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“Operational Command and Control in the Age of Entropy”

(Track 1; Track 5)
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ABSTRACT

“Operational Command and Control in Age of Entropy”

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Operational leaders face a myriad of command and control challenges in 21st Century warfare. These challenges all have a common denominator: the increasing macro-effects of entropy. Entropy effects are far more than Clausewitzian friction on and in the battlespace; they are intrinsic to the very command and control supra-system, its information and succeeding actions. This paper discusses the more important entropic effects as they affect operational art and operational science. It concludes that militaries face significantly different problem-solving and decision-making challenges than in the past: instead of planning to maximize one’s maximum benefit in operations (overwhelming force), one will be forced to plan on minimizing one’s maximum regret (lowering expectations.) Militaries must realize that there is no way to avoid these effects, and that they must expect and plan for the increasing appearance of them in all operations.

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You can't win.
You can't break even.
You can't leave the game.
- Pentagon Briefing Slide, 1993.

Introduction:

To be complete one would add to the above slide the following two phrases: you can't change the rules and you can't know all the rules. These five short phrases capture the essence of this paper. There is a "new sheriff" in national security-town and that sheriff is entropy. Entropy enforces the real limits of natural law on all actions, including and especially those of human behavior.

This paper looks at the idea of entropy, discusses why it is increasingly important for military matters in the current time and foreseeable future, and concentrates on its effects on command and control. Finally, the paper makes some observations and recommendations on how to deal with entropy.

Two laws define entropy: the Second Law of Thermodynamics and Shannon's Law of Information. Both say the same thing mathematically, but in two different physical dimensions. In Thermodynamics, the Second Law states that there always will be energy (heat) that will be produced when work is done that is not associated with the production of that work. Since by the First Law energy cannot be created or destroyed, this means that the heat energy must be taken away from the total energy applied to do the work. Humans call this "lost or waste energy."

Friction, a concept well known to military thinkers, is an excellent example of entropy. For example, consider the task of towing a cart one hundred yards. The work associated with the tow can be by any means (human, animal, mechanical.) Whatever the means, the energy expended by the means will always exceed the work accomplished (the cart moved one hundred yards.) The difference between the expended energy and the accomplished work is friction, which in turn can be construed as entropy. Equally important, entropy always increases with expended energy. Thus, hot water always becomes cool, but cool water, unless a source of heat energy is applied, never becomes hot. The more work and energy used, the more entropy increases.

Entropy also can be understood in information terms. Claude Shannon, in his pioneering work on Information Theory, found that the information transmitted not only does not, but can never, equal the information received. The term, signal noise, captured this concept. However, information entropy is far more than just the noise caused by transmission over hardware and the ether. It

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represents the amount of disorder contained in the information itself. For example, consider the children's game of "pass the message." Six or seven children will pass a message from a starter to the last child in a sequence. The message always comes out a little (or more) different than what was initiated. The error in the message is a measure of information disorder or entropy. As with the energy example, information entropy also always increases. The more information created or transmitted even more disorder and error results. In short, the more one knows the less certain one is about what one knows. Contrary to popular media advertisements, information is anything but free or cheap.

Note that in either case, energy or information, there can be and is no escape from entropy. However, under certain restricted physical conditions, its effects can be evaded or even reversed in the short term over a relatively small area. Consider the example of life, in the specific case, human life. Life exists to obtain and process information; it does so through using energy to enable information processing (learning) to occur. Over time, accrued human information enables individuals and groups to adapt to environmental stresses. More and more information processed enhances survivability of humans. However, that happens only on earth, only in certain regimes of earth (not above 18,000 feet, not under water, not in temperatures over 140 degrees Fahrenheit, not in temperatures under 100 degrees below zero Fahrenheit.) Also, this processing only goes on for a limited time – for males in the United States, about 79 years. Groups of humans can pass accrued information to future generations

