



estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE <i>April 1993</i>	3. REPORT TYPE AND DATES COVERED <i>FINAL</i>	
4. TITLE AND SUBTITLE <i>CENTER OF GRAVITY ANALYSIS AND CHAOS THEORY</i>			5. FUNDING NUMBERS
6. AUTHOR(S) <i>PAT A. PENTLAND LTCOL, USAF</i>			8. PERFORMING ORGANIZATION REPORT NUMBER <i>Unnumbered AWC research paper</i>
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) <i>AIR WAR COLLEGE 325 CHENNAULT CIRCLE MAXWELL AFB AL 36112-6427</i>			10. SPONSORING / MONITORING AGENCY REPORT NUMBER <i>N/A</i>
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) <i>N/A</i>		11. SUPPLEMENTARY NOTES <i>PAPER IS WRITTEN TO FULFILL ACADEMIC RESEARCH REQUIREMENTS FOR AN IN-RESIDENCE SENIOR SERVICE PROFESSIONAL MILITARY SCHOOL.</i>	
12a. DISTRIBUTION / AVAILABILITY STATEMENT <i>APPROVED FOR PUBLIC RELEASE; DISTRIBUTION IS UNLIMITED</i>		12b. DISTRIBUTION CODE	
13. ABSTRACT (Maximum 200 words) <i>See page iii</i>			
14. SUBJECT TERMS <i>Center, Gravity, Analysis, Chaos, Theory</i>			15. NUMBER OF PAGES <i>45</i>
			16. PRICE CODE
17. SECURITY CLASSIFICATION OF REPORT <i>UNCLAS</i>	18. SECURITY CLASSIFICATION OF THIS PAGE <i>UNCLAS</i>	19. SECURITY CLASSIFICATION OF ABSTRACT <i>UNCLAS</i>	20. LIMITATION OF ABSTRACT <i>UL</i>

DTIC
SELECTE
S G D
AUG 11 1994

AIR WAR COLLEGE

AIR UNIVERSITY

CENTER OF GRAVITY ANALYSIS AND CHAOS THEORY

by

Pat A. Pentland
Lt Col, USAF

A RESEARCH REPORT SUBMITTED TO THE FACULTY

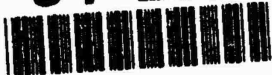
IN

FULFILLMENT OF THE CURRICULUM

REQUIREMENT

Advisor: Colonel Phillip Maffinger

94-25237



SPY

MAXWELL AIR FORCE BASE

April 1993

94 8 10 03 4

DISCLAIMER

This study represents the views of the author and does not necessarily reflect the official opinion of the Air War College or the Department of the Air Force. In accordance with Air Force Regulation 110-8, it is not copyrighted, but is the property of the United States government.

Loan copies of this document may be obtained through the interlibrary loan desk of Air University Library, Maxwell Air Force Base, Alabama 36112-5564 (telephone [205] 953-7223 or DSN 493-7223).

Accession For	
NTIS CRA&I	<input checked="" type="checkbox"/>
DTIC TAB	<input type="checkbox"/>
Unannounced	<input type="checkbox"/>
Justification	
By	
Distribution /	
Availability Codes	
Dist	Avail and/or Special
A-1	

ABSTRACT

TITLE: Center of Gravity Analysis and Chaos Theory

AUTHOR: Pat A. Pentland, Lieutenant Colonel, USAF

Nearly all military authors and theorist at one time or another refer to the Center of Gravity (COG) concept. Clausewitz was the first to refer to COGs and placed them within a military context that lay within a social-political construct. Subsequent authors have not explored COGs to any depth and have failed to provide a wider framework with which to analyze their methodologies. This paper explores COG analysis from the context of the new science of "Chaos Theory." It demonstrates that social, cultural, economic, political, and military systems are open, and non-linear in nature. It postulates a social construct based on Chaos Theory, and explores the interactions of the elements of power. Lastly, it shows methods to identify and disrupt COGs based upon the dynamics of Chaos Theory.

BIOGRAPHICAL SKETCH

Lieutenant Colonel Pat Allen Pentland (M.A. History, Gonzaga University, Ph.D. History, University of Idaho) was commissioned via AF ROTC in 1975. Following pilot training, Lt Col Pentland has flown the A-10 his entire career with over 2,400 hours. He attended the USAF Fighter Weapons School, and won the Outstanding Graduate trophy. He was later assigned as an instructor at the Fighter Weapons School, where he taught A-10 tactics and wrote numerous text books and articles. Lt Col Pentland served on the Air Staff working fighter force structure and fighter planning issues. He has spent two tours in USAFE, his last as commander of the 510th Tactical Fighter Squadron. He served in Operation Desert Storm and Operation Provide Comfort. Lt Col Pentland has attended Squadron Officer School and Armed Forces Staff College. He is a graduate of the Air War College class of 1993.

TABLE OF CONTENTS

	DISCLAIMER	ii
	ABSTRACT	iii
	BIOGRAPHICAL SKETCH	iv
Chapter		Page
I.	INTRODUCTION	1
	Strategy and Centers of Gravity	1
	Airpower and Centers of Gravity	2
	The Paradigm Problem	4
	Clausewitz Revisited	7
II.	CHAOS THEORY	10
	Chaos Explained	10
	Chaos and Deep Social Structure	13
III.	A STRUCTURE BASED ON CHAOS	16
	Basis of Organization	16
	Elements of Power	17
	Sources of Power	18
	Manifestations of Power (Force)	21
	Linkages of Power	24
	A Recap	25
	Center of Gravity Implications	26
IV.	CENTERS OF GRAVITY AND CHAOS DYNAMICS	28
	Linkages, Connectivity, and Bias	28
	Uncertainty Principle	29
	Entropy and the Second Law of Thermodynamics	30
	Scaling Structures within Elements of Power	31
	Interdependence and Self-Compensation	34
V.	CONCLUSION	38
	BIBLIOGRAPHY	40

CHAPTER I

INTRODUCTION

Strategy and Centers of Gravity

The fundamental task any military organization faces is the problem of transforming limited forces and potentially unlimited options into strategies to achieve specific political objectives. Whether peacetime planner or wartime operator, the essential burden remains—develop a strategy and select an option that balances resources, restraints, constraints, and objectives. Strategies are constructed upon larger theoretical frameworks which often include military doctrine and the principles of war as well as various social, political, and economic formulations or models. Campaign planning and campaign targeting is the ultimate crucible where these theories must pass the test of wartime reality. However, the decisions that implement strategy are complex and difficult especially in the context of fighting an air campaign.¹ A useful concept often employed to simplify and guide the airpower targeting process is the notion of attacking "centers of gravity" (COG). The COG concept is fundamental to the principles of war and is critical to the combat planning and employment of airpower. COGs, however, are widely talked about and only superficially understood. They easily become "black holes" sucking in resources and emitting nothing but a false target of glowing energy.

In the classic sense, centers of gravity were initially conceptualized and presented by Carl von Clausewitz in his monumental work *On War*. The most commonly quoted definition from Clausewitz is:

¹ Doctrinal arguments about independent air campaigns are essentially irrelevant. We have yet to adequately define air warfare, air operations, or air campaigns. I believe all "air campaigns" are "joint air campaigns." All "land campaigns" and "naval campaigns" are joint as well. I use "airpower" in the generic sense. If it flies, it's airpower regardless of its parent service.

A center of gravity is always found where the mass is concentrated most densely. It presents the most effective target for a blow; furthermore, the heaviest blow is that struck by the center of gravity. The same holds true in war.²

Clausewitz later identified the 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."³ United States military doctrine, to include Air Force, incorporates the COG concept and defines it as: "That characteristic, capability, or locality from which a military force, nation, or alliance derives its freedom of action, physical strength, or will to fight."⁴ Past air strategists have commonly employed notions that did not quote Clausewitz verbatim, but used arguments closely mimicking his logic. They believed that destroying certain target sets provided a disproportionate leverage or effect that could alter an enemy's capability to continue the war—in fact producing a war winning leverage.⁵

Airpower and Centers of Gravity

After World War I, both Giulio Douhet and William Mitchell developed and popularized theories of strategic airpower designed to attack "vital centers."⁶ This influenced the Air Corps Tactical School during the 1930s that developed its concept of collapsing the "industrial web" by attacking "vital" systems such as electricity,

² Carl von Clausewitz, *On War*, ed. and trans. by Michael Howard and Peter Paret, (Princeton: Princeton University Press, 1989), p. 485.

³ *Ibid.*, p. 596.

⁴ Joint Pub 1, *Joint Warfare of the US Armed Forces*, 11 Nov 1991, p. 34. AFM 1-1, *Basic Aerospace Doctrine of the United States Air Force*, Vol I, Department of the Air Force, Mar 1992, p. 9. FM 100-5, *Operations*, Department of the Army, May 1986, pp. 179-180. The Marine Corps conceals COGs as "critical vulnerabilities." FMFM 1, *Warfighting*, HQ US Marine Corps, 6 Mar 1989, pp. 35-37.

⁵ An excellent synopsis of the history of strategic air power thought (and an original theory on a "national elements of value" model of air power) is presented by Major Jason B. Barlow, "Strategic Paralysis: An Airpower Theory for the Present," unpublished Thesis, School of Advanced Airpower Studies, Air University, May 1992.

