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Airpower, Chaos, and Infrastructure

Lords of the Rings

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Foreword

This interesting study by Lt Col Edward J. Felker, US Air Force, describes a methodology to exploit airpower's capacities at the operational and strategic levels of war. It focuses on the third ring (infrastructure) of John A. Warden III's theory of five strategic rings, which the author argues is often neglected in the debate over the importance of leadership (first ring) versus fielded forces (fifth ring). The author emphasizes that lines of communications transmit all of society's military, economic, and political goods, services, and information. Infrastructure provides the framework that links the various elements of a nation's power. This infrastructure contains critical nodes that are vulnerable to airpower. By understanding this infrastructure, we better understand an adversary as a complex, adaptive, and open system.

Colonel Felker's paper espouses a practical theory of airpower based on the synergistic relationship among societal structure and lines of communications that comprise infrastructure. Rather than isolating different elements of a society and their concomitant targets, the theory views targets in a more holistic way. Of note, the theory articulates a culturally based paradigm with airpower applied against the linkages within a society's system processes, rather than a "one-size-fits-all" target list that attacks form. The theory describes a way to think about airpower, not a way to execute its missions.

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Lt Col Edward J. Felker, USAF, is a maintenance and logistics officer with additional experience in munitions and nuclear planning. His early degrees include work at Ball State University, the Army Command and General Staff College, and the School of Advanced Airpower Studies. Colonel Felker is a graduate of the Air War College, class of 1998.

Airpower, Chaos, and Infrastructure

Lords of the Rings

Airpower can either paralyze the enemy's military action or compel him to devote to the defense of his bases and communications a share of his straitened resources far greater than what we need in the attack.

—Winston Churchill

For the past 34 years, I have been a student of airpower—sometimes a practitioner, always an observer. I have struggled to understand the best way to employ airpower and have come to believe that what matters most is understanding our adversaries' values. The enemy determines his centers of gravity (COG), not those who study the enemy. To be most effective, airpower must be used against those vulnerabilities that create the greatest systemic shock in the fabric of a societal structure. Anything less only chips away at the margins.

Airpower theorists have studied long and hard about airpower shaping battlefields and killing tanks one at a time. But if the Air Force accepts its basic doctrinal tenets of flexibility and versatility to exploit mass and maneuver simultaneously at any level of warfare, then airpower's range, speed, reach, and lethality should have far greater impact at operational and strategic levels than at tactical levels. This is not to say the Air Force should abandon airpower's impact on the ground scheme of maneuver. That, however, should not be our only focus.

We need to also study how to degrade and destroy the adversaries' ability to transmit their military, political, and economic goods, services, and information. This is what airpower can best contribute to the fight to achieve operational and strategic aims. Infrastructure, defining both traditional and emerging lines of communications, presents increasingly lucrative targets for airpower. As airmen move into an age dominated by information, fraught with uncertainty, and laced with a healthy dose of the unknown, they need a vision to guide airpower's practical application; and their vision should focus on lines of communications that will increasingly define modern societies.

This paper does not try to depict how airpower alone can win wars. It does try to explain in what situations airpower might possess great effect in tomorrow's conflicts. It takes a practical approach by synthesizing portions of John A. Warden III, Antoine-Henri Jomini, and chaos theory. But in any case, the importance of Warden's "third ring"—infrastructure—is paramount.

Infrastructure

The history of war proves that nine out of ten times an army has been destroyed because its supply lines have been cut off.

—Gen Douglas MacArthur

During the cold war, Allied Air Forces Central Europe (AAFCE) at Ramstein, West Germany, studied the Warsaw Pact fuel system and rejected it as a viable target because it "would take too many sorties to kill it."[1] AAFCE treated the destruction of the fuel infrastructure form rather than its exploitation as a necessary process within Soviet military doctrine. AAFCE planners were captured by the paradigm of regarding fuel as a single target set comprising far more numerous aim points than could be reasonably attacked.

In the mid-1980s, Air Force Checkmate restudied this fuel system as a process necessary for Soviet military doctrine to support a breakthrough on the northern plain of Germany. By viewing the fuel system as a link between Soviet military doctrine and the commander's operational scheme of maneuver, Checkmate identified 10 critical and vulnerable army-level fuel supply nodes. The new study identified approximately 40 aim points that could disrupt operational-level fuel flow, thereby negating Soviet forces' ability to supply themselves during breakthrough operations. The sortie count to achieve this disruption of a logistic infrastructure changed from AAFCE's original "several thousand" estimate to a more realistic 150. Checkmate planners had considered the fuel system as an infrastructure that provided linkage between Soviet military doctrine and operational art. They reduced the target set to manageable numbers by finding the most vulnerable nodes presenting the greatest potential for degradation at the single most important time. This example highlights an idea taken from chaos theory that the vulnerability of an entire system (the adversary's operational and doctrinal culture) is determined by the vulnerability of nodes linking the system together (infrastructure).

Though provocative and instrumental in stimulating debate over airpower's efficacy, the debate over Warden's five strategic ring theory has neglected three of his rings—organic essentials, population, and infrastructure. The debate has centered on fielded forces versus leadership.[2] Of the three neglected rings, infrastructure (the third ring) might provide the best approach to airpower in future operations.

Infrastructure comprises dynamic systems. Put simply, infrastructure binds a society because it carries its political, military, and economic communications: goods, services, and information. Infrastructure becomes a COG because it serves as form and function. Bridges, highways, railroad tracks, and fiber-optic cables with their corresponding trucks, trains, and servers constitute form. But form is secondary to the processes or functions these components of infrastructure routinely engage—communications.

Societal Structure and Lines of Communications

> *In the Gulf War, two military modes, Second Wave and Third Wave, were employed. The Iraqi forces, especially after most of their radar and surveillance were excised, were a conventional "military machine." Machines are the brute technology of the Second Wave era, powerful but stupid. By contrast, the allied force was not a machine, but a system with far greater internal feedback, communication, and self-regulatory adjustment capability. It was, in fact, in part at least, a Third Wave "thinking system." Only when this principle is fully understood can we glimpse the future of armed violence.*
>
> —Alvin and Heidi Toffler

To understand how military power (and especially airpower) can contribute to achieving strategic and operational aims, one must begin by understanding the adversary's society and culture. Alvin and Heidi Toffler observed that "the way we make war reflects the way we make wealth."[3]

The Toffler Societal Model

The Tofflers describe societies as first wave (agrarian), second wave (industrial), and third wave (informational).

First Wave

First-wave agrarian civilizations are inescapably attached to the land. They are a product of the agricultural revolution whose leitmotif is subsistence and survival.[4] Its infrastructure is preindustrial, heavily dependent on agricultural goods, and reliant on other societies for materials and markets. Societal structure is concentrated on a handful of resources, a stunted manufacturing sector, and underdeveloped services. These factors greatly reduce both internal and external linkages for the society, which typically remains low on the interdependency or connectivity scale.[5]

First-wave warfare is marked by battles regulated by the growing season and agricultural calendar. It pits force against force in a conflict over possessions. Much of the operational strategy is regulated by the search for fodder and organization of the supply trains. First-wave warfare bears the unmistakable stamp of the agrarian economies that gave rise to it, not so much in terms of technology, but in organization, communication, logistics, and administration, as well as reward structures, leadership styles, and cultural assumptions. Agrarian societies are difficult to coerce with airpower because they lack well-developed infrastructure linkages that can be exploited.

Second Wave

Second-wave societies are industrial and marked by large quantities of labor and mass production. Industrialization results in greater connectivity between the production of goods, services, and information and their consumption within the society. As markets expand through imports and exports, these societies become more globally connected. This vast connectivity forms an infrastructure based on the production and control of goods, services, and information. Land, labor, raw materials, and capital are the main factors in second-wave economies. Mass production, bureaucracy, and tangible value are the underpinnings of wealth. Infrastructure linkages are concentrated on mass production and mass consumption processes, in essence, the logistics of wealth.[6]

Second-wave warfare's main feature is the mass destruction of industrial powers. John Keegan points out that twentieth century European civilization left "the world it dominated pregnant with war."[7] The nineteenth century industrial revolution created enormous wealth, energy, and production. It created productive and exploitative industries—foundries, engineering works, textile factories, shipyards, mines, and so forth—far greater than ever envisioned by the intellectual fathers of the industrial revolution. More important, the productive regions of the world were interconnected by roads, railways, shipping lanes, and telegraph and telephone lines. Accompanying these were schools, universities, libraries, laboratories, and churches that constituted a network of world civilization. The industrial revolution also spawned armies possessing vast capabilities to destroy the very things that made society industrialized.

Third Wave

In third-wave societies, knowledge—data, information, images, symbols, culture, ideology, and values—is the central resource of the economy. This allows these economies to reduce the mass associated with the second wave, yet create wealth in exponential quantity. The right knowledge reduces labor, inventory, energy, and raw materials, as well as the time, money, and space necessary to produce wealth. Third-wave societies build new infrastructure linkages inside and outside their societies based on accumulating knowledge. The finite amount of land, labor, raw materials, and capital is replaced by the quest for inexhaustible knowledge. New societal values emerge based not on hard value (form), but on the process needed to acquire, generate, distribute, and apply knowledge. Mass production is replaced by demassification that leads to a reduction in the activity necessary to produce the same level of wealth used in first- and second-wave societies. Demassification also flattens the leadership hierarchies necessary to govern second-wave structures. Industrial plant and leadership are dispersed and networked.