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through evolutionary biological processes (incorporation in inherited genetic traits and codes) and through learning (traditions, education, culture.) However, passage of information across generations invariably must involve increased disorder or lost information due simply from the act of passage. As long as the regime or local environment – the system supporting life – can provide the energy and information for life to continue to exist, grow, and evolve, this loss can be managed and even reversed to the point that it appears that information, called knowledge, increases. In turn, humans can use this knowledge (each species of life has its own body of knowledge) to further delay the inevitable decay and disorder. This phenomenon of a nurturing local regime or environment is understood as an “open system.” Humans and life in general takes the raw information and energy attendant to the earth (air, water, sun, sources of food) and converts these into useful, adaptive information. The key phrase here is “as long as.” Should the system shift from an open system to a closed system, life would have to consume itself to the point of extinction to maintain its energy and information. Jared Diamond reminds that such local examples have occurred in human history: for example, the human devastation on Easter Island caused by overpopulation overrunning the ability of the local ecological system to remain open, with the eventual result of human cannibalism, and finally extinction. Philosophers make the point that being human is to search for truth and knowledge. That may be so, but it is a vain search for nothing lasts or can last.

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Entropy, either in energy or information form or both, has existed for as long as this universe has existed. Why does life even try to continue given the futility of the effort to extend itself into the unknowable future? Why is entropy more important now than at other times?

Life continues because it has a biological and genetic imperative to continue; where that imperative comes from is a matter for theologians and philosophers as much as for scientists. The reality of the matter is that humans, like all life forms, have inherent and strong needs to survive as individuals and to continue the species through procreation. These needs exist in the nurturing and relatively open systems environment of the planet Earth; however, as the case of Easter Island reminds the human race, this “openness” is relative and subject to the inherent resource scarcity of the planet. There is only just so much Earth for humans to use.

Entropy is more important now because humans have started pressing Earth’s resource limits not only through energy consumption (for food, comfort, shelter) but also through information consumption. Entropic effects are observed from social perspectives, for example the increasing human population and associated age demographics, from economic perspectives, for example the increasing disproportion of wealth generated and owned throughout the world, from political perspectives, for example the local and personal nature of political violence, from environmental perspectives, for example the well-known and controversial idea of global warming, and from military perspectives, for example

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the increasing costs of military capabilities. It is this last perspective that is of interest here and now, and it is to this perspective that the paper turns.

War and Entropy

All war is concerned with obtaining and maintaining information. Humans need information to push off into the future the inevitable effects of entropy. They do this through conversion of scarce and distributed planetary resources into information of use in adaptation. Humans can use one of two general approaches to obtain and maintain information: cooperation and competition. Though humans do cooperate, they also tend even more to compete. Competition engenders conflict. Conflict in extrema is violence. When the violence involves human groups, the phenomenon becomes war.

In war, human groups use all the basic tools available to all life forms to obtain the outcome they seek to achieve by the community violence of war. These tools are mass, space, time, energy, and information. All these tools are interchangeable or transformable into one another; however, there a limits on the interchangeability due to specific situational attributes, and due to the inherent uncertainty of all action and interaction. In practical terms, for most of human history, the interchange has been between space, time and mass, also understood as force. These three tools are often referred to in military studies as the operational factors. The Industrial Age has made the interchange of energy possible and desirable for military purposes; the Information Age has done the same for information. One can summarize the relationships among these tools as:

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S(pace) ⇔ Time ⇔ Mass(Force) ⇔ Energy ⇔ Information(H)

History is replete with examples of the manipulation or failure to manipulate the interchange of the basic tools. When Thomas (Stonewall) Jackson conducted his Valley Campaign in 1862, he manipulated space and time to make up for a distinct lack of force. To his opposing numbers, his force appeared to be three to four times its actual size. Similarly, the machine gun in World War I definitively changed the balance of force and energy to the advantage of applying energy for achieving battlefield results. The atomic bomb accomplished much the same kind of result as the machine gun in World War II. Finally, information, in the way of panicked civilians, mutinous soldiers' behaviors, and enemy demands for unconditional surrender played on Lieutenant General A. E. Percival's mind in Singapore, February, 1942, leading to the almost unbelievable surrender of 130,000 allied troops to less than 60,000 Japanese troops who were at the end of their logistic pipeline, out of food and ammunition. In this last case, the Japanese operational commander, Yamashita, already had taken the measure of his opposite number in January, and found him lacking the necessary stubbornness to conduct a true, prolonged defense of the Malayan Peninsula and the associated island city of Singapore. The group that masters the effective interchange, adaptation and use of the basic tools tends to win wars. The tendency is probabilistic because one cannot escape the natural world implications of the Heisenberg Uncertainty Principle: verbally, the Principle says the more closely one observes an object of interest, the less likely one will be able to accurately measure that object's characteristics. The tendency