⁶ Giulio Douhet, *The Command of the Air*, trans. Dino Ferrari, (Wash D.C.: Office of Air Force History, 1983), p. 57. William Mitchell, *Winged Defense: The Development and Possibilities of Modern Air Power — Economic and Military*, reprint edition (New York: Dover Publications, 1988), pp. xvi, 126-127.

transportation, and oil to create "self-reinforcing shortages."⁷ British experience and capabilities during the opening phase of World War II caused them to view the industrial web targets derisively as "panaceas." Instead the RAF stressed "common denominator targets" which in actuality led to a night, city-busting, counter value campaign.⁸ US entry into the war was based on the principle of daylight precision bombing and the industrial web theory which was incorporated in the Air War Plans Division's first plan (AWPD-1).⁹ Modified later into AWPD-42, this new approach essentially concentrated on military industrial "choke points" and "bottle necks" to collapse the production of key weapon systems.¹⁰ Priority switched again in 1944, as the great "oil" versus "transportation" debate was settled by targeting both. Post WW II nuclear deterrence was centered on destroying a selective series of "vital targets." While the technology and targeting emphasis varied over time, the fundamental concept was to attack economic and/or military centers of gravity with nuclear weapons.¹¹ In Korea and again in Vietnam, US airpower was directed (or not directed, as some would argue) against a number of target systems that US planners considered strategically or operationally "vital." Recent conventional air theorists, like Colonel John Warden III, have paid close attention to centers of gravity. His published book *The Air Campaign*, and his unpublished briefings and articles contain numerous references to COGs with primary emphasis on enemy leadership and command and control.¹²

⁷ Robert T. Finney, *History of the Air Corps Tactical School 1920-1940*, (Wash D.C.: Center for Air Force History, 1992) and Wesley Frank Craven and James Lea Cate, *The Army Air Forces in World War II*, 7 Vol. reprint ed., (Wash D.C.: Office of Air Force History, 1983), Vol I, pp. 50-52.

⁸ Lord Arthur Tedder, *Air Power in War. The Lees Knowles Lectures by Marshal of the Royal Air Force*, (London: Hodder and Stoughton, 1947), pp. 97-93 and Sir Arthur Harris, *Bomber Offensive*, (London: Greenhill Books, 1947), pp. 73-85.

⁹ Haywood S. Hansell Jr., *The Strategic Air War Against Germany*, (Wash D.C.: Office of Air Force History, 1986), pp. 37-41.

¹⁰ Carl Kayser, "Note on Some Historic Principles of Target Selection," RAND, RM-189, 15 July 1949.

¹¹ Benjamin S. Lambeth and Kevin N. Lewis, "Economic Targeting in Modern Warfare," RAND, P-6735, July 1982 and Kevin N. Lewis, "Strategic Bombing and the Thermonuclear Breakthrough: An Example of Disconnected Defense Planning," RAND, P-5609, April 1981.

¹² John A. Warden III, *The Air Campaign*, (Wash. D.C.: National Defense University Press, 1988), pp. 9-10, 51-58. John A. Warden III, "Employing Air Power in the Twenty-First Century," *The Future of Air*

Thus from its conception, airpower has been viewed as a tool to attack strategic COGs directly.¹³ In actual practice, however, the identification and targeting of COGs by airpower has been dismal at worst and elusive at best. Often, we have experienced political-military disconnects presenting political objectives that could not be translated into militarily achievable objectives.¹⁴ Because COGs in turn, flow from and must be in harmony with the political-military objectives, they were seldom accurately identified. We have typically stumbled across COGs by trial and error or by accident, and we have characteristically used such overwhelming force that the identification of the COGs became militarily irrelevant.¹⁵ In a similar manner, our application of COG analysis at the operational level has usually resulted in inconclusive theater interdiction campaigns.¹⁶ Why does a fundamental failure exist when it comes to applying the concept of identifying and neutralizing COGs as an inherent part of strategy?

The Paradigm Problem

There are several reasons for this. First, I will attempt to show that our national security decision process is based upon the wrong conceptual framework to deal with the issues at hand. This creates the political-military disconnect over achievable objectives. Our mechanistic political science models and national security theories are mostly based

Power in the Aftermath of the Gulf War, ed Richard H. Shultz Jr and Robert L. Pfaltzgraff Jr, (Maxwell AFB: Air University Press, 1992), pp. 57-82. John A. Warden III, "Strategic Warfare, The Enemy as a System," draft manuscript, 1993.

¹³ A difficulty for airmen has been their insistence on the unique ability of airpower to produce direct political, social, and economic effects. While the traditional definition of success for armies and navies is their ability to destroy military means (enemy armies and navies), the measure of merit for airpower is often direct political effects rather than military measures of merit.

¹⁴ Mark Clodfelter, *The Limits of Air Power: The American Bombing of North Vietnam*, (New York: The Free Press, 1989) and Andrew H. Krepinevich Jr, *The Army and the Air Force*, (Baltimore: Johns Hopkins University Press, 1986).

¹⁵ A classic example of this in WW II was the shift in 8th Air Force bombing priority from oil, to ball bearings, to the Luftwaffe, to transportation, and to oil.

¹⁶ Edward Mark, *Case Studies in Air Interdiction*, unpublished draft, Office of Air Force History, n.d. See also F.M. Sallagar, "Operation 'STRANGLE' (Italy, Spring 1944): A Case Study of Tactical Air Interdiction," RAND, R-851-PR, 1972.

upon Newtonian ideas and principles.¹⁷ They assumed an international state system that was partially "closed," nearly linear in nature, and bordering on equilibrium. Our very terminology reflects its Newtonian origin: "power politics," "balance of power," "multi-polar," "centers of gravity," "mass," "friction," *ad nauseam*. The Newtonian approach is three fold: first, with known initial conditions and (second) an understanding of natural laws and principles, one can (three) calculate the current and probable future behavior of a system. Newtonian science relies heavily on linear cause and effect relationships; in fact it depends on single causes.

Unfortunately, our national security decision process often mirrored this methodology and has stagnated upon its Newtonian foundation. Social science has not kept pace with hard science in attempting to explain or more accurately describe the real world. We see no equivalent national security framework that incorporates the insights to be gained by using relativity, quantum theory, system dynamics, or "chaos" theory.¹⁸ Our Newtonian approach is fundamentally inappropriate for describing complex social systems. Initial conditions can never be known, only estimated. Even "identical" initial

¹⁷ Hans J. Morgenthau, *Politics Among Nations*, (New York: Knopf, 1973) and Kenneth N. Waltz, *Theory of International Politics*, (Menlo Park: Addison-Wesley Pub Co, 1979). Most political science methodologies for studying "systems" derive from the sociologist Alfred Kuhn. See his *The Study of Society, A Unified Approach*, (Homewood, Illinois: Dorsey Press, 1963) and *The Logic of Social Systems*, (San Francisco: Jossey-Bass Pub, 1974). These works analyze systems by defining the independent variables and controlling each in turn rather than analyzing patterns within the entire system with the independent variables uncontrolled and interacting with each other. A good summary of theory is presented by John Lewis Gaddis in "International Relations Theory and the End of the Cold War," *International Security*, Winter 1992/93, Vol 17 No 3, pp. 5-53.

¹⁸ Volumes of research have recently been published in the hard sciences related to chaos theory. The popular works are: James Gleick, *Chaos, Making a New Science*, (New York: Penguin Books, 1987), Peter Coveney and Roger Highfield, *The Arrow of Time*, (New York: Fawcett Columbine, 1990), Gregoire Nicolis and Ilya Prigogine, *Exploring Complexity - An Introduction*, (New York: W. H. Freeman, 1989), M. Mitchell Waldrop, *Complexity: The Emergence of Science at the Edge of Order and Chaos*, (New York: Simon and Schuster, 1992), Roger Lewin, *Complexity: Science on the Edge of Chaos*, (New York: Macmillan, 1992), Stuart A. Kauffman, *Origins of Order: Self-Organization and Selection in Evolution*, (London: Oxford University Press, 1992), M.F. Eamsley and S.G. Denke, editors, *Chaotic: Dynamics and Fractals*, (New York: Academic Press, 1985), J.M.T. Thompson and H.B. Stewart, *Nonlinear Dynamics and Chaos*, (New York: Wiley Press, 1985), Ilya Prigogine and I. Stengers, *Order Out of Chaos*, (London: Heinemann, 1984), and Benoit Mandelbrot, *The Fractal Geometry of Nature*, (New York: W.H. Freeman, 1983). From the mid 1930s, the scientific journals have had a growing number of articles pertaining to chaos theory. See fn. 31 below.

conditions can bifurcate or diverge, and self organize into totally different results because causality is normally infinite not singular. Nature and human organizations are rough and abrasive not smooth and simple. Social, cultural, and political systems are generally open and interactive with their environment and each other rather than closed. They are complex, synergistic, nonlinear, and dynamic. Applying theories that ignore and are antithetical to these conditions renders our national security process inefficient internally and ineffective externally.¹⁹ This disconnect in "cause and effect" theory within complex social systems, by definition, makes the identification of COGs by traditional linear methods nearly impossible. The astute may question this statement, based on the assumption that Clausewitz's entire COG theory was Newtonian in origin. I will explore the implications and potential solutions to this later, but the simple answer is that Clausewitz used Newtonian "terms," but was fundamentally nonlinear in approach.²⁰

The second reason we have inadequately dealt with COGs is because we do not completely understand the airpower "tool" that effects and interacts with COGs. We do not have a comprehensive theory of airpower explaining the nature of war, discussing airpower as a political instrument within war or analyzing the role of airpower in combined, joint, strategic, theater, and tactical operations. We have overwhelmingly concentrated on strategic theory and tactical application at the expense of operational art. We have not explored the dynamics of airpower application across the spectrum of conflict, or assessed the "relationships among the physical, cognitive, and moral domains of air power."²¹ Importantly, we constantly dwell on the capabilities of airpower while failing to acknowledge the fundamental limitations of this instrument of power. Lastly,

¹⁹ An excellent article exploring these implications is: Steven R. Mann, "Chaos Theory and Strategic Thought," *Parameters*, Vol XXII No 2, Autumn 1992, pp. 54-68.

²⁰ Alan Beyerchen, "Clausewitz, Nonlinearity, and the Unpredictability of War," *International Security*, Vol 17 No 3, Winter 1992-93, pp. 59-90.

²¹ Harold R. Wilson, "A Black Hole in the Wild Blue Yonder: The Need for a Comprehensive Theory of Air Power," *Air Power History*, Vol 39 No 4, Winter 1992, pp. 32-42.

we have not fully examined the dynamic influence of various value systems, cultures, and social organizations on the application of airpower.