In third-wave societies, economies of scale are frequently outweighed by "diseconomies" of complexity. Rising complexity necessitates a high order of systemic integration in the infrastructure that links the society together. What emerges is a vast informational network that replaces much of the second-wave infrastructure.[8] In their external relations, third-wave societies evolve into hyperconnected communities. They fracture into smaller parts as they demassify. An extremely complex global system of often competing and different interests results. Paradoxically, the most powerful societies like the United States, Japan, and Europe need the most linkages because they become interdependent with the outside world to sustain their advanced economies. Taken together, this amounts to what the Tofflers describe as a "monumental change in how wealth is created" and, for our purposes, an equally remarkable change in how war is waged.[9]

The Gulf War can be regarded as a precursor of third-wave warfare. It emphasized precision targeting rather than mass destruction, operational effectiveness based on the transfer of massive quantities of information, and information dominance to generate an operational tempo that eluded the enemy's ability to observe, orient, decide, and act. John Boyd coined the term *OODA loop* (observe, orient, decide, act) to describe this cycle of perception, decision, and action.[10] Boyd's notion of an organism's interaction with the environment touches chaos theory. He contends that an organism observes and orients itself in such a way to succeed and prosper by adapting and shaping the environment to its own ends. The environment is, however, not inert but adaptive in its own right and often chaotic in behavior. Like the weather, which comprises only one of its elements, the environment is bounded but is unpredictable and highly sensitive to small variations in initial conditions. Societal structure may, in this sense, be viewed as another element of the environment.

Understanding societal structure is crucial to discerning the processes that underpin it, and where vulnerabilities might be militarily exploited. The Tofflers provide a good model to relate societal structure (culture), the production of wealth (economics), and warfare. This model is also useful in determining how societies transmit their wealth. Communications carry the society's goods, services, and information. Infrastructure then circumscribes the process for distributing a society's communications whose lines are defined by geography and culture. Hence, communications are as much the function of values as geography.

Defining Lines of Communications

Joint Publication (JP) 3-0, *Doctrine for Joint Operations*, describes lines of communications as "all the routes, land, water, and air, which connect an operating military force with a base of operations and along which supplies and military forces move." It treats lines of communications as a subset of "lines of operation . . . the directional orientation of the force in time and space in relation to the enemy . . . that connects the force with its base of operations and its objectives." This latter distinction implies the lines are more than physical since they also connect force with objectives. Furthermore, JP 3-0 goes on to note that these lines take on a three-dimensional quality and "pertain to more than just maneuver." Joint doctrine defines them as a way for joint force commanders to focus "combat power effects toward a desired end (to) . . . converge on and defeat enemy centers of gravity."[11]

This definitional landscape splits hairs over focusing operations on form or process. A better and more relevant definition of lines of communications is the infrastructure for the transmission (to include collecting, processing, analyzing, and disseminating) of all forms of goods, services, and information. This definition makes no distinction among military, economic, political, or cultural lines of communications. Additionally, a more universal definition of lines of communications makes implicit the integration of all societal infrastructure.

Jomini's Lines of Communications

Jomini provides the first exposition of military force focused on infrastructure. In *Treatise on Grand Military Operations* (Paris, 1865), Jomini notes that (1) strategy is the key to warfare, (2) all strategy is controlled by invariable scientific principles, and (3) these principles describe offensive action to mass forces against weaker forces at some decisive point to lead to victory. He describes these decisive points in geographical terms: a road junction, river crossing, mountain pass, supply base, or an open flank. Jomini sees decisive points as elements vulnerable to attack or capture that would imperil or seriously weaken the enemy. Without exception, enemy dispositions and supply lines define decisive points within Jomini's construct. Jomini uses Napoleonic historical examples to emphasize interior versus concentric lines of communications.[12]

Rather than positing a pure theoretical construct, Jomini transforms the intellectual component of war into operational art. Lines of communications have natural and physical characteristics; however, they also portend strategic choice. His theory attempts to provide an operational template to describe where to fight, for what purpose, and with what force.[13]

Jomini reinforces the importance of infrastructure. His conceptual lines of communications are more than territorial. They become maneuver lines of operation in much the same way that Air Force Doctrine Document 1 (AFDD 1) describes airpower as a maneuver force and *Joint Vision 2010* describes dominant maneuver.[14] To Jomini, whether describing Napoleonic success, Frederick II's less spectacular victories, or the outcome of all warfare past and future, infrastructure targets had similar characteristics.[15] For example, he was less concerned with the characteristics of bridges than with the total strategic and operational value of the transportation infrastructure that determined how a commander conducted warfare. Making the proper strategic choice was not a matter of servicing specific targets. Choices were made for operational and strategic decisiveness. In much the same manner as Boyd articulates his OODA loop, Jomini described a construct for commanders to apply decisive, aggressive, offensive action to deprive the enemy of "time to think and act, with superior force at the time and place of battle is the best guarantee of victory."[16]

Chaos Theory, Warden, and Infrastructure

> *For want of a nail the shoe was lost . . . For want of a shoe the horse was lost . . . For want of a horse the rider was lost . . . For want of a rider the battle was lost . . . For want of a battle the kingdom was lost . . . and all for the want of a horseshoe na il.*
>
> —Poor Richard

This quote exemplifies the chain of events that might cause a chaotic outcome in an otherwise orderly world. Warden's (infrastructure) third ring, Jomini's lines of communications, and chaos theory provide a synthetic base for a general theory of airpower.

Understanding Chaos Theory

The word *chaos* has many interpretations. Webster's *New World Dictionary* defines it as "extreme confusion or disorder."[17] Contrary to what the name implies, chaos theory studies sequential events in perceived chaotic behaviors in the hope of finding order. Paradoxical as it may seem, chaos is neither random nor erratic. Scientific and mathematical literature defines chaos theory[18] as "the science of complex, dynamic nonlinear systems . . . (and) since organizations are complex, dynamic systems, chaos is the science of organization."[19] The theory lies at the ill-defined, somewhat arbitrary, border between mathematics and physics (and as some critics might imply—alchemy).

Chaos theory applies to dynamic systems—systems that contain a very large number of shifting and varying component parts.[20] These parts are interconnected and interrelated in some fashion. The stock market illustrates this principle. A look at the daily market indicators demonstrates it is not static. Individual brokers, investors, and the companies whose stocks are traded comprise interrelated subsystems of the stock-market system.

Within these dynamic systems, nonperiodic order exists; that is, seemingly random collections of data can yield orderly yet nonrecurrent patterns. Even though the patterns may appear repetitive, they are not. If the patterns are truly repeated, the system behavior would follow a definitive path, and would no longer be chaotic and apparently unpredictable. Weather patterns illustrate this principle. At a given location, weather cycles through seasonal changes are well defined; however, from year to year the cycles vary.

Such chaotic systems exhibit sensitive dependence upon initial conditions; that is, a slight change in any one of the initial inputs leads to disproportionately divergent outcomes.[21] This principle is one of the most important factors for military planners. The essence of the principle is that small changes or perturbations may result in very different, and sometimes unpredictable, behaviors at later times. The fact that order exists suggests that patterns can be predicted in at least weakly chaotic systems.[22]

Complex system structures resemble fractals—patterns formed by an iterative process that display self-similarity. Self-similarity means that small bits and pieces of the structure are similar to the overall shape from which they came. If a branch of a cauliflower head were dissected, the smaller piece would look very similar to the whole. The iterative process uses the output, like the dissection of the cauliflower, as the next input. This input is then further dissected into its iterative output, and so on. Each output possesses the self-similarity of its corresponding input.[23]

Scaling describes how objects retain self-similarity when viewed from different distances. In nature, a mountain provides an excellent illustration of this property. From a distance, the mountain appears rugged. As one gets closer and examines a small peak of the mountain, the same ruggedness repeats. Viewing one outcrop of this peak closer also shows the same ruggedness. This scaling property can continue all the way down to the microscopic level.[24]

Chaos draws a fine line between the predictable and unpredictable. Initial conditions are sensitive and are often popularized in chaos literature as the "butterfly effect,"[25] where a butterfly flapping its wings over Brazil can spawn a hurricane in the Caribbean Sea.[26] This means small changes may result in very different behaviors at later times; however, it might be possible to place bounds on a range of behaviors if they are weakly chaotic. We can then make assertions about the future states that the system might pass through, even though we cannot exactly predict the form of those states.

Linear systems display two important characteristics. Input and output are proportional; if input doubles, output doubles. Second, linear systems obey the superposition rule; that is, several simultaneously applied inputs to a system yield an output whose total equals the sum of the inputs. A system is linear when it has proportionality and superposition. These properties give linear systems their predictable behavior.