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reflects the incompleteness of such mastery because one also cannot escape the natural world implications of the Gödel Incompleteness Proof: again verbally, the Proof says that one can never completely define (understand) a system from within that system.

Of course, all these interchanges, involving exchanges of information and energy, are subject to the effects of thermodynamic and logical entropy. Many classical strategic thinkers intuitively recognized the importance of these effects. Sun Tzu advises that the best battle is the one not fought; hence, there is no energy or information loss in the activation, manipulation and interchange of the basic tools of societal groups. If one does have to fight, Sun Tzu advises that one should know one's self above all other things to ensure success. A modern take on that phrase can be heard in the fictional movie character "Dirty" Harry Callaghan's remark that "a man's got to know his limitations." A parallel thought is found in Sun Tzu's Enlightenment/Romantic Age intellectual descendent, Carl von Clausewitz; von Clausewitz advises his readers that "no one starts a war – or rather, no one in his senses ought to do so – without first being clear in his mind what he intends to achieve by that war and how he intends to conduct it." Among the modern strategic thinkers, Alexander Svechin and John Boyd appear to have the most appreciation for the effects of entropy on warfare. Svechin in his magnum opus, Strategy, argues that Russia should use its natural advantages, space and mass (population), to stretch any invader's lines of communication and operation to the point where "friction" (a Clausewitzian concept describing entropic effects on the movement and maneuver of armies) overwhelms the

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invader’s capability to attack. At that point, the culminating point of the attack (another Clausewitzian term), the invader becomes vulnerable to attack and collapse; both the experience of Napoleon and Hitler with their failed, catastrophic attacks on Russia bear witness to Svechin’s argument and to the brutal reality of entropic effects on the battlefield. Boyd, in his multi-dimensional approach to warfare (on physical, cognitive, and moral levels), argued that by operating faster information processing cycles (leading to decisions) one could effectively cause an opponent to become paralyzed and prey to whatever one wanted to do with the opponent. The paralysis due to mismatched information or decision cycles conducted iteratively over a period of time is an illustration of entropic effects.

Entropy all appears in the development of the physical tools for war, from training soldiers to fight and retaining them at the acme of their skills to building the weapons that soldiers, sailors, airmen and marines use. There are a number of research studies on training soldiers and units for combat that indicate that it is difficult to keep a well-trained unit ready for a long period without requiring the unit (and the soldiers) to undergo remedial and repeated training. Essentially, the sword must be continually sharpened *even when it is not used*. Why this is so can be understood from a perspective of information and related logical entropy. A well-trained unit is one imbued with a great deal of information; it knows itself, its capabilities and its limitations. In fact, all or most of the individuals in that unit share that information. Each knows what to do, and what others will do. The training provides the soldiers and skills with confidence and

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knowledge that they will prevail in any competition or combat. They have reduced or believe to have eliminated uncertainty from any contest. To achieve such a high level of competence and confidence, a great deal of information must be accrued by the unit and the individual soldiers. Recall the short version of the definition of logical entropy: the more one knows, the less certain one is sure of what one knows. In a closed system, one in which the unit and soldiers do not train, uncertainty or disorder always increases over time. The unit loses its “edge.” To maintain or regain the edge, the unit must import energy and information in the guise of training events for individuals and the unit; this requires an open system.