The third reason for our poor track record of identifying COGs is we have no unifying COG theory that incorporates or compensates for the two shortfalls listed above. A workable COG theory must explain the nonlinear dynamic processes that effect society and cultures as a whole to include the military, political, economic, social, cultural, and ideological elements of power. A workable COG theory must disclose how the airpower tool is a part of this very process, and how it interacts with this openly "chaotic" system.²² In short, it must be applicable to other forms of power besides military power or airpower, and thus it should provide practical guidance for the development and execution of national strategy.

Clausewitz Revisited

Before I offer a construct for these ideas, we need to re explore Clausewitz and fully examine his notion of COGs. Clausewitz expanded his initial discussions in a very instructive manner and stated:

The fighting forces of each belligerent . . . have a certain unity and therefore some cohesion. Where there is cohesion, the analogy of the center of gravity can be applied. . . [In] war as in the world of inanimate matter the effect produced on a center of gravity is determined and limited by the cohesion of the parts. In either case, a blow may well be stronger than the resistance requires, and in that case it may strike nothing but air, and so be a waste of energy. . . It is therefore a major act of strategic judgment to

²² Surprisingly, very little writing has been devoted to the subject of COG theory other than in Clausewitz, some paragraphs in doctrinal manuals, and some campaign planning handbooks. A lot has been written about the practical application of airpower against "vital centers," which are synonymous with COGs. However, very few define, categorize, or explain the interconnected mechanisms that transform causes into effects. None provide a theory of COGs. For additional reference to pure COG articles see: Major Evan J. Hoapili, "Carl von Clausewitz: Hope and Fear," unpublished paper, Naval War College, 13 February 1992, James J. Schneider and Lawrence L. Izzo, "Clausewitz's Elusive Center of Gravity," *Parameters*, Sep 1987, pp. 46-57, Lawrence L. Izzo, "The Center of Gravity is Not an Achilles Heel," *Military Review*, Jan 1988, pp. 72-77. The best discussion of COGs is in: Steven Metz and Frederick M. Downey, "Centers of Gravity and Strategic Planning," *Military Review*, Apr 1988, pp. 23-33.

distinguish these centers of gravity in the enemy's forces and to identify their spheres of effectiveness.²³

Clausewitz also pointed out how COGs are dependent upon objectives as well as decisions. For example, in explaining defense of a theater he stated:

Defense consists of two different elements--the *decision* and the *period of waiting*. . . [The] true relationship between the state of waiting and the whole, is valid only if a decision is really intended, and is regarded as inevitable by both sides. It is the decision that changes the centers of gravity on each side, and the operational theaters they create, into *active agents*. If one drops the idea of a decision, the centers of gravity are neutralized, and so, indeed, in a certain sense, are all the forces.²⁴

My last quotation from Clausewitz concentrates on identifying COGs. He stated:

The first principle is that the ultimate substance of enemy strength must be traced back to the fewest possible sources, and ideally to one alone. The attack on these sources must be compressed into the fewest possible actions--again, ideally, into one. . . The task of reducing the sources of enemy strength to a single center of gravity will depend on: 1. The distribution of the enemy's political power. 2. The situation in the theater of war where the various armies are operating. . . From this it follows that the concept of separate and connected enemy power runs through every level of operations, and thus the effects that events in a given theater will have elsewhere can only be judged in each particular case. Only then can it be seen how far the enemy's various centers of gravity can be reduced to one.²⁵

Clausewitz also illustrated several examples of COGs that were valid for his historical context. These were: enemy fighting forces; the enemy capital if there was domestic strife; the protectorate of a smaller country; the "community of interest" of an alliance; and the leaders of popular uprisings.²⁶

At this point, it is useful to summarize some important observations about Clausewitz's view of COGs. First, COGs existed on either side of a conflict in a dynamic manner. Second, the COG is a strength not a vulnerability, and the strongest blow comes

²³ Clausewitz, *On War*, pp. 485-86.

²⁴ *Ibid.*, p. 488.

²⁵ *Ibid.*, pp. 617-18.

²⁶ *Ibid.*, p. 596.

from a COG. Third, COGs involve complexity, cohesion, mass, and freedom of action. Fourth, COGs exist at all levels of war and are intimately tied to political objectives. The enemy's political aims and decisions must be considered in determining his COG. Last, strategy requires the identification and protection of COGs as well as the prioritized decision to attack, threaten or avoid COGs.

Part of the traditional attractiveness of Clausewitz stems from the mental appeal of his dynamic nonlinear view of the real world, and his presentation of a comprehensive theory of land warfare within his cultural context that incorporated this principle. Clausewitz in essence was a chaos theorist/practitioner, but he lacked the modern science or the vocabulary to express himself as such.²⁷ Thus Clausewitz's theory of COGs is fairly complete because he presented a coherent "setting" in which to identify COGs, and an over arching analysis of the tools that could affect COGs. Any modern day synthesis or theory of COGs must accomplish these same basic tasks.

²⁷ Beyerchen, "Clausewitz, Nonlinearity, and the Unpredictability of War."

CHAPTER II

CHAOS THEORY

Chaos Explained

The key to COG analysis, therefore, is to incorporate the real and dynamic complexities of the natural world explained by chaos theory. I have already noted the growth in scientific literature pertaining to this new area of research. While all the literature points to the obvious applicability of chaos theory to social structures, none have proposed a suitable overarching construct. I will attempt to do so, but space permits only a bare outline. I will not recite the tenets of chaos theory easily available and contained in extant literature. Rather, I will highlight several key points and then propose a structure consistent with the theory and its functions. For the uninitiated, the basics of chaos will hopefully become self-evident. I then propose to answer several important questions: How does chaos theory help to identify and prioritize COGs? What is the nature of the forces or "tools" that influence COGs? What are the dynamics involved when these tools interact with COGs? Hopefully this will also answer the "so what" question: does chaos theory help us to better understand our world and, in the process, become better airpower strategists?

Some key propositions for chaos theory need to be understood. The theory applies to all nonlinear, dynamic systems and "predicts" certain features that are independent of the system's detailed structure. Chaos theory predictions are themselves general in nature, and describe system interactions rather than specific end states. Chaos can be either "deterministic" (exhibiting regularities) or "stochastic" (exhibiting erratic randomness).²⁸

²⁸ The "degree" of chaos is often measured by the average rate at which information about the system is produced and by the number of functional dimensions within the system.

Many of these patterns or structures of regularity and randomness are universal in nature and apply to physics, mathematics, geometry, biology, meteorology, ecology, and presumably social systems. An extremely important point is that the initial conditions and the dynamic factors that govern system dynamics can seldom be absolutely known or defined. This occurs because systems, particularly the functions that define them, are complex and "fractal" in nature—the further you attempt to investigate and refine them the more intricate and detailed they become. They are often self-repeating, exhibiting scaled structures. This would not be important except that minute differences over time can produce surprisingly diverse results, thus chaos theory does not lend itself to gross simplifications or to long term predictions. It does allow you, however, to anticipate certain functions and processes within dynamic systems that are consistent with the theory. This "double speak" means you can usually predict *how* to make some general event happen, and *why* dynamic processes interact as they do, but you cannot predict specifically *what* happens after the event or *when* the event will occur.

Chaos principles are extremely straight forward. First, patterns within a dynamic system will form around functions known as "strange attractors."²⁹ These patterns will resemble each other by exhibiting similar properties, but will never *exactly* repeat themselves. Second, nature favors order along few rather than many pathways. Strange attractors (i.e. functions) then magnify initial randomness, small uncertainties, and these few pathways into larger scale patterns. Third, simplicity thus grows into complexity, and the inner underlying patterns ultimately influence the outward forms of a structure. These scaling structures, or self-similar organizations, within a system run deep and exhibit

²⁹ "Attractors" are of three types: fixed-point, limit-cycle, and strange. They are simply terms used to describe physical and mathematical functions associated with steady-state, periodic-state, and dynamic systems. Properties within dynamic systems which can be used to characterize strange attractors are: the rate of decay of predictability, the rate of information flow, and the tendency to create mixing.

universal consistency with the laws of nature at all levels.³⁰ Fourth, systems open to their environment will self-organize into similar patterns in accordance with their fundamental structures. Note that the act, or process, of self-organization is different from the characteristic of self-similarity. Fifth, nonlinearity can stabilize systems as well as destabilize them. Systems use feedback to detect, alter, and minimize or accentuate perturbations. Sixth, open systems can be driven to crises points where they will either bifurcate and self-organize again, or go into a period of stochastic chaos. Seventh, crises points can be precipitated by: a. closing the system off from its environment and propelling it to equilibrium; b. eliminating feedback within the system; c. driving any one of the dimensional dynamics to singularity by overloading or destroying it; or d. applying quantum amounts of broad external energy to the entire system. Eighth, some systems can create disorder in one direction while remaining trim and methodical in another. This depends on the connectivity of the system's linkages and potential biases within its functions.³¹ Lastly, chaos theory is not time reversible.³² The arrow of time moves one direction, because time is required to reveal the patterns of a system.

³⁰ The "universality" of chaos principles in dynamic systems is a critical point. It indicates that similar processes, mechanisms, and laws exist from the micro to the macro level, which presents a considerable task for theorists proposing grand-unified system structures.