We tend to treat most systems as if they were linear. A factory is a good example. We predict that if we add a certain number of people, or additional inventory, we will increase the output by a comparable amount. What goes into the system should be a predictor of what comes out. But in reality factories do not operate this way. Change the number of people and inventory and a widely differing output might occur—far from what we predicted. This is because factories are nonlinear systems that do not obey the properties of proportionality and superposition. Small inputs may yield huge outputs depending upon the nature of the system.[27] Additionally, nonlinear systems will attempt to self-regulate with internal modifications as a coping mechanism to external disturbance.[28]

The subsystems that organize a society—for example, leadership; command and control; electrical power production and distribution; petroleum, oil, and lubricant (POL) networks; finance and banking; telecommunications; and other subsystems—also form systems. Each system or subsystem is more or less vulnerable to internal and external disturbances. Many of the systems and subsystems are interconnected and interact with each other. These linkages define the normal operation of the systems and convey nonlinear, chaotic processes. Disturbances in one subsystem of the system may have effects on other subsystems that are completely out of proportion to the initial disturbances, or may ripple through the entire system via the direct and indirect linkages, thus affecting all the subsystems.

An understanding of chaos allows us to find bounds and/or patterns within systems that appear to be, but may not be completely, unpredictable. This understanding allows us a measure of predictability when a number of interactive systems are involved. Crucial to applying chaos theory to warfare in coherent fashion is a comprehension of the enemy's culture and a contextual notion of its systems, subsystems, linkages, and critical vulnerabilities.

In spite of what we might think is obvious about chaos, chaos and order are not opposites of each other. They are rather yin and yang, inseparably intertwined. Chaos theory is a conceptual device for describing an incredibly complex world. While theory may fall short of an absolute insight into complex systems, it at least provides a powerful "navigational tool" to perceive the conditions on the edges of chaos.

A Practical Example of Chaos

An electrical power grid provides an excellent example of chaos. The power grid from generation station, transformer substations, to customers, forms a networked system. This network's exponential branching demonstrates complex scaling. Complexity and underlying order makes the system susceptible to failure. If a generator is removed, or some other power isolation occurs, the system attempts to self-regulate to compensate for the power well and frequency droop. Other power suppliers, whether backup systems or outside sources, attempt to take up the slack. If the reserve is insufficient, or the system is already at peak production, the energy well might cause a failure in the entire grid. Circuit breakers are provided to disconnect the energy well to prevent catastrophic failure. But if the circuit breakers are defective, and/or other power generation stations are taken off-line, the energy well and frequency droop can cause a surge or bow wave that also might bring the entire system down. Once this bow wave begins, it is impossible to stop unless the defective part in the system can be quickly located and replaced. Self-regulation keeps the system precariously balanced on the edge of chaos, where any subsequent minute pulse might result in unexpected catastrophic system failure. Conversely, an inadequate reserve allows a wave of dynamically unstable energy to propagate throughout the system and also configure it for failure. The power system is interconnected and interrelated to other systems of the society. Just as the unstable energy propagated throughout the power grid, a catastrophic failure of the power grid can propagate throughout the interrelated systems (transportation, communications, industrial production, computer networks, etc.)

Warfare on the Edge of Chaos

It is important to understand the behavior of a chaotic system, particularly the relationship between input and outcome. If a society at war were perceived as a chaotic system, then the application of force is an input and corresponding behavior an outcome. The unpredictability of outcome, bounded in the extremes by indifference and annihilation, defines chaos, or at best, nonlinearity. Alan Beyerchen points out that war is inherently nonlinear, and that its character changes in ways that continually alter the political ends that guide war. Politics, then, is more than a guiding hand for war. It is power, and the cycling from violence to power and back again is an intrinsic part of war. Beyerchen points out:

> We can never recover the precise initial conditions even of known developments in past wars, much less developments in current wars distorted by the fog of uncertainty. Interactions at every scale . . . between adversaries amplify microcauses and produce unexpected macroeffects.[29]

In general, most military theorists assume that given enough information, outcomes become predictable, and courses of actions can be generated to meet objectives.[30] Emergent behavior is an important characteristic of chaotic systems.[31] Interactions within the system can lead to emerging global properties that are strikingly different from the behaviors of the individual subsystems. These global properties are impossible to predict from prior knowledge of the components and then affect the entire environment that the components "see," thereby influencing their behavior. A synergistic feed-back loop forms such that the interactions between the subsystems determine the global properties, which in turn influence the subsystems themselves. Each subsystem exhibits its own emergent behavior, and in turn influences the global behavior of the entire system.

This spiral of behavior—global properties—can be best seen in the stock market. Interactions among the traders (buying and selling) can prompt global properties (rise and fall of the Dow-Jones Industrial Average). Sometimes no degree of analysis of individual trader actions can predict the Dow. Each trader then interprets the Dow trend and reacts in a given way (perhaps selling when the Dow goes up). The competition and rivalry among the traders result in an emergent behavior on the part of the system based on the individual perceptions of the global properties.[32] In this case, a market that appears to be selling off stock might result in emergent action on the part of the traders to start buying.

An emergent behavior pattern on the part of complex system implies that reductionist analysis has limits. As an analyst attempts to deconstruct the system into smaller parts, the analysis usually focuses on the properties of the pieces, rather than the dynamics of the system.[33] But by studying the parts instead of the system as a whole, global properties are lost. The blurring of emergent behavior occurs because the global properties are functions of the interaction among the subsystems and their effects. This is what occurred in AAFCE's study of Soviet fuel. The global property of the Soviet fuel system was lost because the planners had focused on the characteristics of the storage sites (subsystems) as individuals, not the interaction of the components of an entire system (within the conceptual framework of Soviet military doctrine). Checkmate applied a holistic approach to include the interaction of the subsystems and the global properties (the fuel system's impact on Soviet military doctrine). The result was a nodal analysis that did not treat the subsystems in isolation but focused on the global properties of the entire system.

This point is crucial in understanding chaos theory's contribution to armed conflict, since "war is . . . an act of force to compel our enemy to do our will."[34] The target and timing of attack should be designed to trigger a mechanism that precipitates a desired outcome. If the global properties of the enemy system are not considered, then the specific results will probably not occur. At worst, the connection between the desired outcome and the attack breaks; at best, the outcome is blurred because the system's complex behavior cannot be assessed against the input. The Rolling Thunder campaign in the Vietnam conflict illustrates this point.

Rolling Thunder was an air interdiction campaign designed to cut off the insurgent Vietcong in the South from North Vietnamese support. The primary targets were transportation, storage, and some North Vietnamese industrial plants.[35] American planners attacked second-wave targets in an attempt to influence first-wave warfare.[36] Contemporary analysis labels Rolling Thunder a failure. The planners concluded that without direct support from the North, the insurgent war in the South was doomed. One reason for Rolling Thunder's failure was that the planners misidentified infrastructure linkage between the North Vietnamese and the Vietcong in the South. The actual linkage was between the source of the Vietcong's power (the society of the South) and their cultural and ideological force, not North Vietnam. Rather than relying on an infrastructure, the Vietcong derived their power from word-of-mouth, socialization, ideology, politicization, and "family." North Vietnam could not be coerced by airpower during the southern insurgent phase because there was no infrastructure linking them to the Vietcong beyond people in communication.[37] Airpower never provoked an acute cost-benefit analysis. The insurgents were never coerced by airpower because there was no linkage between their emergent behavior and the system global properties.

Later, bombing in Linebacker I and II was more successful at coercing North Vietnam because the insurgent war had subsided in the South, and first-wave warfare had transitioned into second wave. Infrastructure linkage became more "conventionally based." Once the North Vietnamese became reliant on their infrastructure linkages of communication, transportation, technology, logistics, and command and control, airpower was better able to coerce.[38] A more pronounced infrastructure linkage existed between the North Vietnamese emergent behavior and its global properties.

Chaos theory suggests that some systems are unpredictable, so gathering more information to improve prediction is impossible and becomes counterproductive when it creates a false sense of security.[39] As we explore what information dominance means in the future, we must understand that perfect situational awareness is an illusion.[40] Enhanced technology might help pierce the fog of war; however, it will never eliminate it. Reductionist methods simply do not work for chaotic systems. Complexity emphasizes both structure and behavior, with neither being 100 percent predictable. Our understanding of information dominance says that comprehensive situational awareness will be required not only to locate the target and establish targeting parameters but also to gauge the effectiveness of the attack and its impact on the enemy. To wage information warfare to the fullest extent of our capabilities, military planners will have to develop a better understanding of how cultures are linked, and where those linkages are most vulnerable.

If the planners understand the structure and linkages, military actions become more than a continually moving and unfolding series of targets. Chaos theory states that since initial conditions and behavior are unpredictable, end states are also unpredictable. The form of the complex, adaptive systems may be ill defined; its processes, however, have structure.[41]

Figure 1 illustrates how chaos theory and system dynamics might be relevant to military planners. Since chaos theory can only approximate reality because initial conditions are never known and end states are unpredictable, the processes that link subsystems are more important than their form.