Similarly, the weapons of war continue to cost more without real per capita improvement on the investment. The capability of the new weapon may appear to be greater than the old one, but the cost (expressing use of energy, information and matter) will even be greater. The difference in costs is a shadow measure of entropy. Here is an illustration:

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COMPARING CRUISERS

Photo # 80-G-383754 USS Brooklyn underway on 11 June 1943

To demonstrate the effects of entropy on weapon construction, consider the comparative costs of two weapons systems built for the same mission with similar capabilities and with a similar overall defining characteristic. Here the example of United States Navy cruisers fits the requirement. The ship depicted above on the right is a Ticonderoga class AEGIS cruiser, in the specific case being the USS Hue City, CG-66. The defining characteristic is its size, measured by its tonnage, in this case somewhat over 10,000 tons. It cost approximately $1 billion to build. The Hue City's mission is multidimensional: it does surveillance and reconnaissance, capital ship protection (carriers), anti-aircraft, anti-submarine, and strike missions against land targets. It can conduct surface fleet-on-fleet warfare ideally from a distance because its passive protection (armor) is very small. Its maximum speed is thirty plus knots. A crew of around four hundred sailors operates the ship.

The ship on the left was the U.S.S. Brooklyn, CL-40, the lead ship for a class of cruisers bearing its name. Its tonnage was approximately 11,000 tons. It cost approximately $17 million to build in 1937. The Brooklyn's mission was multidimensional: it did scouting, an older form of surveillance and reconnaissance, surface fleet warfare, capital ship (carrier and battleship) protection, anti-aircraft, and naval gunfire support to ground forces. Its passive protection, while light by the standards of the day, enabled it to go into harm's way, take a beating and escape to fight another day. The Brooklyn's recorded maximum speed was 33.5 knots. It took a crew of almost 900 sailors to operate the Brooklyn.

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The Hue City can do anti-submarine warfare and can extend strike capabilities up to one thousand miles inland. It takes less than half the manpower to operate than the Brooklyn. However, the Brooklyn can engage the enemy more closely and with more power. The Brooklyn can engage ashore targets up to 25-30 miles for a sustained period of time before requiring rearming, something the Hue City cannot because it can only carry 122 missiles and requires rearming at a distance. Also, ashore parties awaiting strike or gunfire support would have to wait different times from the two ships: the Hue City's Tomahawks would take a little less than two hours to reach targets at maximum range. The Brooklyn's 6 inch shells would strike their targets within two minutes at maximum range. Though each platform indeed has its advantages and disadvantages, their similarities enable one to compare the entropic effects reflected in their costs. The way to do this is to bring the 1937 construction costs for the Brooklyn up to 1991 costs (the year the Hue City was commissioned). By using historical Consumer Price Indices, one finds that $17 million of 1937 dollars buys $161 million of 1991 dollars. In other words, a similar weapons capability from 1937 would cost about 16% of that capability in 1991. What's the reason for so dramatic a difference? First, basic material costs have gone up in real price, reflecting the increasing difficulty to obtain the raw resources. This difficulty, reflected in price, is a shadow measure of the energy required to extract the resources and make them available for ship construction. Second, the difference reflects the greatly expanded information capabilities of the Hue City over the Brooklyn. The Hue City uses AEGIS radar that can detect

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objects as high as near space, with its integrated computers, it can track and intercept multiple targets with extreme accuracy and speed. The Brooklyn's radars could find targets about 30 miles away and up to 40,000 feet; it had electro-mechanical fire directors that tracked and intercepted targets with varying degrees of success. Both reasons reflect entropic effects: the resource cost through increased energy recovery costs, the information cost through increased requirements to reduce the uncertainty of attacks.

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Command and Control and Entropy

If entropy is endemic to everything one does in war, why haven't people noticed its effects before now? In fact, they have but have discarded the notion as a cost of doing the business of war. Command and control is the essential first and best place to observe this phenomenon and its consequences. Martin van Creveld in his classic work Command in War defines command as the quest for reduction of uncertainty on the battlefield. Through his historical research he found that this quest can have perverse effects, and that these effects are amplified as the Industrial Age morphs into the Information Age. Van Creveld refers to these effects as information pathologies. In reality, they are the physical manifestations of entropy. They are increasing.