³¹ These views have been summarized from the works listed in f.n. 18 above and from the following articles: James P. Crutchfield, J. Dooyne Farmer, Norman H. Packard, and Robert Shaw, "Chaos," *Scientific American*, Dec 1986, pp. 46-57, Stuart A. Kauffman, "Antichaos and Adaptation," *Scientific American*, August 1991, pp. 78-84, Ary L. Goldberger, David R. Rigney, and Bruce J. West, "Chaos and Fractals in Human Physiology," *Scientific American*, Feb 1990, pp. 43-49, Alan Wolf, "Simplicity and Universality in the Transition to Chaos," *Nature*, Vol 305, Sep 1983, pp. 182-183, Arun Holden, "Chaos in Complicated Systems," *Nature*, Vol 305, Sep 1983, p. 183, Larry L. Smarr, "An Approach to Complexity: Numerical Computations," *Science*, Vol 228 No 4698, 26 Apr 1985, pp. 403-408, Per Bak and Kan Chen, "Self-Organized Criticality," *Scientific American*, Jan 1991, pp. 46-53, Norman J. Zabusky, "Grappling with Complexity," *Physics Today*, Oct 1987, pp. 25-27, W. Brian Arthur, "Positive Feedbacks in the Economy," *Scientific American*, Feb 1990, pp. 92-99, Leonard M. Sander, "Fractal Growth Processes," *Nature*, Vol 322, 28 Aug 1986, pp. 789-793, Celso Grebogi, Edward Ott, and James A. Yorke, "Chaos, Strange Attractors, and Fractal Basin Boundaries in Nonlinear Dynamics," *Science*, Vol 238, 30 Oct 1987, pp. 632-638, Benoit Mandelbrot, "How Long is the Coast of Britain? Statistics! Self-Similarity and Fractional Dimension," *Science*, Vol 156, 5 May 1967, pp. 636-638, Robert M. May, "Biological Populations with Nonoverlapping Generations: Stable Points, Stable Cycles, and Chaos," *Science*, Vol 186, 15 Nov 1974, pp. 645-647, and Russell Ruthen, "Adapting to Complexity," *Scientific American*, Jan 1993, pp. 130-140.

³² This may seem obvious, but Newtonian science is theoretically time reversible. Acknowledging time as an irreversible function means you can never return to the *status quo ante* in a dynamic system.

Let's take a moment to quickly restate the three most important aspects of chaos theory. It instructs us how to examine dynamic systems--look for deep structures and patterns. It shows us how dynamic systems can self-organize, how they are closely interrelated, and how they use feedback to regulate themselves. Lastly, it tells us how to disrupt dynamic systems. It does not allow us to predict accurately the specific end states that may develop after disruption occurs. Nor does it permit long term prediction of detailed end states of dynamic systems that are not subjected to disruption. Identifying the deep structures and processes, and predicting the *how* and the *why* of disrupting dynamic systems closely corresponds to the processes we must use to analyze COGs. I submit it is the same process.

It should be evident, however, that applying chaos theory to human social systems requires both inductive and deductive approaches. Furthermore, the inherent fundamental structures of systems, combined with the ultimate unpredictability of end results by chaos theory should make it intriguing, if not acceptable, to both social science and historical methodologies. The classic Newtonian method used to test cause and effect relationships is to be able to repeat the test. This is intrinsically impossible with chaotic systems. To test these systems, one often has to rely on identifying underlying dimensions, functional variables, and statistical patterns or properties rather than being able to make detailed predictions. Furthermore, chaos directly challenges the reductionist method of breaking systems down and studying each component or factor in isolation as a sole method to determine outcomes. While there are some closed, non-dynamic systems in which the sum of the whole equals the sum of its parts, chaos shows that systems can have complicated behaviors that transcend the sum of all parts! "Chaos provides a mechanism that allows for free will within a world governed by deterministic laws."³³

Chaos and Deep Social Structure

³³ Crutchfield, Farmer, Packard, and Shaw, "Chaos," *Scientific American*, p. 57.

In many ways, the justification to apply chaos theory to cultural systems resembles the arguments used by others who have looked for deep structures within society. For example, I would echo the reasoning presented by Joshua Goldstein in his work *Long Cycles*. He stated:

My approach acknowledges the importance of both repetitive and evolutionary change. . . Long cycles are not a mechanical process but a repetition of themes, processes, and relationships along the path of an evolving social system. . . They do not allow us to predict the future, but they can help us to understand the dynamics of international politics in its deep context. . . It is not clear that *scientifically* meaningful statements can be made about macrohistorical processes that are historically unique, especially if one believes, as I do, that the future is indeterminate.³⁴

An obvious method one might use to begin to apply chaos theory to cultural structures, would be to review the literature of the major social disciplines pertaining to deep underlying processes and theories. This should include history, political science, economics, sociology, anthropology, military studies, and even religion.³⁵ However, a deep structure comparison could easily become the subject of an entire paper or book. Thus without dwelling on this topic too long, I point out that no single social-cultural theorist specifically ties his methodologies to chaos. One also needs to realize that the bulk of contemporary *social science* has focused on the political, military, social, and economic manifestations of relatively modern advanced societies. Chaos theory argues these visible forms of society stem from inner cultural structures that are less studied or understood.

³⁴ Joshua S. Goldstein, *Long Cycles, Prosperity and War in the Modern Age*, (New Haven: Yale University Press, 1988), pp. 6, 8, & 12. Emphasis in original. There has been a new emphasis on statistical studies of war of which Goldstein is a part. Other important scholars in this field are Jack Levy, Immanuel Wallerstein, J. David Singer, Kalevi Holsti, Paul Diehl, and John Vasquez

³⁵ I have already mentioned the works of Morgenthau, Waltz, Kuhn, Goldstein, and Clausewitz. One would need to review the following authors: Karl Marx, Adam Smith, Max Weber, Thomas Hobbes, David Hume, George Modelski, Claude Levi-Strauss, Stanley Hoffmann, Benjamin Ward, John Gaddis, Morton Kaplan, Robert Merton, Graham Allison, Robert Jervis, Paul Kennedy, Raymond Aron, Marion Levy Jr., J.S. Slotkin, Pitirim Sorokin, James March, Neil Smelser, Arthur Stinchcombe, and Reinhold Niebuhr.

Persistent indications of human patterns are as evident as the disciplines we study: military art, politics, economics, sociology, cultural anthropology, and value systems. One could also view dialectic or cyclical economic and political processes as essentially the dynamics of a strange attractor. The interactions between major subsystems, for example military, political, and etc., illustrate connectivity linkages evident in chaos systems. Likewise, major wars could be interpreted as crises points or bifurcations, and periods of stability under balance of power systems can be seen as periods of self organization. Command, control, and communications theories in many ways resemble the feedback loops and control mechanisms that are prevalent within dynamic systems. Analysis of collective behavior patterns and decision making processes often imitate the descriptions of nonlinear open systems. Lastly, studies that explore dynamic interdependence within political, economic, and social systems often closely mirror the scientific and mathematical discussions one finds of fractal boundaries. In short, chaos essentials have been there a long time within social science, but we have failed to synthesize them.³⁶

³⁶ Pioneering work in system dynamics was made by Jay W. Forrester in the 1960s. A management specialist at MIT, his primary works are: *Industrial Dynamics*, (New York: John Wiley & Sons, 1961) and *Principles of Systems*, (Cambridge: Wright-Allen Press, 1968). A close attempt to apply system dynamics, but with a military perspective, has been two RAND proposals: David A. Shlapak, "Exploring Paralysis: An Introduction to the Study," RAND, PM-107-AF, Dec 1992; and Meg Cecchine and Mark Hoyer, "Applying System Dynamics to Effective Air Campaigns," RAND, PM-106-AF, Jan 1993. However, all these studies are confined to the economic, political, and military level and do not examine or explore the underlying social, cultural, or value system base. Neither RAND study attempts to use chaos theory.

CHAPTER III

A STRUCTURE BASED ON CHAOS

Basis of Organization

The fundamental constant within social-cultural constructs is human free will. Free will is analogous to the space-time concept in relativistic physics, defining the dimensions of human society. Free will is always present, it permeates decisions, structures and culture providing a vehicle for randomness to be introduced into the system. Human will occurs in various forms, but the primary ones for our purposes are: the will to survive, the will to power, and the will to truth.³⁷ The highest reaches of individual or personal will are dependent upon the social substance from which they arise and can only be fulfilled in the context of a community. Man, like all primates, is a communal animal first and foremost. Communal relationships exist within all levels of human society in endless elaboration. The necessity to define man's relationship to other individuals, his relationship to the community, the community's relationship to nature, and the community's relationship to other communities give rise to value systems. These value systems reflect the will to truth and the will to power, and they comprise what many would call norms, mores, and laws. Common expressions of value systems are religion, ethics, philosophy, political ideologies, and doctrine. The value systems that arise from human will and community are the underlying element of power and organization within human society from the most primitive tribe to modern nation states. Values are the

³⁷ I borrow this construct from Reinhold Niebuhr, *The Children of Light and the Children of Darkness*, (New York: Charles Scribner's Sons, 1944), pp. 48-49. In some ways this corresponds to Maslov's hierarchy of needs.

gravity that rules the human universe. Values are the first element of power. They define the organization and dynamics of the other elements of power.

Elements of Power

Power is not well understood. Power is the ability to do what you want, and the ability to influence others to conform to your desires. Power is strength that permits freedom of action. Because power is exercised by humans and is applied to human societies, it is both real and perceived in nature. Power is amoral. It is neither "good" nor "bad," but it can have positive or negative effects on social organization—sometimes both simultaneously. This means it can increase or decrease cohesion in society. The effectiveness of power is always situational in terms of who is using it, which element of power is being used, where it is being used, and who or what is the object of influence. Power is dynamic over time and its full force is rarely mustered without crossing fractal boundaries and connecting into other sources and types of power. The effect of a single type of power is rarely persuasive if used independent of other types of power, and influence is magnified when the various elements of power are used in combination rather than isolation. For example, military action, diplomatic pressure, and economic sanctions should be coordinated to achieve maximum effect.

Power essentially supports, defends, or implements the goals and values of society. Each element of power is three dimensional. It consists of a "source," a manifestation (or "force"), and a "linkage." The linkage assists in transforming the source into a force, and it provides connectivity within and between the elements of power. Each complete element of power is a center of gravity, and each element of power is a strange attractor. The dimensions that define it vary, but the essential ones are: the mass of the source, the intensity of the force, interconnectivity within the system, and the rate of exchange flow within the linkages. These systems can then be characterized by their predictability, their rate of information flow, and their tendency to create mixing.