Figure 1 depicts a factor overlooked by early airpower theorists. War occurs between and within societies; therefore, to understand war, one must understand how societies are structured. Initial conditions are modified and reacted upon by all elements of a society over time and become end states. A society's structure is based on the processes that link its elements of power. Initial conditions

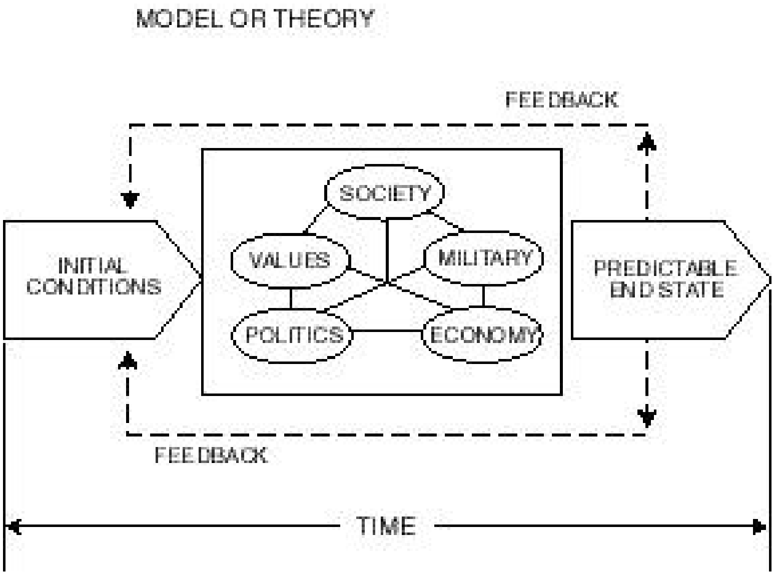

Figure 1. Chaos as a Military Strategy Model

become end states as a result of the interactions among the societal linking processes. These processes are illustrated in figure 1 as the lines that connect the various subsystems of the society. This weblike network forms an infrastructure that binds a society together. Any theory of airpower that overlooks or omits the societal and cultural elements underlying the value system of the adversary is inherently incomplete.

The Strategic Bombing Survey of the war in Europe during World War II noted that careful selection of targets for air attack should have emphasized the German experience. In particular, it concluded that "the Germans were far more concerned over attacks on one or more of their basic industries and services—their oil, chemical, or steel industries or their power or transportation network—than they were over attacks on their armament industry or the city areas. The most serious attacks were those which destroyed the industry or service which most indispensably served other industries."[42] This observation runs exactly counter to the Allied Combined Bomber Offensive, whose priority was German war production.[43] The Allies had made the same mistake as the AAFCE planners. They had failed to identify the infrastructure deemed indispensable by the adversarial culture. The Allies failed to determine the culturally relevant infrastructure because the information on the "German economy . . . at the outset of the war was inadequate."[44]

The Strategic Bombing Survey reinforces the logic of considering society and culture. Rather than describing the process, we would be left with only the form. This, then, becomes a description of specific targets: switching nodes, telephone exchanges, computer networks, bridges, choke points, and so forth. We would have a comprehensive target set; however, we would have little understanding of what any given target contributes to the process that links various systems. To impact society's decision making, we need to affect its process, not simply attack its form. A theory focused on process leads to target selections in specific and unique situations relevant to the interrelations of the subsystems of the adversary's systems. Key targets are based on linkages within the important elements of an adversary's power structure. The targets are less a finite description of specifics and more a description of system linkage. As such, a practical theory is culture bound, because culture determines the value placed on components of the adversary's system and determines the form and process.

Infrastructure: Warden's Third Strategic Ring

Rethinking Warden's third strategic ring provides a major element to form our practical guide to applying airpower in the future. Combining chaos and Jomini provides a framework to look at the transmission of goods, services, and information within a social context to identify potential COGs. By combining this idea with a revised way to view Warden, we develop a theory of airpower that is infrastructure centered, operational- and strategic-COG driven, and culturally determined.

While a student at National War College, Warden wrote an academic thesis, later published as "The Air Campaign." Warden's thesis focused on COGs and interdiction.[45] He advocated that airpower's inherent speed, range, and flexibility allowed it to extend beyond the bloody battle to strike a full spectrum of enemy capabilities in a swift and decisive manner.[46] Warden's thesis focused on the Clausewitzian idea of COG refined as "that point where the enemy is most vulnerable and the point where an attack will have the best chance of being decisive."[47]

Although Warden's thesis discussed the importance of COGs, it lacked a conceptual model to simplify the relationship between COGs and airpower. In 1988, he began work on an organizing scheme to explain his thesis and produced a model formed by five concentric rings depicted in figure 2 below.

Warden's five-ring model views the enemy as a hierarchical system composed of five subsystems: leadership, organic essentials, infrastructure, population, and fielded

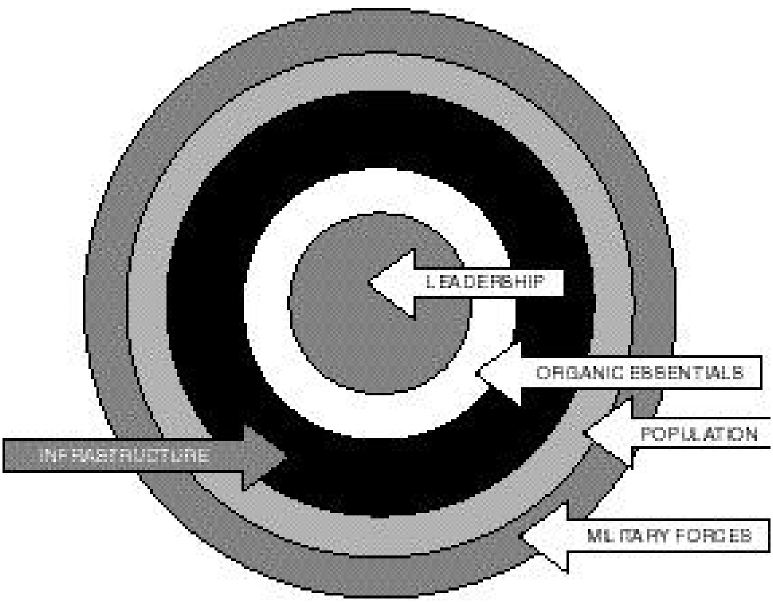

Figure 2. Warden's Five-Ring Model

military forces.[48] Figure 2 depicts the subsystems as five concentric rings with the innermost ring, leadership, being the most critical for the system to operate. Criticality decreases as one moves outward, with the least critical ring being fielded military forces. Within each ring is a collection of COGs for that particular ring. If the COGs are neutralized, the function of the ring (or subsystem) ceases. According to Warden, other rings are affected depending on whether the subsystem destroyed is an inner or outer ring. Herein lies one of the greatest weaknesses of Warden's model. Rather than a separate and independent ring, infrastructure permeates the entire system. Rather than an inner ring affecting the outcome of an outer ring, perhaps it is the infrastructure that binds the entire system and is the mechanism for the interdependence of all the rings.

Warden decomposed each ring into its own set of five rings with the same concentric structure (leadership, organic essentials, etc.) that describes the complete system. These subsystems can continue to be broken down (scaling) into fractals until true COGs emerge. Warden's five-ring model implicitly contains the linkages between the various components of an enemy system. Warden's central theme is that for the most effective use, airpower should focus on leadership. In the practical application of his theory, one is left asking the following questions: What is a leadership target? Can leadership be affected in ways other than direct attack? If infrastructure links the subsystems, might it be the most important target? Although Warden's theory is compelling in its focus on the mind of the leader, that may not always be the most important target.

Chaos theory helps us understand that Warden's rings are linked and interdependent rather than independent. Chaos helps explain how linkage of the various systems allows an attack on one subsystem to have tremendous effect on another, for example, how a concentrated attack on infrastructure might alter leadership behavior.

Reformulating Warden's Model

Warden's model explicitly neglects how infrastructure might be the mechanism by which coercion occurs. By portraying five subrings of the same structure within the major rings (fractals), Warden hints implicitly at this linkage. Within these subrings, linkage is probably made through the physical infrastructure comprising the subsystems.[49] They include command and control, transportation, support, communications, logistics, and so forth. Rather than a separate infrastructure ring, the other four rings of Warden's model become interconnected and interrelated through infrastructure. With so much of the debate over Warden's theory focused on the first ring (leadership) versus fifth ring (fielded forces) debate, infrastructure (third ring) as a complex system linkage is lost. Also lost is Warden's potential utility for third-wave warfare.