Van Creveld reviews the American experience in war in the latter part of his book. He notes the American predilection to exchange mass or force for any of the other basic tools for warfare in an effort to minimize casualties. By

Vietnam, information technology, especially concerning communications, provided the Americans with a new opportunity for interchanging mass for information. Because the American command structure from the President to the tactical could know, they wanted to know what was going on in order to obtain victory on the battlefield, the ultimate reduction of war's uncertainty. Bandwidth and channel capacity increased many times over during the war with concomitant increases in information flowing throughout the command. Of course, this necessitated controls to be in place to maintain and increase the efficiency of the flows. The numbers that van Creveld reports are staggering, but they need not be replicated here; of more importance is what happened with the increased bandwidth, channel capacity, and information. Information processing cycles slowed to the point of military ineffectiveness; van Creveld illustrates this ineffectiveness through the example of the failed Son Tay POW raid. The American command took over seven months to formulate and implement a plan for less than 500 total people; van Creveld notes it took the German high command in WWII less than three weeks to do a similar exercise for their successful invasion of France (with considerably more than 500 personnel.) In their pursuit of certainty of battlefield success, the Americans paralyzed themselves. Remember: the more one knows, the less one is certain of what he/she knows.

Van Creveld's observations are seconded and reinforced by systems research done originally for the United States Army, and generalized to the larger society. This work, started at the Army Human Resources Research Office at

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Ft. Benning and expanded to the University of Louisville in support of Ft. Knox's armor school between 1968 and 1982, measured the effects of the increased information flows on battle staffs, including commanders. All the studies' findings were consistent though they used two different theoretical models of organizational behavior (one psychological, the other organic or biologic.) The research first found that battle staffs, upon initiation of contact, undergo an extremely fast and huge increase of information to the point of information overload. This led to the second and critical finding that those battle staffs that best handled the overload (through a variety of different techniques) also performed most effectively. In effect, those battle staffs that were comfortable with the attendant ambiguity and uncertainty associated with information overload (being able to separate the wheat from the chaff), were winners. Van Creveld and the Army researchers both arrived at the same conclusion: to accomplish the reduction of battlefield uncertainty, command (and control) must reduce their needs for information. Both approaches also targeted the same kinds of solutions: more decentralized command and control with far more thorough common training and education of leaders and led. Basically, these solutions can be categorized as redistributing the risk of battlefield uncertainty among the stakeholders, most of whom are far down on the chain of command. These findings and recommendations reflected a consensus among command and control theorists by the mid- to late-1980s. That time period was before the information revolution attendant to the personal computer and the Internet.

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Since the mid-1980s, bandwidth and channel capacity have expanded on a scale measured by Moore's Law, stating that the power of a microchip doubles every twenty four months. There are vastly more powerful information systems integration devices like cell phones that can access the Internet, perform office tasks, provide GPS coordinates and personal navigation, broadcast television and music, load video games, provide text messaging, and make occasional telephone calls. People, especially commanders, have access to incredible amounts and qualities of information at the touch of a key. What has been the result?

The author believes the main result of this unprecedented increase of accessible information has been the development of a dangerous delusion that humankind has evaded the natural laws involving entropy. When one scans the applied research publications and conferences on command and control issues, one finds a great deal of interest in the technological, the systems solutions to information challenges posed by the new command and control. Terms like collaborative planning, effects-based planning, rapid decisive operations, and full spectrum dominance (let alone information dominance) proliferate discussion and doctrine. It is as if only one can get more, clearer information to more people faster one can solve the old command and control challenge of the renamed battlefield, the battlespace: to reduce the uncertainty of the outcome. Such approaches invariably are technological in nature and they are expensive. Unfortunately, they address only one half of the definition of information found in Joint Publication 1-02, wherein information is defined as data plus meaning.

Technological applications work on data because data is quantifiable and measurable. Technology is less helpful with meaning because it is inherently uncertain, vague and of questionable measurability.

The information flood that now overwhelms command and control centers and almost drowns tactical commands – even in peacetime – requires more command and control attention in that perverse way observed by van Creveld back in 1985. More information generates more uncertainty which in turn forces command and control entities to seek a reduction that requires more information; that is the essence of logical or information entropy. It is a costly spiral that often ends up with real consequences. Consider the example of Operation ANACONDA in Afghanistan, November 2002.