Sources of Power

There are relatively few true sources of power in human society. In Einstein's terms they would constitute the mass or "rest-energy" of society. These sources are the basic substance of societies and nations, and consist of value systems, culture, economic resources, and social organization. Important features of social organization in the modern world are government and security or military organizations. Having already discussed value systems, let's examine the others in turn.

Culture is the learned body of customs and knowledge within human communities. Cultures exist for extended periods of time and may incorporate several types of societies. Culture arises from values, and is the means by which values are defined or expressed. Culture determines how man adjusts to his community, and how societies adjust to their environment. The most common approaches to the environment are: naturalism, supernaturalism, estheticism, and mysticism.³⁸ These approaches often exist in mixed form, although they can exist in societies in prevalent or pure forms.

Economic resources include populations, natural resources, and territory. Man and primates were not originally territorial, but human culture and society developed sedentary expressions versus nomadic forms. When this occurred, territory became closely identified (if not inseparable) with definitions of community and thus was incorporated into fundamental value systems.

Social organizations can be categorized into three fundamental types: solidary, contractual, and antagonistic.³⁹ Solidary societies are typified by familistic, tribal and ethnic affiliation, but can also exist in economic and religious forms. Normally, solidary groups define or attempt to encompass all values for social organization, and thus are intense and mutual. Contractual types of organizations are commonly associated with

³⁸ J.S. Slotkin, *Social Anthropology, The Science of Human Society and Culture*, (New York: MacMillan Company, 1950), pp. 143-145. Also see f.n. 41 below.

³⁹ Pitirim A. Sorokin, *Society, Culture, and Personality: Their Structure and Dynamics*, (New York: Harper and Brothers Publishers, 1947) pp. 69-150.

cooperative groups, where rights, privileges, and obligations are clearly defined. Only a few values are encompassed, projected, or monitored by the contractual group. Modern democratic, bureaucratic nation states are the archetypal contractual organization.

Antagonistic social organizations are coercive in nature and usually involve domination of one group by another. Antagonistic types of organizations are normally one-sided and involve the imposition of value systems either internally or externally. Antagonistic groups often assume a pseudo-solidary or pseudo-contractual guise, and are typified by ideological totalitarian states. These three types of social organization can exist in "mixed" varieties, and they are not permanent because societies develop and change. For example, solidary societies can slowly evolve into contractual or antagonistic forms. Likewise, revolutions can occur when major disconnects develop between fundamental value systems and the outwardly apparent social organizations.

These broad categories can be further classified by the prevalent type of functional interdependence between the group's members. This includes the ability to organize "unibonded" groups and "multibonded" groups.⁴⁰ Unibonded groups have one set of meaningful norms or values as the vehicle or magnet for organization, while multibonded groups collate around two or more sets (or potentially large numbers) of norms or values. The method of bonding helps determine the connectivity within society, but more importantly helps to indicate the potential "biases" or predisposition toward decisions that may occur within groups.

Solidary societies will tend to horizontally organize themselves around unibonded groups, and will use reinforcing unibonded groups to organize vertically. For example, the tribe or the clan becomes the defining factor that determines status throughout social, economic, political, and military organizations. These societies are normally focused

⁴⁰ *Ibid.*, pp. 171-178. Important unibonded groups are: perceived race, sex, age, kinship, territorial proximity, language, occupation, economic, religious, political, scientific, and leadership elites. Important multibonded groups are: clan, tribe, nation, caste, and social classes.

inward upon their defining element. Contractual societies will be horizontally and vertically organized around multibonded groups while permitting the existence of unbonded groups. A multitude of competing and complementary pluralistic groups exist at all levels of contractual societies. Antagonistic societies will organize vertically along unbonded groups, using these groups to suppress other unbonded groups and to control multibonded groups. Antagonistic societies can be focused either internally or externally.

These fundamental classifications and characteristics, which derive from values, help determine the outward forms of economic organization, governmental function, and military capability. This is especially evident when one studies social and cultural history back to antiquity, and examines diverse civilizations other than modern Europe. Values, culture, and social groups interact in many permutations and combinations. They form the basis for beginning a systematic center of gravity analysis. This is especially true when looking at the entire spectrum of conflict rather than just conventional operations. Checklist center of gravity methodologies simply will not work, nor will methods solely focused on analyzing the external vestiges of society such as government leadership.⁴¹

Reinhold Neibuhr points out:

Government may be the head of the body, which without a single head could not be or become, a single body; but it is not possible for a head to create a body. . . [It is] axiomatic that the less a community is held together by cohesive forces in the texture of its life the more must it be held together by power.⁴²

The obvious corollary of this statement is that cohesive governments and societies do not require strong leadership to bind their social fabric together and maintain power.

The sources of power are not centers of gravity in and of themselves. They are the raw material that gets molded into another dimension of the element of power that we call

⁴¹ Metz and Downey, "Centers of Gravity and Strategic Planning," pp. 30-31. This is contrary to the ideas espoused by Warden and others. For example, see: Bruce A. Ross, "The Case for Targeting Leadership in War," *Naval War College Review*, Vol. XLVI, No 1, Winter 1993, pp. 73-93.

⁴² Neibuhr, *Children of Light and Children of Darkness*, pp. 165 & 168.

force. Lets move on to investigate these manifestations of power and the linkages of power that produce them.

Manifestations of Power (Force)

The important manifestations of power are: military force, political/diplomatic force, economic force, cultural force, and ideological force. The existence and the strength or magnitude of these various forces differs widely between societies and nations. Relative to our cultural viewpoint, some societies are incapable of organizing effective forces, although they may occupy a seat at the General Assembly of the United Nations. This stems from their underlying cultural values and their social organization. They may, however, possess a deeper force. A force that binds their society together, and is capable of eluding modern means to overcome it. To understand this, we must explain how force is created in society and examine the dynamics of different types of force.

In the natural world we know there are four fundamental forces: gravity, electromagnetism, and the weak and strong nuclear forces. These forces exhibit similar characteristics and functions. They can attract and/or repel. They can exhibit positive and some negative charges. They possess different strengths, and they exert their influence at different ranges. For example, gravity is the weakest force, it always attracts, and it has the longest "range," able to literally travel the distance of the universe. On the other hand, in large concentrations, gravity is cumulative and in large masses it can overcome all the other forces to create singularities such as black holes. Another good example is the strong nuclear force. It is 10^{39} times stronger than gravity, but is only capable of exerting its influence within the radius of the nucleus of an atom. The forces of nature are created by constant "exchanges" between subatomic particles, in essence extracting and instantaneously returning energy from "virtual" mass in accordance with $E=MC^2$. For example, protons and neutrons exchange quarks to create the strong nuclear force. Electron exchanges produce electricity, and can emit photons to create light and

magnetism. In addition, all matter exchanges gravitons to create the force we know as gravity.⁴³

The forces within human society exhibit similar behavior and characteristics. They are not all of the same strength. They can be both destructive and constructive. Their influence or power varies in its projectability over various distances. Furthermore, human social forces are created in the same manner as the forces of nature—the constant exchange of mass-energy in the form of "things" and/or "ideas." Neither the forces of nature, nor the forces of human society, can be visibly touched, although their effects can be felt. They do not have mass because they are a form of energy derived from mechanisms of exchange. Force is therefore an event, a process, or an action that is always covertly present and overtly felt.

Let's examine the specific force creation process for the important manifestations of power in society. Military force arises from the consumption and expenditure of logistics to conduct training or operations. Political force arises from the constant redistribution of wealth and power in society. Diplomatic force simply represents the redistribution of wealth and power outside the boundaries of a society. Economic force is the production and exchange of goods and services. Cultural force is the exchange of knowledge and customs. Ideological force is the transmission or exchange of values. These forces constitute the primary "strange attractors" in human culture and the boundaries between each of them are closely interwoven. This blurring makes it sometimes difficult to distinguish between the elements of pure force. Indeed, the fighter aircraft flown by the military, procured by the government, manufactured by the economy,

⁴³ John Gribbin, *In Search of Schrodinger's Cat, Quantum Physics and Reality*, (New York: Bantam Books, 1984). Also see: Roger Penrose, *The Emperor's New Mind*, (New York: Penguin Books, 1989), Stephen W. Hawking, *A Brief History of Time, From the Big Bang to Black Holes*, (New York: Bantam Books, 1988), Albert Einstein, *Relativity, The Special and the General Theory*, trans. Robert W. Lawson, (New York: Bonanza Books, 1961), Nigel Calder, *Einstein's Universe*, (New York: Penguin Books, 1979).

organized by society, and conceived by a culture is a product of many interacting systems.⁴⁴

As I previously stated, ideological force or values constitute the "gravity" of human society. Ideology projects rapidly but weakly over long distances, however, in concentrated masses it dominates all other forces. In relativistic terms, values may actually be the "rest energy" that distorts the space time-continuum of human will, becoming the fabric on which the other forces of society play. It creates biases and predispositions which influence the connectivity within systems determining their susceptibility to chaos. The more solidary the system, with many unbonded groups, the more islands of stability it will exhibit. These areas are triggered into locked states that become isolated from feedback. This provides temporary stability that can only be disrupted by quantum inputs of energy.

The fundamental organization of each society determines the strength of the military, political/diplomatic, economic, and cultural forces at its disposal. This "strength" is only meaningful when compared to another society. However, a rule of thumb for modern nation states would categorize their strengths in decreasing order as: cultural, economic, political, diplomatic, and military. This may seem surprising and there may be some exceptions, but it explains the historic difficulty of targeting military force against deeply rooted political, economic, and cultural systems! By contrast, the projectable range and the time response is inversely proportional to the strength. Military force projects fast and over long distances. Economic force projects slower, over shorter distances, and requires a longer period to produce effects.