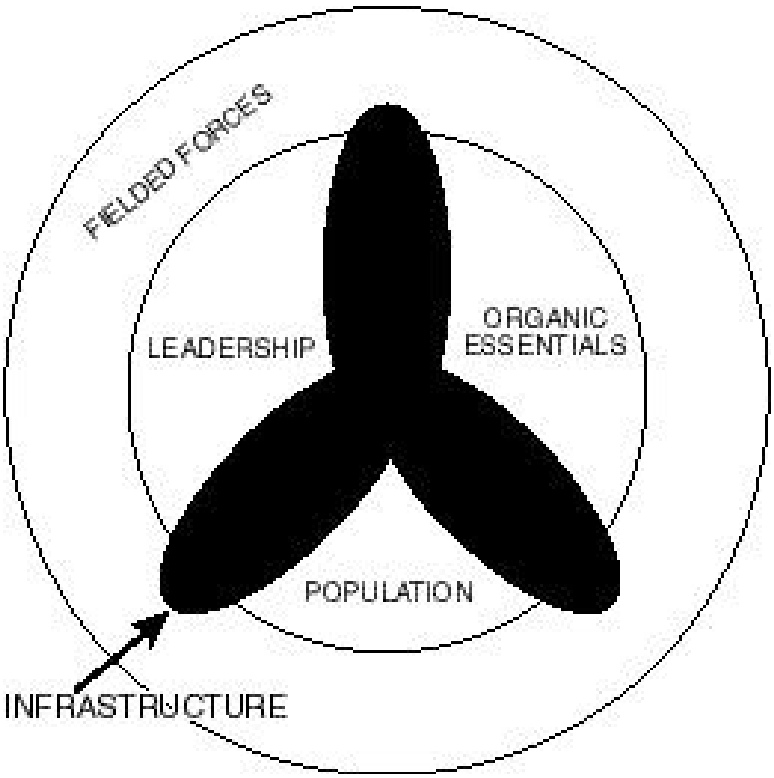

Figure 3. A New Model for Societal Structure

Figure 3 offers an alternative to Warden's model. A ring comprising three segments depicts the core of a society—population, organic essentials, and leadership. These three subsystems are interrelated and are much the same as Warden articulates them; however, they are not hierarchical. The new model depicts third-wave warfare, whereas Warden's model addresses second-wave warfare where decisions on targeting had to be hierarchical. Surrounding the core subsystems of the society are the fielded military forces that protect the others from outside influence. In the center of the figure is a black area that represents the society's infrastructure. It is depicted in such a way that it links every subsystem of the society.

The infrastructure depicted in figure 3 binds every subsystem of its society in an interrelated structure. Chaos theory is important to understanding the mechanics of the infrastructure. Attacking infrastructure in any specific subsystem of society can have effects on other subsystems; for example, attacking a fiber-optic network node can simultaneously impact banking, industrial production, and telecommunications (organic essentials); military command and control, intelligence dissemination, and logistics database integration (military forces); and National Command Authorities communications, strategic intelligence, and propaganda production (leadership). Already effective in second-wave warfare, attacking infrastructure in third-wave warfare may be the only alternative because (1) leadership is flattened and dispersed, (2) organic essentials are scaled down and dispersed, (3) population is beneath our scruples to attack directly, and (4) military forces are first-wave, out of fashion, and fight back.

Warden notes that "the essence of war is applying pressure against the enemy's innermost ring, its command structure."[50] A final element of his theory is that of parallel attack. After understanding the enemy as a system, the problem becomes one of reducing the enemy to the desired level or paralysis. Warden notes that the number of vital targets obtained by studying the enemy system is relatively small, and if struck in parallel (near simultaneously), damage to the enemy becomes insuperable. As one studies this idea in greater detail, one sees its application is directly related to the transmission of the society's goods, services, and information—its lines of communications. Warden pays too little attention to the notion that these systems are linked through their infrastructures. What better way to induce paralysis than attacking the nervous system, especially when the brain is elusive or inaccessible? If the mind of the commander ("first-ring" leadership) is important, then "third-ring" infrastructure may be the most doable way to influence the leaders. Loss of important infrastructure may become what matters most.

Synthesizing a Different Approach for Applying Airpower in the Information Age

> *Science today stands on something of a divide. For two centuries it has been exploring systems that are either intrinsically simple or that are capable of being analyzed into simple components. The fact that such a dogma as "vary the factors one at a time" could be accepted for a century, shows that scientists were largely concerned in investigating such systems as allowed this method; for this method is often fundamentally impossible in complex systems.*
>
> —Ross W. Ashby

Understanding the nature of cultural patterns can provide insight into the dynamics of the systems comprising the culture. Chaos theory can help us reduce the fog and friction, understand the uncertainties of warfare, and bound the range of future outcomes in employing military force. But research into chaos is relatively new, and its formulation into comprehensive algorithms has only begun. More important, application of chaos to the military planning process is even more recent—yet, history does provide a window to explore new ideas for the future.

Three Examples of Airpower, Chaos, and Infrastructure

We can explore three historical examples applicable to our study—two from World War II and one from the recent Gulf War.

World War II Campaign against German Transportation

In the 1930s, the Air Corps Tactical School (ACTS) developed a strategic bombing theory known as the "industrial web." Led by Harold George, Don Wilson, and a handful of other faculty, ACTS focused on a belief that economies were intricate and interconnected entities that rested on certain basic industries (transportation, steel, iron ore, and electrical power). Destroying one or more of the threads in this "web" would unravel the economic and social fabric of an adversary. The subsequent collapse of national morale and economic means of waging war would bring about the capitulation of the adversary.[51] On the surface, this is also the worldview expressed by Warden. Paradoxically, he and many other air planners treat the interconnections between the elements of a society, especially its economy, as secondary in importance to the things connected.

In practice, many airpower enthusiasts behaved exactly as Ashby describes. They dissected elements of a society into component parts and targeted each in isolation from the global properties of the system. During World War II, the industrial web idea influenced planners to search for bottlenecks. The Committee of Operations Analysts wrote a memo to Gen Henry H. "Hap" Arnold in March 1943 that reflects this observation best:

> In the determination of target priorities, there should be considered (a) the indispensability of the product to the enemy war economy; (b) the enemy position as to current production, capacity for production and stocks on hand; (c) the enemy requirements for the product for various degrees of activity; (d) the possibilities of substitution for the product; (e) the number, distribution and vulnerability of vital installations; (f) the recuperative possibilities of the industry; and (g) the time lag between the destruction of the installations and the desired effect upon the enemy's war effort.[52]

Once industries were identified, the planning tended to focus on destroying individual target sets rather than attacking key interconnected links in different sets. This trend is apparent when comparing Air War Plans Division-1 (AWPD/1), *Munitions Requirements of the Army Air Force*, and AWPD/42, *Requirements for Air Ascendancy*. The plans identified the German electrical power system, transportation, petroleum and synthetic oil, and morale for possible air attack.[53] US Army Air Corps planners in Europe believed destroying synthetic oil and selected military industry (airframe, aircraft engine, and ball bearings) would collapse Germany's ability to support the war. The targets identified within AWPD/1 and AWPD/42 came from a study of New York City. The ACTS industrial web theory mirror-imaged US strengths onto Germany. ACTS planners had not conducted a detailed study of German society.[54] Both plans provided great detail on target sets, but rarely was the effect of attacking one viewed in light of its impact on disrupting another. The net result was when one system failed to yield the desired results, priorities shifted to another target.[55] The targeting of the German rail transportation is a case in point.

Air Marshal Sir Arthur W. Tedder believed transportation was Germany's "Achilles' heel"; however, he only succeeded in having transportation listed as a secondary target for radar bombing when weather was bad. In the winter of 1945, weather was generally bad on the European continent, and German railroads were bombed extensively. Rail transportation turned out to be vital for both military and economic reasons, although the Allies did not realize it at the time.[56] The marshaling yard subsystem also contained critical command, control, and communications nodes.

The sustained bombing against the marshaling yards paralyzed Germany's rail system, and it was unable to deliver bulk coal from the mines. This degraded electrical power production and coke manufacturing for the iron and steel industry; aluminum, copper, and war materiel production virtually halted. When the trains stopped, German war industry could not ship supplies to the troops needing them most, especially on the eastern front. Lateral reinforcement was almost impossible because of the lack of rail transport. Civilian morale suffered because heating fuel was scarce and trains could not be sent to southeastern Europe for the grain harvests. All these were unintended consequences the air planners missed because they had focused only on the *form* of the German rail system rather than its process of linking population, fielded forces, and organic essentials.[57] Japanese shipping provides another compelling example for the same time period.

Aerial Mining Campaign of the Japanese Home Waters

The Army Air Forces' aerial minelaying operations in Japan's home waters (Operation Starvation) in 1945 allows us retroactively to explore the relationships among airpower, chaos, and infrastructure. Although not planned, the comparison of intended to unintended consequences in the operation is revealing.

In midsummer 1944, Adm Chester W. Nimitz's staff developed a plan to use B-29s to mine Japanese home waters.[58] The operation was named Operation Starvation because it intended to strangle what remained of the Japanese sea lines of communications in 1945.[59] The plan's architects believed that aerial mining would starve both Japan's industry and population, thereby fatally weakening Japan's will to continue the war. The plan contained three operational objectives: prevent raw materials and food from reaching Japan, prevent the supply and deployment of Japanese military forces, and disrupt maritime transportation within the Inland Sea.[60] Without the aid of a formal understanding of chaos theory, the planners had defined a complex system (Japanese population and industry) that was vulnerable to chaos by employing airpower (B-29 aerial mining) against infrastructure (Japanese maritime shipping) to achieve a strategic aim (weaken Japan's will to continue the war).