ANACONDA used the most elite forces of the United States who used to most sophisticated information assets (surveillance in this case via satellite) to pin down the location of a substantial Taliban force in the Shah-i-Kot Valley in southeastern Afghanistan. The local command and control center developed its plans based upon sensor reports that the enemy size was small, their position not fortified and concentrated in settlements, not the mountainsides and tops. Late in the planning, the center allowed a few elite reconnaissance troops to provide human intelligence. They found that the enemy size was triple that reported by the sensors, that the enemy had fortifications, and was on the mountainsides and tops, not just the villages. When the command and control center found these facts out, it did not change the plan because there were only 36 hours to go before the operation started.

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During the operation, a CH-47 helicopter attempted to land a recon team on one of the mountaintops that the enemy had fortified. Under intense fire, the helicopter barely made an escape but left two American special operations members behind. A Navy special operations command and control center, not affiliated with or netted with the overall command and control center, initiated a rescue attempt after conferring with superiors back in MacDill Air Force Base in Florida via an intermediate command and control center in Qatar. The attempt took place about two hours after the initial engagement. The rescue team landed in the same place as the first team; this time the helicopter was so badly shot up that it only managed to crash land behind friendly lines some miles away. Enemy forces quickly pinned down the rescue team, who in turn called for help. A quick reaction force on alert took off to relieve the team, but had to stagger their numbers in two flights because there were now not enough helicopters to take the whole force in at one time. No one alerted the reaction force to the danger on the mountain; they landed, or crashed, in the same place the two previous helicopters had tried to land. Under intense fire, the reaction force managed to stabilize the situation after incurring several casualties including six KIA. With the help of the second part of the reaction force that had landed less than a mile away without any opposition, they secured the mountaintop, relieved the first rescue team and recovered the by now dead American special operations forces that had started the whole affair.

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Other examples of information confusion, delays and deadly decision-making abound in ANACONDA. In the end, the enemy left the valley of their own accord. The United States declared a victory.

In the eternal and futile spiral to achieve certainty on the battlefield, American command and control has behaved as one might expect: “give me more and better weapons systems that provide me more information and give me more access to the battlefield so I can assure success. “ This means more bandwidth and channel capacity coupled with more levels of organizational hierarchy. Forgotten is the case that humans and organizational structures are limiting case in processing information; forgotten is the case that humans can only process so much information at one time, and that organizations, while capable of processing far more information than humans, do it much more slowly. Forgotten is a corollary to the logical entropy definition: the more complex the entity or system, the more information and energy required to maintain it, and the more uncertainty and wasted energy generated by the work to maintain itself.

Command and control entropic effects can be found blossoming everywhere in today’s operations environment, including and especially in the joint operational planning environment. Operation IRAQI FREEDOM, the effort to liberate Iraq, required more than twenty revisions over a fifteen month planning period. The revisions were necessary because different command and control centers, in this case the Secretary of Defense and the unified command leader, could not agree on a scheme or force size. Legally, the unified commander is

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the person tasked to plan and execute operations. However, the bandwidth and channel capacity available to all echelons now enables real-time collaborative planning for all stakeholders – especially the Secretary of Defense.

Operational planning concepts themselves are affected by entropy now. The new joint doctrine defining center of gravity multiplies the data points necessary to identify such centers to the point of decision paralysis. Whereas Clausewitz, the inventor of the concept, envisioned one center; new doctrine envisions several, perhaps dozens of them. Each one requires information so that appropriate mix of force, energy and information can be applied to achieve the desired results. If the center of gravity is found everywhere on a battlefield, perhaps it is nowhere and irrelevant as a useful planning concept. Likewise, the idea of a culminating point at which the attacker stalls and the defender attacks, a very illustrative concept of entropic effects, becomes more illusive to predict and explain because, in a multiplication of command and control centers operating with similar but not identical perceptions of the battlefield, there may be many such points occurring at less predictable (more uncertain) intervals during an operation. This makes planning for operational “pauses” to push back the culminating point far more difficult to anticipate.