⁴⁴ A good argument could be made that military force is just the external manifestation of a more comprehensive "security force." The internal manifestation of this force provides internal security and police functions within society.

Linkages of Power

We have discussed the first two dimensions of power, **sources and manifestations**, so let's move on to the third dimension we call linkage. The linkages of power are the **human, cultural, and material networks and capabilities that assist in transforming the sources of power into forces, and that provide connectivity within and between the elements of power. The primary linkages consist of: communications, logistics, transportation, leadership, science, technology, education, and training. Linkages determine how efficiently power is organized, and ultimately how effectively it is applied. Connectivity facilitates or hinders the transmission of data and feedback within the various systems. This, along with bias, helps determine system dynamics and its susceptibility or resistance to chaos.**

The linkages of power are often mistaken for COGs when in actuality they possess no force in and of themselves.⁴⁵ However, a linkage of power can possess either strengths or vulnerabilities which can be exploited to disrupt a COG system. Some linkages may have to be avoided, depending on the particular society. For example, transportation systems are often identified as "vulnerable COGs," despite some transportation systems being so redundant they are almost impervious to targeting. The nature of the linkages of power ultimately derive from a culture's approach to its environment (naturalistic, supernatural, esthetic, or mystic). This determines a society's technology or its method of altering the environment to suit its culture. Naturalistic or scientific approaches seek and use technology at all levels of society. Thus they are more capable of creating linkages that organize, orchestrate, and transform sources of power into force.⁴⁶

⁴⁵ Airpower theorists in particular have considered transportation and communications as "vital centers." In some cases they were indeed vital "linkages," and thus the appropriate target.

⁴⁶ Slotkin, *Social Anthropology*, pp. 156-181. Slotkin goes on to categorize supernaturalism as the use of symbols and beliefs to transform the environment (p. 182). An esthetic approach essentially defines the environment as something that is pleasing and of value in and of itself therefore only minor attempts are made to change it (p.270). A mystical approach achieves adjustment to the environment by changing an

The linkages of power create the energy which drives open dynamic social systems. This energy can be created by less efficient "chemical" means. In nature chemical reactions release energy by exchanging electrons between atoms. In society, this is analogous to the trade, exchange, and service industries. However, nature also creates energy by "nuclear" methods involving fission and fusion. The production of industrial goods from raw source materials is the social equivalent. "Chemical" linkages and "nuclear" linkages represent distinctly different targeting choices both in terms of the energy required to effect the linkage, and the expected results. Similar distinctions exist as to which "level" of linkage is being attacked within the structure. Strategic and tactical linkages produce different dynamics, and thus require different targeting strategies.⁴⁷

A Recap

It may be helpful to graphically depict the elements of power and the corresponding social structure that I have just presented.

<u>SOURCE</u>	<u>LINKAGE</u>	<u>FORCE</u>
Armed Forces	Command & Control Training & Logistics	Military
Government Bureaucracy	Leadership & Communication	Political & Diplomatic
Industry & Natural Resources	Transportation & Technology	Economic
Society & Culture	Family, Education & Socialization	Social-Cultural
Value System	Religion & Philosophy Indoctrination	Ideological

individual's internal experience or perception rather than producing outward change to the environment (p.309). The last three approaches have a common demoninator in that they provide only a partial adjustment to the environment.

⁴⁷ Mancur Olson Jr. "The Economics of Target: Selection for the Combined Bomber Offensive," *Journal of the Royal United Service Institution*, Vol CVII, No 628, Nov 1962, pp. 308-314.

Let's briefly access this construct of society. First, individual human will permeates everything, introduces chance, and establishes the arena for all social activity. Second, the interactions of individuals and community give rise to value systems, culture, and higher levels of organizational activity. Third, this human activity, or elements of power, consist of sources, linkages, and forces. Higher levels of activity are more "particle" in nature and their small mass-energy can be rapidly directed against specific points. The underlying levels of social organization resemble "fields." These forces surround their source with energy that in effect makes it more difficult to distinguish force from source. "The arena joins in the very action taking place within itself."⁴⁸ Fourth, the more complex areas of social activity self-organize from simple structures. These activities are closely interwoven with each other and clearly function as open nonlinear systems. Fifth, deep structural patterns in human society clearly exhibit characteristics of strange attractors and are subject to the processes governing chaos theory.

Center of Gravity Implications

These areas of activity, the elements of power, are true centers of gravity within human society. They exist at all levels of organization, and they represent centers of power and strength. They change dynamically within and between societies, and they provide freedom of action to exercise power. They involve complexity, cohesion, energy and mass, and it requires deep analysis to determine where they lay and to prioritize them. Lastly, they are intimately tied to human will and value systems, and thus by default, to political objectives.

Of the three dimensions of power (source, force, and linkages), only force is projectable—but in varying degrees. However, force can be applied against any of the other dimensions of power. Generally, applying force against a source is difficult, and can be counterproductive because it always threatens vital national interests. It can create a

⁴⁸ Penrose, *The Emperor's New Mind*, p. 217.

"dangerous paradox," whereby a strategy for unlimited war, if systematically pursued in a war of limited aims, can lead to escalation and transforming the war into something inconsistent with the political objectives.⁴⁹ This is also often associated with attrition type warfare. Force against force involves clashes between classic centers of gravity, and can equate to battles of annihilation. Lastly, employing force against power linkages is an "indirect" approach.

⁴⁹ Hoapili, "Carl von Clausewitz," p. 22. Also see Clausewitz, *On War*, p. 486.

CHAPTER IV

CENTERS OF GRAVITY AND CHAOS DYNAMICS

Linkages, Connectivity, and Bias

The linkages of power fulfill key dynamic functions within COG analysis and chaos theory. They help determine the openness and/or closure of a system in terms of how energy is produced, used, and expended. They help determine the connectivity of a system both internally and between the other elements of power. A highly connected system rapidly spreads information, energy, and perturbations throughout a system. Low connectivity can hinder the spread of disturbance, but it can also result in concentrated local effects. Linkages fundamentally define the feedback within a system. Value biases and human free will are crucial to determining the probable courses of action and the effective implementation of options that arise from feedback.

Whether we assume that "rational actors," "bureaucratic organizations," or "political processes" make key social decisions based on information feedback, it is important to understand that what is "rational" will be relative to the cultural value biases of that society.⁵⁰ Latent bias can be indicated by: the culture's approach to its environment (naturalistic, supernatural, esthetic, or mystic); its historical value system and ideology; its fundamental type of social organization (solidary, contractual, or antagonistic); and the prevalence of unbonded and multibonded groups. Vulnerable linkages represent avenues whereby social systems can be driven to critical points to precipitate stochastic chaos. On the other hand, strong linkages can reduce the magnitude and duration of dynamic disruptions.

⁵⁰ A groundbreaking work on the nature and importance of relative cultural bias is: Ken Booth, *Strategy and Ethnocentrism* (New York: Holmes and Meier, 1979)

Uncertainty Principle

An interesting aspect of efforts to investigate or "measure" a potential system's structure is the possibility of producing an effect comparable to the Heisenberg Uncertainty Principle of quantum physics. The Heisenberg uncertainty principle results when attempts are made to measure either the position or momentum of a subatomic particle. It tells us that the more accurately a position is measured, the less accurately we can determine the momentum or vice versa. This occurs because the energy required to effect or record the measurement exceeds the energy of the force or particle being measured.⁵¹

A similar circumstance occurs whenever a strong external force interacts with another system. The mere act of measuring, investigating, or projecting power can skew the position or outcome of a system. The probability of interference increases when the force is equal to or exceeds the strength of the forces in the other system. This is particularly true when a "superpower" becomes involved. For example, the simple interest of the United States Congress to investigate the Bosnian Crises in 1992 caused the positions of the various ethnic groups to alter their diplomatic bargaining positions.⁵² The probability of interference decreases when the force relationship is smaller—but it is always possible. This plainly indicates the dynamics of forces in complex systems. It shows that the application of any form of economic, social, diplomatic, or ideological involvement must be approached as a constant ongoing process in which the process itself can impact the expected results!

⁵¹ Werner Heisenberg, *Physics and Philosophy*, (New York: Harper Torchbooks, 1962). In physical terms it also causes the wave function to resolve itself from many potential possibilities into one state.

⁵² See testimony of General Lewis MacKenzie, Commander of United Nations Peacekeeping Forces in Sarajevo. United States Congress, Senate, Committee on Armed Services, *Situation in Bosnia and Appropriate U.S. and Western Responses*, Hearing before the Committee on Armed Services, Senate, 102nd Congress, 2nd sess., 17 August 1992, pp. 50-61.

Entropy and the Second Law of Thermodynamics

Some among you will try to equate the effects of chaos to entropy associated with the second law of thermodynamics. This is particularly tempting since some authors directly attribute attacks on centers of gravity to precipitating entropy within social, economic, political, and military systems due to the second law of thermodynamics.⁵³ However, there are some significant differences that must be clarified. The second law of thermodynamics states that "heat in a closed system can never travel from a low temperature region to one of higher temperature in a self-sustaining process."⁵⁴ The direct implication of the second law is that entropy, or disorder, in a closed system always increases. Low entropy represents the capacity to change or organize, and this concept under the second law has often been misapplied to all measure of phenomenon including social systems.⁵⁵

According to the second law, the march to entropy is inescapable within *closed systems*. At the macro level, the closed system is the universe itself. However at smaller scales, other systems can self-organize for "temporary" periods as long as they draw upon energy from their environment and follow the first law of thermodynamics (i.e. the energy going in must equal the energy going out, which is also Newton's law of the conservation of energy). In effect these micro systems are maintaining or decreasing entropy for themselves by increasing entropy within the macro system. Dynamic nonlinear open systems can organize to higher and higher levels as long as they maintain this energy balance and the overall macro system supports the decreased entropy within the micro system. In addition, non-dynamic systems can also remain functioning in equilibrium as

⁵³ See Warden, "Strategic Warfare," manuscript, 1993.