General Arnold, Army Air Forces chief of staff; Maj Gen Laurence S. Kuter, chief of plans, Air Staff); and Brig Gen Haywood S. Hansell Jr., chief of staff, Twentieth Air Force, were opposed to the plan. They saw the long-awaited demonstration of the independent capability of airpower within reach. Aerial mining represented yet another attempt to divert strategic airpower from its primary mission—strategic bombardment of industry and population.[61] Unlike the theater planners, the airpower advocates viewed aerial mining within the narrow paradigm of individual target form, rather than in the context of process within a complex system.

General Arnold compromised once Twentieth Air Force reached full strength and "weather precluded normal visual bombing operations . . . in the primary mission."[62] Even so, airpower advocates remained cautious about what aerial mining might contribute to achieving the strategic aims.[63] Brig Gen Lauris Norstad, the new Twentieth Air Force chief of staff, made it clear that "the commitment to mining was experimental [and] should not interfere with established bombardment policies."[64]

The Strategic Bombing Survey concluded that "mines, perhaps more than any other weapon of equal accomplishment, were orphans during the war."[65] To most airmen, a mine was only effective in sinking a ship (an independent tactical event). Bombing industrial and population centers were the most attractive uses of strategic airpower to the airpower advocates. They understood that by 1945 Japanese industry had dispersed as a result of strategic bombing (a third-wave effect from a second-wave course of action). In fact, this was the rationale used to justify incendiary bombing of the cities. What planners did not understand was this dispersal also made the Japanese critically dependent on traffic from their inland seaports. Bombing a dispersed manufacturing base became irrelevant if raw materials and energy were unavailable. Airmen were unable to discern the linkage, especially infrastructure, that determined this segment of Japanese culture.

On 27 March 1945, Operation Starvation began, and ended 14 August.[66] In all, 1,529 sorties were flown (only 5.7 percent of XXI Bomber Command's total sorties during this period) with 12,135 mines laid in 26 fields on 46 separate missions.[67] XXI Bomber Command lost 15 B-29s (a 1 percent loss rate) while sinking or damaging 670 ships totaling 1,252,256 tons (62.5 percent of shipping existing at that time).[68]

The outcome of the operation included operational and strategic effects never considered by the planners. The operation imposed a blockading effect that hampered Japanese army offenses in China during 1945.[69] The Strategic Bombing Survey noted that Operation Starvation was "among the most significant contributions of Army air in the strategic war against merchant shipping . . . (because it) reduced the remaining merchant shipping, virtually closed the vital Shimonoseki Strait and ports not accessible to Allied submarines, denied access to repair yards, and threw the administration of shipping into . . . hopeless confusion."[70]

Before the war, the Japanese had not invested in countermine capabilities. By war's end they had devoted more than 35 million yen, 20,000 men, and 349 ships to defend against the mining campaign. These statistics include neither the small suicide craft to detonate the mines nor the searchlights and antiaircraft artillery drawn away from the cities to cover the most important mining targets.[71] Moreover, the Naval Analysis Division of the bombing survey judged aircraft "to be generally superior to other means of laying mines."[72]

Perhaps the most telling analysis of Operation Starvation came from postwar interviews of Japanese officials. Japan's former prime minister, Prince Fumimaro Konoe, said that the aerial sinking of Japanese vessels and the B-29 harbor-mining operations were as equally effective as the direct B-29 attacks on industry.[73] Takashi Komatsu, director of a Tokyo steel company, reinforced the former prime minister's view by stressing that although bombing badly hurt factories, the denial of essential raw materials from the loss of shipping was a greater loss.[74] Capt Kyugo Tamura, a Japanese minesweeping officer stated, "The result of B-29 mining was so effective against the shipping that it eventually starved the country. I think you could have shortened the war by beginning earlier."[75]

Operation Starvation was a part of the concurrent submarine and air attack on Japanese merchant shipping. The bombing survey notes that of the 8.9 million tons of merchant shipping sunk or damaged, 54.7 percent was credited to submarines, 30.8 percent to direct air attack, 9.3 percent to mines (largely dropped by B-29s), and the rest to gunfire and accidents.[76] Though the mining contribution seems small, it represented a 4½-month B-29, compared to a 44½-month submarine, effort. S. W. Roskill, a British naval historian noted that

> the blockade had, in fact, been far more successful than we realized at the time. Though the submarines had been the first and main instrument for its enforcement, it was the air-land mines which finally strangled Japan.[77]

The Desert Storm Strategic Bombing Campaign (Instant Thunder)

The reductionist approach employed by the World War II planners has evolved, if not been wholly transformed, today. In articulating Instant Thunder, the strategic bombing phase of the Gulf War, planners postulated a series of outcomes that appear to have corrected the oversights of earlier World War II planners. Instant Thunder planning contains discrete projections about how various subsystems of the Iraqi society might be linked. Infrastructure targets were identified and the bounds of emergent behavior were estimated based on successfully striking these targets from the air. The Instant Thunder plan stated that

> the destruction of a few key elements of the Iraqi electric distribution will plunge much of Baghdad into darkness; elimination of half-a-dozen key POL facilities will have immediate effects on the military and civilian sectors; interdiction of several key transportation nodes will impede reinforcement and stop operations of Iraqi forces in Kuwait and along the Iranian border; negating the telecommunications system and Saddam Hussein's internal control forces will isolate him from the populace . . . the psychological impact on the Iraqi populace of being open to remitting air attack will be a powerful reminder of the bankruptcy and impotence of the Saddam Hussein regime . . . when taken in toto, the result of Operation INSTANT THUNDER will be the progressive and systemic collapse of Saddam Hussein's entire war machine and despotic regime.[78]

But although the Instant Thunder planners speculated on outcome, they forecasted in a relative vacuum. Like the World War II planners, the Instant Thunder planners did not perform detailed systems analyses detailing the nature and structure of Iraq's culture. In devising Instant Thunder, Checkmate planners tried to identify targets that would cut across all the rings of Warden's model to inflict strategic paralysis on the system. The targets they identified possessed form but had no bearing on the processes that bound the society together. As chaos theory suggests, outcomes could not be predicted because the initial conditions and the functioning of the linking processes were unknown. What resulted was a set of independent targets focused on Iraq's internal control network, nuclear-biological-chemical capability, telecommunications, industrial and transportation systems, and critical military systems. As in prior conflicts, airmen recognized complex interconnections among the elements of a society, but they could not exploit them because the planners did not recognize their interrelationships. The net result of the Instant Thunder plan was that targeting and timing were correct because the identified targets were struck and extensively damaged, but the anticipated end state did not occur because the linkage of targets and aims was missing or at best misguided.

From the Past, the Future

Having developed the theoretical underpinning (the Toffler societal structure, Jomini's lines of communications, chaos theory's ideas about complexity, and Warden's infrastructure), all that remains is to assemble them in a reasoned fashion. In the final analysis, airpower theorizing bows to the throne of targeting because you cannot bomb with an idea or a theoretical construct. Airpower targeting for the future also stands at the same divide that Ashby noted. We have reached the point where we can begin disassembling the old reductionist targeting process. Rather than separating different elements of a society and their concomitant targets in isolation, we need to approach the practical application of airpower from a synergistic or holistic viewpoint. An adversary's society is generally a complex structure, and we need to target it as such.

One might assume that conflict in the future might be conducted at the strategic level and take advantage of American technological capabilities that become increasingly pronounced to provide commensurately greater leverage. If we stay only at the tactical level of attacking military forces, we will make only marginal improvements in our ability to conduct second-wave warfare. If we strive to impact the adversary's infrastructure in a way that has the greatest strategic and operational effect, we might attain our objectives without the need to engage in widespread and possibly prolonged destructive warfare.

By focusing at the strategic and operational level, we are immediately forced to answer several basic questions: What national security objectives (political, economic, social, and military) are we trying to accomplish? What military objectives will support attaining these objectives? What do we know about the adversary, and how does the adversary structure his society? Where are the most decisive points to leverage disruption of the adversary's societal structure (its infrastructure)?

Using Warden's model, fielded forces would be the most logical object of second-wave warfare, for in the age of mass warfare, one could not "get at" any of the other rings (especially leadership) without first breaking down the nation's military line of defense. World War II in Europe illustrates the point. Eighth Air Force was assigned the task in Operation Pointblank (the Combined Bomber Offensive of 1944) to achieve air superiority over Europe as an intermediate objective of the highest priority.[79] This was necessary before either the invasion of Europe or the full weight of the strategic bombing campaign could take effect.