The very boundaries of operational planning, captured in the ideas of theater geometry erode and lose meaning. If the boundaries enabled by information systems now reach back to the homeland, the geometric configurations of operations become far more complex and uncertain as the information about them increases. One can think of the old idea of a theater

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geometry as some kind of three dimensional space structured with lines, curves and points that are firm like a ball moving in time; the idea requires one to conceive of a possible space that, the more structure one adds, the less firm the ball becomes – first soft, then fuzzy, then opaque, then gone.

The six operational functions, necessary and sufficient to ensure sound operational planning now require more attention, more energy and more information to accommodate them. One observes this in the great expansion of (virtual) pages associated with even simple operations plans and orders. Even After Action Reports, accounting for what happens during an operation, have radically increased in size. Compare Admiral Spruance's After Action Report to Admiral Nimitz summarizing what happened at the battle of Midway - less than fifty pages – with a similar report of the Third Infantry Division during the major combat operations phase of IRAQI FREEDOM – over three hundred pages. Who is reading these greatly expanded tomes? Who is using them? Who has the time? Perhaps it is another hierarchy of command and control.

Because of the American pursuit of complete command of the battlefield (itself a contradiction by the Gödel Proof), entropy now appears limiting its ability to interchange of space, time, mass, energy, and information for the purpose of war. Entropy makes the possible interchanges far more uncertain and far more expensive; that is the real lesson of the cruiser comparison. American efforts to substitute information, time, space and/or energy for mass have perversely ended up endangering its valued and treasured armed forces. Accentuating this endangerment, using up available resources to make certain of results on the

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battlefield have diverted resources from the only programs that can enable those armed forces to regenerate: training and education. Through world-wide robust networking of information, the Americans have gone far in succeeding in closing the supra-system of its armed forces in a global environment. One should recall that a closed system very quickly requires that its life forms to consume their own in order to forestall the entropy associated with death.

Concluding Observations

Entropy is a real phenomenon that has always existed. One can evade its effects, both energy-wise and information-wise, but only in relatively small regimes. Eventually everyone and everything must pay the entropic piper. Not only is it expensive to do anything, including living, but it is a losing proposition to do anything, that is it costs more than its worth. Life, however, for whatever reason demands the effort to contradict the natural law; some argue that life itself is an invalidation of entropy and its associated laws. These are philosophical ideas and best left to philosophical minds. The mind in this paper is on war and the waging of it; specifically, it is interested in how command and control affected and is affected by entropy. The paper has demonstrated that entropy pervades warfare; it always has and always will. Entropy does this through extracting costs for use of the basic tools of war and their interchange. Command and control, acting as the “brain” for operations and warfare, tries to achieve success on the battlefield through reducing the uncertainty of outcomes; it does this through obtaining more information. In doing so, the command and control

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function intrinsically connects itself to entropy and powers the production of entropy.

If the above arguments are indeed as true as existing but anecdotal evidence seems to make them, then the American national security and military leadership have made a bad bargain with themselves in an admirable but vain effort to succeed. The situation, however, is not hopeless, just irreversible. To slow down the pace of degradation of the American military force, and possibly reverse the degradation effects locally over time, leadership must re-open its relevant global information system. Following van Creveld's recommendations, this means senior leadership must learn to tolerate and be comfortable with more ambiguity and uncertainty. They must learn to learn – continuously – and distribute "libraries" throughout the organizations of the military down to the most basic tactical levels. Leadership must develop the capacity to implicitly trust its followers to do what it wants, implementing commander's intent as it were. This may seem an easy thing to write, but it is a most difficult thing to do in practice.

D.M. Malone, a former and late colonel in the U.S. Army, provided a reasoned approach to the problem, focusing only on the Army. Malone, who was one of the godfathers of Army organizational transformation in the post-Vietnam era, recognized that different levels of leadership and followership necessitate different actions to achieve common goals. Focusing on trust and competence, he recommended senior leadership develop and promulgate the values and standards necessary for such a trust environment to grow; he recommended operational or mid-level leadership to insure the values and standards are

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implemented; finally, he recommended that the production leadership at the "point of the spear" practice and train to those standards and values. Always there were to be feedback loops to regenerate discussions and learning at all levels. Perhaps there are better ways to conceive of such a trust relationship, but Malone's way is a good starting place.

