of friction and the magnitude of the normal force (perpendicular to the surfaces). The normal force usually includes a component of weight, which is determined by the object's mass – its measure of inertia. In more detailed examinations of dissipative mechanisms in systems, the inertia of the constituents of the system always plays an important part. In either the physical or the moral sense, friction describes an impediment to action. The magnitude of this resistance is always contextual, and it is never completely determined – the magnitude of friction itself is somewhat uncertain. See also the discussion of "phase transition" beyond a *superconductive critical temperature* to eliminate the *friction* in the "cybernetic domain" at the endnote to "phase transition."

109.These notes are heavily influenced by the course text by Raymond Serway (see bibliography) and by many members of the Department of Physics, particularly MAJ Timothy Creamer, who was the course director during the fall 1994 semester, and COL Raymond Winkel, head of the Department. Any errors in this presentation are attributable only to this author however.