⁵⁴ John W. Wright, ed. *The Universal Almanac, 1993*, (New York: Universal Press, 1992), p. 545.

⁵⁵ Penrose, *The Emperor's New Mind*, pp. 302-347. See also Conway and Highfield, *The Arrow of Time*, pp. 147-181, Hawking, *A Brief History of Time*, pp. 108-112. It is important to clarify that all excess energy (or low entropy), including heat, in the universe is ultimately the result of gravity. Gravity organizes mass and creates the nuclear fires that provide the thermodynamic energy of the universe. The eventual state of "maximum entropy" will occur billions of years in the future when all the matter of the universe has been absorbed into black holes of the "big crunch," or gone cold in the "big chill."

long as they remain open and consume energy from the macro system. Thus the first law of thermodynamics permits life to exist and societies to organize. The energy that societies consume in reality comes from the "sources of power," which are the raw resources that are converted into the manifestations of force by linkage mechanisms.

Chaos theory is important because it describes what can happen when additional external force is introduced into open systems, or what happens when the linkages of power are severed. I wish to emphasize that the complex descriptions of self organization and potential stochastic chaos occur within *open systems* under the first law of thermodynamics! The impact of the second law of thermodynamics, and the resulting increased entropy, are only introduced if you first close the system and drive it to equilibrium. These distinctions are critical to center of gravity analysis and the development of strategy. For example, the decision to close a system involves eliminating the sources of energy. This is traditionally more difficult to accomplish and requires time. On the other hand a decision to destroy feedback mechanisms to precipitate stochastic chaos involves targeting linkages. These should normally be fewer, and the effects should be produced more rapidly.

Scaling Structures within Elements of Power

I have previously referenced chaos as showing that larger patterns of self-organization spring from few simple patterns that repeat themselves in a manner similar to fractal geometry. This occurs because of the self-referential nature of strange attractors where the behavior of one dimension is guided by the behavior of another hidden inside it.⁵⁶ We are reminded that "fractal" means an unending series of patterns that are repeated at smaller and smaller scales. The flexibility and strength of irregular fractal structure also permit adaptability and robustness within a system.⁵⁷

⁵⁶ Gleick, *Chaos*, p. 179, Barnsley and Demko, *Chaotic Dynamic and Fractals*.

⁵⁷ Goldberger, Rigony and West, "Chaos and Fractals in Human Physiology," *Scientific American*, p. 44.

This scaling effect manifests itself to produce outwardly recognizable and persistent patterns within human society. By inference, scaled patterns should exist within each of the elements of power that demonstrate self-similarity to the pattern as a whole. They should exhibit solidary, contractual, and antagonistic patterns with unbonded and multibonded characteristics. We should also see evidence of dynamic functions such as security, political, economic, cultural, and ideological activity repeated at these lesser scales. Analysis of these should assist in identifying operational and tactical centers of gravity. Let us explore the military element of power as an example.

At the value system level, military organizations normally reflect the conservative values of societies. Just as often, they display an internal code of military ethics and can possess their own justice system. Each service and smaller branch of service will commonly internalize their own sense of values and traditions right down to the unit level. These collective values are instilled into the psychology of new members to develop a will to cohesion and will to *esprit d' corps*. This becomes an unquantifiable but commonly acknowledged social-cultural force within all levels of military organization.

Militaries exhibit structural organizations based on solidary, contractual, or antagonistic guidelines, in effect reflecting the cultural basis of their societies. Solidary, unbonded organizations, however, are the prevalent type. Militaries normally take a "naturalistic" approach to the environment, thus their technology linkages and organizations mirror a pattern of land, sea, and air functional service structures.⁵⁸ These are often interconnected and overlapping from the strategic to the tactical level. Military economics also exist at all levels from defense acquisition and national structure to supply squadrons as tactical units. Logistics permeates the military element of power.⁵⁹

⁵⁸ For example see Martin van Creveld, *Technology and War, From 2600 B.C. to the Present*, (New York: The Free Press, 1989).

⁵⁹ Julian Thompson, *The Lifeblood of War, Logistics in Armed Conflict*, (London: Brassey's, 1991) and Martin van Creveld, *Supplying War, Logistics from Wallenstein to Patton*, (Cambridge: Cambridge University Press, 1977).

Sources of power within these scaled structures are the armed forces themselves as well as the logistical supplies. The linkages of power are transportation, C³I, and other combat service support. The manifestation of power, or force, is the consumption of logistics to produce military power itself. "Political" force within the military, acts to redistribute wealth and power, and this is evidenced in the military rank and command structures.

Scaled structures within the military element of power function with nonlinear dynamics just like the larger military organizations of which they are a part. Herein lay the operational and tactical centers of gravity. When analyzed, their linkage mechanisms will reveal both strengths and vulnerabilities. Substructures will demonstrate bias, in terms of predisposed values, traditions, "commander's intent," or standard operating procedures. Connectivity is just as important in the feedback process at the microscale as at the macroscale. Within military organizations, in particular, decision processes have been closely studied. The observation, orientation, decision, action (OODA) loop exists for all levels of combat from the individual up to strategic command and control.⁶⁰ Operational and tactical military organizations can exhibit self-organizing regularities, and they can be driven to crises points and stochastic chaos. Crises points can still be precipitated by closing the system down, by overloading one of the dimensional dynamics, by applying broad force against the entire system, or by eliminating feedback processes.

Just as scaling structures are evident within the military element of power, it is apparent they exist as well within the political, economic, social, and ideological elements of power. The framework could be easily filled in to illuminate the basic structures. Space forces me, however, to postpone this task and proceed with an analysis of higher level system dynamics.

⁶⁰ John R. Boyd, "A Discourse on Winning and Losing," a collection of unpublished briefings and essays, Air University Library, Document No MJ 43947, August 1987. Much of Boyd's work was developed in the mid 1970s. His essay on "Destruction and Creation" is particularly insightful. It anticipated many of the tenets of chaos theory, and is consistent with it.

Interdependence and Self-Compensation

The elements of power do not exist in rigid structures or fixed relationships. An important feature that emerges from chaos theory is the interdependence and self-compensating characteristics of systems. The interdependence exists vertically through scaling structures and horizontally across the elements of power. Self-compensation exists because of the dynamic self-referential nature of strange attractors that use feedback loops to keep systems functioning.⁶¹ I have constantly stressed the dynamic, evolving nature of patterns within the elements of power. Arising from value systems and culture, these patterns are unique to each individual society. Not only are the elements of power working with and reacting to each other, but the entire social system adjusts when subjected to external forces.

In wartime situations, the elements of power function differently than in peacetime. If targeted, an element of power adjusts from within to compensate, and draws upon resources from the other elements of power through interconnected linkage mechanisms. This is very evident within military systems. For example, the military can draw upon wartime reserves, roles and missions can be adjusted, joint task forces can be created, weight of effort can be reapportioned, and units can be reassigned. In addition, the other facets of society (elements of power) can be mobilized to support the military effort because they are interconnected. Interconnected dynamics can continue until the entire society is reoriented to a wartime footing in situations of total war.⁶² All this will occur in a dynamic manner that responds to the actions of the opponent—who is experiencing the same process. It is also time dependent and time sensitive.

Self-compensation and interconnectedness are also evident within the economic element of power. This area has been particularly studied because of traditional airpower

⁶¹ Barlow in his thesis, "Strategic Paralysis," (pp. 89-95) recognized these historical characteristics, but was unable to theoretically explain them. He approached interdependence and self-compensation as "assumptions."

⁶² For example see Raymond Aron, *The Century of Total War*, (Boston: Beacon Press, 1955).

targeting methods against economies.⁶³ The ability of robust industrial economic systems to interconnect with political and military requirements, and to adjust to wartime targeting is well documented.⁶⁴ The primary means of self-compensation are: use of economic slack, substitution, reallocation, reengineering, reconstitution, and increased productivity. Other work arounds include stockpiling, rationing, importing, smuggling, dispersing, and hardening assets as well as actively defending them.

While it is theoretically possible to destroy an entire element of power (source, linkage, and force) through rapid parallel or simultaneous campaigns, it is unlikely this could occur except in scenarios of massive force disparities. The most likely circumstance where this could happen would be in a condition of total war. Other potential situations would be to target a specific dimension of one or more elements of power—for example all political and/or all military linkages of power—in an attempt to drive a specific element of power to dysfunction. While it is possible to accomplish this objective, it is important to realize that it is extremely difficult. The more fundamental the element of power that is selected for targeting, the more difficult it becomes to effect core changes. For example, while military and political results are achievable, economic power can be very resilient, and deep cultural and ideological powers are almost immune to military force, short of total prolonged occupation.

The level of effort or energy expended against an adversary can only be achieved by offsetting amounts of energy from your own system. Even if it is "only" a few stealth platforms with precision weapons, the military, political, and economic sunk costs in these

⁶³ The United States Strategic Bombing Surveys (USSBS) provide a wealth of data on the European and Pacific theaters during WWII. An excellent overview of WWII airpower effects is found in R.J. Overy, *The Air War 1939-1945*, (New York: Stein and Day, 1981).

⁶⁴ Carl Kayser, "Note on Some Historic Principles of Target Selection," RAND, RM-189, 15 July 1949, Mancur Olson Jr, *The Economics of Wartime Shortage*, reprint (Ann Arbor: University Microfilms International, 1991). Alan S. Milward, *War, Economy and Society 1939-1945*, (Berkeley: University of California Press, 1979), and Alfred C. Mierzejewski, *The Collapse of the German War Economy, 1944-1945, Allied Air Power and the German National Railway*, (Chapel Hill: University of North Carolina Press, 1988).

systems will be found to be quite high. Furthermore, because the elements of power are interconnected, we must realize that targeting one of them will have a ripple effect that impacts them all to some extent. Depending on the society, one must define objectives and attempt to decide whether you want to confine disruption solely to one element of power (COG), to induce chaos throughout several COGs, or the whole society. A likely result is to precipitate localized, temporary periods of stochastic chaos followed by self organization at a lesser energy level (i.e., bifurcation).