Trust is the starting place, but not the finish. Trust enables leaders to decentralize effectively, knowing or believing that the subordinate independent entities under their titular command and very loose control will do what they want. A role model for such leaders might be Chester Nimitz. Again using the Midway battle illustration, one finds that Nimitz was "out-of-the-loop" during the actual battle; he waited for Spruance and Fletcher to report to him after the battle. Nimitz may have been anxious about the outcome, but he refused to intrude on his fighting commanders. In fact, the one time Nimitz did intrude resulted in an infamous incident, during the battle of Leyte Gulf in October, 1944. Listening to the pleas for help from units under Seventh Fleet that were being attacked by significant Japanese surface forces, Nimitz heard nothing from Third Fleet which was supposed to protect the mostly amphibious and supply ship Seventh. Finally, his staff persuaded Nimitz to send a short inquiry. The message asked "Where is TF 34?" TF 34 was the tactical element of Third Fleet that was supposed to do the protection mission. In a case of logical entropy, error entered the information communications system; when the message was received on the flagship of the Third Fleet's commander, Admiral Halsey, the receiver inadvertently left a procedural tag line, "World Wonders," on the message.

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Halsey *perceived the meaning* of the message to be an explicit insult to his leadership. He wondered whether he was being relieved of command (he was not.) As a result, Halsey's Third Fleet neither completed the defeat of the Japanese force which he had engaged (a decoy force) nor arrived back in time to rescue the endangered units of the Seventh Fleet (the Japanese left on their own accord without accomplishing much damage.)

Nimitz exerted loose command and control on both his subordinate commanders and his staff. He unconsciously practiced a German form of order writing and operational control called "Auftragstaktik." The Germans practiced what they preached throughout WWII. As a result, senior German operational commanders could write short, concise orders directing what needed to be done, and could leave the details of accomplishing them to subordinates. An illustration of this is that then General Heinz Guderian could write the operations order for the decisive crossing of the Meuse at Sedan in May, 1940, on one and a half pages and get that order to the executing units within an hour. This case shows that information and energy costs are avoided, locally, through implicit trust in the behavior of others outside leadership control.

Military operations in the twenty-first century are more complex than at any other time in human history; the increasing complexity of human artificial life forms (organizations, nations, groups) is directly responsible for this trend. These operations in turn require requisite complexity in the organizations that process them. The result, as complexity scientists attest, is the need for complex adaptive systems to act as the model for organizations. Such systems

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have three main desirable design features: robustness, resiliency, and redundancy. They explicitly reject any idea of optimality because there are many ways an organization or group can succeed or adapt. Also, any one selection of a way to proceed may negate consideration of alternatives. These systems usually have simple rules of behavior, or as the military would write simple doctrine. To achieve high levels of success, complex adaptive organizations need to continually learn, experiment, and remember; they need to be very agile, or possessed of a “flat” chain of command versus a hierarchal one, and they need to continually scan their relevant landscapes both internally and externally to search for potential strengths and weaknesses, opportunities and threats. Finally, these organizations require not just good leadership, but extraordinary leadership to succeed. Characteristics of such leaders are comfort with ambiguity, curiosity about their world, creativity in their thinking, trust in their subordinates, ruthlessness and relentlessness in their pursuit of success. They recognize that one cannot do “more with less,” one can only do “less with less,” and in fact can only do “less with more.” What leaders like this realize is that what in the local space-time environment seems to be negative entropy is in reality a forestalling of a long-term degradation or loss. These leaders master the art and science of graceful degradation of organizations; they take Clausewitz’s dictum concerning starting a war to heart. Be very careful before starting wars because they always cost more than they are worth. They know themselves, their advantages and disadvantages; they fight their wars on all three levels: moral, mental, and physical; they take advantage of the

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opportunities for interchanging the basic tools at the best times; they ensure that their opponents have a much more difficult time doing so. These leaders provide clear objectives because they know they must to ensure minimal loss of understanding among their subordinates. They know and practice what all the great thinkers of war have known and written: as Boyd has written and spoken, “People fight wars, not machines. And people use their minds!”

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