If the Tofflers and Warden are correct, third-wave, parallel, and hyperwarfare enables us to bypass, penetrate, and otherwise overcome all or most of the fielded forces to strike directly at other subsystems. We have seen how infrastructure, and especially those linkages that define the communication of goods, services, and information, might have the greatest operational and strategic effect. As we enter the information age, much of this infrastructure will be information based. Comprehensive situational awareness must be used to complement the twin capabilities of exact intelligence gathered in real time and precision weapons delivered from stealthy platforms. Some targets will be vulnerable to soft-kill mechanisms, such as computer virus attacks to disable a national telephone switching system, intrusive electronic warfare to wipe out an adversary's logistics inventory database, or an electromagnetic pulse to disrupt electronic systems. Regardless of the method we employ in our attacks, infrastructure linkages in an adversary's society provide the best target set to achieve operational and strategic objectives. Targeting for airpower in the future should consider the following:

Political Infrastructure

- National governmental apparatus and centers—headquarters or administrative offices; National Command

Authorities (individuals or groups); command/control/communications nodes (hard or soft) that support national leadership; command posts (mobile/fixed, air/land/sea); and ministry-level offices.

- Internal state police and control forces—headquarters for internal control agencies ("secret police"); intelligence collection systems (i.e., SIGINT [signals intelligence] intercept); databases supporting internal control systems.
- Propaganda systems (domestic and international)—propaganda production facilities; public affairs-type offices and organizations; linkages to public diplomacy; religious and cultural centers and networks; linkages into area/international telecommunications networks.

Information Infrastructure

- Telecommunications (radio and TV); public and secure switching networks; radio relay facilities; telephone exchanges; fiber-optic networks, nodes, and repeater stations; microwave transmission networks and nodes; satellite communications nodes; computer and data processing centers; national C^3I centers.

Economic Infrastructure

- Energy and power production (electrical and POL)—transformer stations; distribution nodes; control centers for POL production; pump and compressor stations; electrical control facilities; cooling systems; power transformers and substations; fuel dispensing manifolds; pipelines; distribution terminals; liquid natural gas plants and storage; backup systems; fuel storage for backup systems; transportation system to resupply fuel; dispatch centers.
- Transportation—traffic control at choke points; bridges, rail yards, critical interchanges; air traffic control centers; airports; ports, ocean terminals, oil tankers, and offshore unloading sites; inland waterways, barges, and off-loading sites; motor trafficking facilities; rail fuel storage facilities; computer and electronic supporting infrastructure for the transpor-

tation systems; intermodal ties; repair facilities; traffic signal controls; canal locks.

- Financial centers and networks—institutions (banks, trading centers, etc.); currency controls and depositories; databases for financial management.

Industrial Production Infrastructure

- Inventory management systems; computer-assisted design facilities; computer-controlled production; robotic assembly systems; automated product distribution systems; production support systems and infrastructure; raw material request and distribution systems.

Population Stability Infrastructure

- Control points for food and water distribution systems; cultural icons to include statues, memorials, and monuments.

Military Infrastructure

- Warning systems and sensors; defense command and control centers; satellite communications (SATCOM) links to space-based systems; control centers and command posts (fixed, mobile, air, land, sea); weapons of mass destruction (research and development [R&D], storage, nodes controlling release and employment); intelligence collection, processing, and dissemination; logistics management and databases; force deployment and employment control infrastructure; electronic communications and data processing.

The target nodes above were selected based on their potential synergies with the infrastructure of culture. They parallel what might be seen in second- and third-wave cultures. They do not reflect, however, a universal applicability across every society. Each adversary must be examined within its own cultural context to discern relevant infrastructure. The list does not take into account design variances; for example, not every pipeline is identical. Synergistic system impact is the most critical factor in considering any of the listed nodes; for example, a pipeline distribution node might affect transportation (railroad engine fuel), power production (generator fuel), military (vehicle fuel), population stability (gasoline distribution), and information (telecommunications backup generator fuel) simultaneously. This example illustrates target values in terms of system processes, not in isolated value of the form in a petroleum subsystem. As a society becomes more third wave in structure, the preceding list becomes more relevant to the operational and strategic employment of airpower.

Summary

All societies rely on the movement of goods, services, and information. How this movement occurs in modern societies is a cultural variable. An infrastructure, based on these lines of communications, binds the elements of a society together. This infrastructure forms a complex system that responds to self-regulation against disruption within the construct of chaos theory. Airpower is an effective and decisive military instrument of influence in a societal system. By understanding a culture and its systemic linkages, we can employ airpower to achieve direct operational and strategic aims. Understanding a society's infrastructure, lines of communications, and propensity for chaos form a basis for a general theory of airpower.

Conclusion

> *Most air and space forces can perform multiple functions to achieve various strategic, operational, or tactical effects; some perform them in unique ways. It is this inherent versatility when combined with the speed, flexibility and global nature of our reach and perspective that generates the unique Air Force contribution to joint force capability. These battle-proven functions can be conducted at any level of war and enable the Air Force to shape and control the battlespace.*
>
> —AFDD 1, *Air Force Basic Doctrine*

Almost all airpower theory focuses on COGs in one form or another. As airmen move from theory to practice, isolated and single-focused applications of airpower usually emerged in the target sets. These target sets usually focused on form, not societal process. The problem with this approach was that the target set represented the perceived values of the theorist, not the adversary. The future battle space will take on new dimensions in mobility, lethality, and scope, but one constant will remain—the strategic aim will continue to serve as the guide for planning.[80] Although speed of the modern battle will surely blur the distinction between sequential and parallel operations, the linkage between strategic aims and enemy COGs should focus our efforts.

This paper offers an application of airpower based on understanding the adversary's lines of communications as potentially the most vulnerable links in the structure of its society. Airpower's flexibility and versatility put these lines of communications at risk.

Airpower is an excellent coercion tool. Some might argue it is the preferred choice.[81] To make the strategy work, one must understand the adversary, not just search for independent targets. If we are ever to achieve information dominance in tomorrow's battle space, we need to do far more than locate and strike targets in isolation. We must also process knowledge and comprehension of the critical nodes in the enemy's national infrastructure, how its political and other vital systems function, whether these systems possess exploitable vulnerabilities, and how the adversary's informational and other systems work.

The recently completed report of the National Defense Panel notes that future military power projection should focus on disabling an enemy's strategic COGs. It states that to do this we must "rapidly target and access whatever an adversary values most, the loss of which would render him either unable or unwilling to continue his hostilities."[82] The report notes that this has always been an objective of war, though difficult to achieve because of uncertainty and friction. This paper has offered one view on how airpower might best serve the National Defense Panel's view of the future.

Notes

1. Colonel Warden uses this study as the introduction to presentations he gives at Air War College Senior Leadership seminars to show Air

Force thought had a dramatic change during the mid-1980s. He cites this study as an example of the break in the old "target servicing" paradigm.

2. Robert A. Pape, *Bombing to Win: Air Power and Coercion in War* (Ithaca, N.Y.: Cornell University Press, 1996).

3. Alvin and Heidi Toffler, *War and Antiwar: Survival at the Dawn of the Twenty-First Century* (Boston: Little, Brown, and Co., 1993), 3.

4. *Leitmotif* comes from a style that Wagnerian opera uses to repeat a marked melodic phrase or figure; in its current vernacular it means a dominant recurring theme.

5. Toffler, 3–25 and 246.

6. Ibid., 38–43.

7. John Keegan, *The Second World War* (New York: Penguin Books, 1989), 12.

8. Toffler, 57–63.

9. Ibid., 63.

10. Grant T. Hammond, "The Essential Boyd," paper, Maxwell AFB, Ala.: Air War College, 1997, 5–9.

11. Joint Publication 3-0, *Doctrine for Joint Operations* (Washington, D.C.: Joint Chiefs of Staff, 1 February 1995), III–17.

12. John Shy, "Jomini" in Peter Paret, ed., *Makers of Modern Strategy: from Machiavelli to the Nuclear Age* (Princeton, N.J.: Princeton University Press, 1986), 146, 154, 159.

13. Ibid., 166.

14. Air Force Doctrine Document 1 (AFDD 1), *Air Force Basic Doctrine*, September 1997, says it is a decisive advantage. "The ability of airpower to engage at any place in minimum time, from either centralized or widely dispersed locations, and to shape the conflict, describes an important aspect of dominant maneuver. Air and space forces are inherently maneuver forces, with unmatched organic lethal and nonlethal 'firepower,' " 37. *JV 2010* states that "dominant maneuver will be the multidimensional application of information, engagement, and mobility capabilities, to position and employ widely dispersed . . . forces to accomplish the assigned operational tasks." See Joint Chiefs of Staff, *Joint Vision 2010* (Washington, D.C.: Government Printing Office [GPO], July 1996), 20.

15. Shy, 167.

16. Ibid., 168.

17. *Webster's New World Dictionary*, 2d ed. (New York: Simon and Schuster, 1982), 125.

18. It is beyond the scope of this paper to explain the mathematical theorems contained in chaos theory. In fact, it is beyond the scope of the author's understanding. Chaos theory can be understood in terms of its practical manifestations without understanding its exceptionally complex mathematical underpinnings.

19. Laurie Fitzgerald, "What is Chaos?" Available from http://www.orgmind.com/chaos.html.

20. Steven R. Mann, "Chaos Theory and Strategic Thought," *Parameters* 22, no. 3 (Autumn 1992): 54–68.

21. A *chaotic* (or *chaordic*) *system* is defined as a complex and dynamical arrangement of connections between elements forming a unified whole the behavior of which is both simultaneously unpredictable (chaotic) and

patterned (orderly). Chaos is the science of such chaotic and orderly, that is chaordic entities found in abundance throughout the universe. See Fitzgerald, 1.

22. Uri Merry, "Nonlinear Organizational Dynamics," n.p.; on-line, Internet, n.d., available from http://pw2.netcom.com/~nmerry/art2.htm.

23. Edward Ott, *Chaos in Dynamical Systems* (Cambridge, England: Cambridge University Press, 1993), 31–44 and 57–59.

24. Ibid.

25. James Gleick, *Chaos: Making a New Science* (New York: Penguin Books, 1988), 104.

26. The "Butterfly Effect" is a good example of the paradox of chaos theory. In reality, it seems to be an ambiguity that this effect might occur. The math of the theory shows it *might* be possible for the butterfly to have this effect; however, the null set does not yield a result that says the butterfly *could not possibly* have the effect.

27. Joseph O'Connor, "Thinking Past the Obvious: What is a System?" Available from
http://www.radix.net/~crbnblu/assoc/oconnor/chapt1.htm.

28. Stuart A. Kauffman, *The Origins of Order: Self-Organization and Selection in Evolution* (New York: Oxford University Press, 1993), 191.

29. Alan Beyerchen, "Clausewitz, Nonlinearity, and the Unpredictability of War," *International Security* 17, no. 3 (Winter 1992–1993): 80.

30. Clausewitz shows this to be the essence of why military leaders need theory, "Theory will have fulfilled its main task when it is used to analyze the constituent elements of war, to distinguish precisely what at first sight seems fused, to explain in full the properties of the means employed and to show their probable effects, to define clearly the nature of the ends in view, and to illuminate all phases of warfare in a thorough critical inquiry." Carl von Clausewitz, *On War*, ed. and trans. Michael Howard and Peter Paret (Princeton, N.J.: Princeton University Press, 1984), 141.

31. Roger Lewin, "The Right Connections," *New Scientist* 137, no. 1859 (February 1993): 12–13.

32. M. Mitchell Waldrop, *Complexity: The Emerging Science at the Edge of Order and Chaos* (New York: Simon and Schuster, 1992), 88.

33. Gregoire Nocolis and Ilya Prigogine, *Exploring Complexity: An Introduction* (New York: W. H. Freeman and Co., 1989), 13.

34. Clausewitz, 75.

35. Mark Clodfelter, *The Limits of Airpower: The American Bombing of North Vietnam* (New York: Free Press, 1989), 102–7.

36. Ibid., 144.

37. Ibid., 205.

38. Ibid.

39. T. J. Cartwright, "Planning and Chaos Theory," *Journal of American Planning Association* 57, no. 1 (Winter 1991): 44–56.

40. Kenneth Allard, *Command, Control, and the Common Defense,* rev. ed. (Washington, D.C.: National Defense University Press, 1990), 297–99.

41. Cartwright, 53.

42. *US Strategic Bombing Surveys (European War) (Pacific War)* (Maxwell AFB, Ala.: Air University Press, 1987), 39.

43. Richard G. Davis, *Carl A. Spaatz and the Air War in Europe* (Washington, D.C.: Office of Air Force History, 1993), 345–52.

44. *Strategic Bombing Surveys*, 39.

45. Clausewitz defines center of gravity as "the hub of all power and movement on which everything depends. That is the point against which all our energies should be directed." See Clausewitz, 597–98.

46. John A. Warden III, *The Air Campaign: Planning for Combat* (Washington, D.C.: National Defense University Press, 1988), 9, 51–58, 94–95.

47. Ibid., 9.

48. John A. Warden III, "The Enemy as a System," *Airpower Journal* 9, no. 1 (Spring 1995): 41–55.

49. Ibid., 45–46.

50. Ibid., 49.

51. Robert T. Finney, *History of the Air Corps Tactical School, 1920–1940* (Washington, D.C.: Center for Air Force History, 1992), 67–68.

52. Guido Perera, *History of the Organization and Operations of the Committee of Operations Analysts, 16 November 1942–October 1944* (Maxwell AFB, Ala.: USAF Historical Research Agency), vol. 2, tab 22, file 118.01.

53. Air War Plans Division-1 (AWPD/1), *Munitions Requirements of the Army Air Force*, 9 July 1941, tab no. 1, 1–6.

54. Air Corps Tactical School, *National Economic Structure* (Maxwell Field, Ala., 5 April 1938), 1–12; and *New York Industrial Area* (6 April 1939), 16–21.

55. Haywood S. Hansell Jr., *The Air Plan That Defeated Hitler* (Atlanta: Higgins-McArthur/Longino & Porter, Inc., 1972), 163–65.

56. Alfred C. Mierzejewski, *The Collapse of the German Economy (1944–1945): Allied Air Power and the German National Railway* (Chapel Hill, N.C.: University of North Carolina Press, 1963), 168–76.

57. *Strategic Bombing Surveys*, 37.

58. Wesley Frank Craven and James Lea Cate, *The Army Air Forces in World War II*, vol. 5, *The Pacific: Matterhorn to Nagasaki, June 1944–August 1945* (Chicago: University of Chicago Press, 1953), 662.

59. The earlier submarine campaign had reduced Japanese maritime shipping capability from 6,823,000 tons at the start of the war to 2,000,000 at the start of Operation Starvation. See ibid.

60. Headquarters Twentieth Air Force, A-3, "Starvation: Phase Analysis of Strategic Mining Blockade of the Japanese Empire," 1945, 3. Found in USAF Historical Research Agency, file no. 760.491-1.

61. Haywood S. Hansell Jr., *Strategic Air War against Japan* (Washington, D.C.: GPO, 1980), 42.

62. Henry H. Arnold, *Global Mission* (New York: Harper, 1949), 541.

63. In his memoir, General Arnold wrote how essential it was to mass the maximum number of bombers possible to destroy Japan's war-making capability. He described Admiral Nimitz's desire for B-29s (to aerial mine) as a purely "tactical purpose." See ibid., 550.

64. Craven and Cate, 666.

65. *US Strategic Bombing Survey (Pacific War), Naval Analysis Division, The Offensive Minelaying Campaign Against Japan* (Washington, D.C.: GPO, 1 November 1946), 25.

66. Frederick M. Salagar, *Lessons from an Aerial Mining Campaign (Operation Starvation),* RAND Report R-1322-PR (Santa Monica, Calif.: RAND, April 1974), 30.

67. *The Offensive Minelaying Campaign*, 1.

68. Ellis A. Johnson and David A. Katcher, *Mines against Japan* (Silver Spring, Md.: US Naval Ordnance Laboratory, 1973), 30.

69. *The Offensive Minelaying Campaign*, 9–14.

70. *US Strategic Bombing Survey (Pacific War), Transportation Division, The War against Japanese Transportation, 1941–1945* (Washington, D.C.: GPO, 1947), 8.

71. *The Offensive Minelaying Campaign*, 27.

72. Robert C. Duncan, *America's Use of Sea Mines* (Silver Spring, Md.: US Naval Ordnance Laboratory, 1962), 157.

73. Headquarters Army Air Forces, A-2, *Strategic Effectiveness of Aerial Mine Warfare*, Air Intelligence Division Study no. 131 (Washington, D.C.: Air Intelligence Division, 27 September 1946), 5.

74. Ibid., 7.

75. *US Strategic Bombing Survey (Pacific War), Naval Analysis Division, The Interrogation of Japanese Officials* (Washington, D.C.: GPO, 1946), vol. 1, Interrogation Nav. No. 26, 22 October 1945, 117.

76. *US Strategic Bombing Survey, Summary Report (Pacific War)* (Washington, D.C.: GPO, 1 July 1946), 11.

77. S. W. Roskill, *The War at Sea, 1939–1945,* vol. 4, pt. 2, *History of the Second World War* (London: Her Majesty's Stationery Office, 1961), 371.

78. It is still unclear what the strategic impact was of the strategic bombing phase of Desert Storm *actually* achieved. The degradation of the Iraqi military forces at the operational level is well documented. The strategic aims as quoted clearly did not occur. See Department of the Air Force, Checkmate, *Proposed Iraq Air Campaign Outline Plan: INSTANT THUNDER* (Maxwell AFB, Ala.: USAF Historical Research Agency, 16 August 1991), file CHSH 1-2, 1-3.

79. Davis, 287–90.

80. *JV 2010*, 13–19.

81. Ben Lambeth of RAND Corporation says "airpower, with its newly acquired capabilities over the past decade for precision standoff attack, now commands a strong presumption of being the tool of choice for shaping the contours of war as the supported rather than the supporting combat element." See Benjamin S. Lambeth, "Bounding the Air Power Debate," *Strategic Review* 25, no. 4 (Fall 1997): 54.

82. National Defense Panel, *Transforming Defense: National Security in the 21st Century*, final report (Arlington, Va.: National Defense Panel, December 1997), 35.