Lastly, the strength, interconnectedness, and nature of self-compensation within the elements of power partly determine the courses of action available to a given social group. Societies will employ certain elements of power, or combinations thereof, based on their perceived advantages *vis-a-vis* a potential adversary. During the course of a dynamic conflict, societies will constantly appraise, innovate, and adopt new combinations of power to achieve different results. This is why some societies always use ideological weapons, some use cultural and economic elements of power, and others habitually adopt military and political/diplomatic options. Under conditions of total war, all must be focused together. However, groups can resort to low intensity conflict if they are at a significant disadvantage. This is often the strategy of choice for societies incapable of organizing or employing sophisticated military forces. It can also be adopted if societies have suffered stochastic destruction of military and economic power, but have self organized toward low intensity war because their ideological and cultural elements of power remain intact.

The permutations of this line of discussion are endless, and I have so far only explored the general organization of modern industrialized nation states. Using the same basic approach of searching for underlying structures and basic values, one would have to develop potentially different constructs for other forms of society. For example, one should expect to see distinctly different social structures for theological, ideological, and

ethnic oriented states. Likewise, sub-state actors, multi-national organizations and alliance systems would all have different forms, functions, and COGs because their underlying value systems are dissimilar. Essentially each social entity is unique, therefore COG analysis and strategy development begins by following Sun Tzu's imperative to know the enemy.⁶⁵

⁶⁵ Sun Tzu, *The Art of War*, ed. & trans. James Clavell, (New York: Delacorte Press, 1983), p. 13.

CHAPTER V

CONCLUSION

I have attempted to provide an overarching intellectual and philosophical basis for analyzing the center of gravity concept. In tracing the previously used historical approaches to center of gravity theory, I have highlighted some strengths, but more often I have shown their weaknesses. These theoretical shortcomings ultimately derived from the unconnected, unidirectional assumptions employed. In turn, these were usually based upon faulty Newtonian cause and effect logic. In combination, these two problems have made previous center of gravity theories, and their application, very tenuous at best.

In contrast, I endeavored to use a multi disciplined approach in this arena. I attempted to incorporate scientific, social science, and historical methodologies. I began with the obvious fact that warfare itself, and the entire notion of centers of gravity are based upon underlying social processes. If the social and cultural basis of centers of gravity could not be explained, then one could not hope to develop an adequate theory. Such a theory would remain suspended from reality and offer no confidence in useful application.

In developing a social underpinning, I primarily employed the new field of chaos theory to show the system dynamics involved. Only this approach seems to demonstrate the interconnected and complex relationships associated with social structures. I then proposed an integrated technique, examining the complexities of society and laying the basis for systematically identifying and disrupting centers of gravity. Importantly, it

shows the necessity of understanding and synthesizing the elements of power if one hopes to achieve success.

My construct is broad enough to apply to all types of societies, including alliances and non state actors. It is sufficiently relevant and flexible to encompass the entire spectrum of conflict – not just conventional military operations. This is a tremendous advantage over traditional center of gravity methodologies. The next task to build upon this initial foundation, and to explore more fully the strategy applications of this theory.

BIBLIOGRAPHY

Books

- Aron, Raymond. *The Century of Total War*. Boston: Beacon Press, 1955.
- Barnsley, M.F. and Demko, S.D, editors. *Chaotic Dynamics and Fractals*. New York: Academic Press, 1985.
- Booth, Ken. *Strategy and Ethnocentrism*. New York: Holmes and Meier, 1979.
- Calder, Nigel. *Einstein's Universe*. New York: Penguin Books, 1979.
- Clausewitz, Carl von. *On War*. ed. and trans. by Michael Howard and Peter Paret. Princeton: Princeton University Press, 1989.
- Clodfelter, Mark. *The Limits of Air Power, The American Bombing of North Vietnam*. New York: The Free Press, 1989.
- Coveney, Peter and Highfield, Roger. *The Arrow of Time*. New York: Fawcett Columbine, 1990.
- Craven, Wesley Frank and Cate, James Lea. *The Army Air Forces in World War II*. 7 Vol, reprint ed. Wash D.C.: Office of Air Force History, 1983.
- Crevelde, Martin van. *Technology and War, From 2000 B.C. to the Present*. New York: The Free Press, 1989.
- Crevelde, Martin van. *Supplying War, Logistics from Wallenstein to Patton*. Cambridge: Cambridge University Press, 1977.
- Douhet, Giulio. *The Command of the Air*. trans. Dino Ferrari. Wash D.C.: Office of Air Force History, 1983.
- Einstein, Albert. *Relativity; The Special and the General Theory*. trans. Robert W. Lawson. New York: Bonanza Books, 1961.
- Finney, Robert T. *History of the Air Corps Tactical School 1920-1940*. Wash D.C.: Center for Air Force History, 1992.
- Forrester, Jay W. *Industrial Dynamics*. New York: John Wiley & Sons, 1961.

- Forrester, Jay W. *Principles of Systems*. Cambridge: Wright-Allen Press, 1968.
- Gleick, James. *Chaos, Making a New Science*. New York: Penguin Books, 1987.
- Goldstein, Joshua S. *Long Cycles, Prosperity and War in the Modern Age*. New Haven: Yale University Press, 1988.
- Gribbin, John. *In search of Schrodinger's Cat, Quantum Physics and Reality*. New York: Bantam Books, 1984.
- Hansell, Haywood S. Jr. *The Strategic Air War Against Germany*. Wash D.C.: Office of Air Force History, 1986.
- Harris, Sir Arthur. *Bomber Offensive*. London: Greenhill Books, 1947.
- Hawking, Stephen W. *A Brief History of Time, From the Big Bang to Black Holes*. New York: Bantam Books, 1988.
- Heisenberg, Werner. *Physics and Philosophy*. New York: Harper: Torchbooks, 1962.
- Kauffman, Stuart A. *Origins of Order: Self-Organization and Selection in Evolution*. London: Oxford University Press, 1992.
- Krepinevich, Andrew F. Jr. *The Army and Vietnam*. Baltimore: Johns Hopkins University Press, 1986.
- Kuhn, Alfred. *The Study of Society, A Unified Approach*. Homewood, Illinois: Dorsey Press, 1963.
- Kuhn, Alfred. *The Logic of Social Systems*. San Francisco: Josse-Bass Pub., 1974.
- Lewin, Roger. *Complexity: Science on the Edge of Chaos*. New York: MacMillan, 1992.
- Mandelbrot, Benoit. *The Fractal Geometry of Nature*. New York: W.H. Freeman, 1983.
- Micrzejewski, Alfred C. *The Collapse of the German War Economy, 1944-1945, Allied Air Power and the German National Railway*. Chapel Hill: University of North Carolina Press, 1988.
- Milward, Alan S. *War, Economy and Society 1939-1945*. Berkeley: University of California Press, 1979.
- Mitchell, William. *Winged Defense: The Development and Possibilities of Modern Air Power - Economic and Military*. reprint edition. New York: Dover Publications, 1988.

- Morgenthau, Hans J. *Politics Among Nations*. New York: Knopf, 1973.
- Nicolis, Gregoire, and Prigogine, Ilya. *Exploring Complexity: An Introduction*. New York: W.H. Freeman, 1989.
- Niebuhr, Reinhold. *The Children of Light and the Children of Darkness*. New York: Charles Scribner's Sons, 1944.
- Olson, Mancur Jr. *The Economics of Wartime Shortage*. reprint. Ann Arbor: University Microfilms International, 1991.
- Ovary, R.J. *The Air War 1939-1945*. New York: Stein and Day, 1981.
- Penrose, Roger. *The Emperor's New Mind*. New York: Penguin Books, 1989.
- Prigogine, Ilya. and Stengers, I. *Order Out of Chaos*. London: Heinemann, 1984.
- Slotkin, J.S. *Social Anthropology, The Science of Human Society and Culture*. New York: MacMillan, 1950.
- Sorokin, Pitrim A. *Society, Culture, and Personality: Their Structure and Dynamics*. New York: Harper and Brothers Pub, 1947.
- Sun Tzu. *The Art of War*. ed. and trans. by James Clavell. New York: Delacorte Press, 1983.
- Tedder, Lord Arthur. *Air Power in War. The Lees Knowles Lectures by Marshal of the Royal Air Force*. London: Hodder and Stoughton, 1947.
- Thompson, J.M.T. and Stewart, H.B. *Nonlinear Dynamics and Chaos*. New York: Wiley Press, 1986.
- Thompson, Julian. *The Lifeblood of War, Logistics in Armed Conflict*. London: Brassey's, 1991.
- Waldrop, M. Mitchell. *Complexity: The Emerging Science on the Edge of Order and Chaos*. New York: Simon and Schuster, 1992.
- Waltz, Kenneth N. *Theory of International Politics*. Menlo Park: Addison-Wesley Pub Co., 1979.
- Warden, John A. III. *The Air Campaign*. Wash D.C.: National Defense University Press, 1988.

Warden, John A. III. "Employing Air Power in the Twenty-First Century," *The Future of Air Power in the Aftermath of the Gulf War*. ed. Richard H. Shultz Jr. and Robert L. Pfaltzgraff Jr. Maxwell AFB: Air University Press, 1992.

Wright, John W. ed. *The Universal Almanac, 1993*. New York: Universal Press, 1992.

Articles

Arthur, W. Brian. "Positive Feedbacks in the Economy." *Scientific American*. Feb 1990.

Bak, Per. and Chen, Kan. "Self-Organized Criticality." *Scientific American*. Jan 1991.

Beyerchen, Alan. "Clausewitz, Nonlinearity, and the Unpredictability of War." *International Security*. Vol 17 No 3. Winter 1992-93.

Crutchfield, James P., Farmer, J. Dooyne, Packard, Norman H., and Shaw, Robert. "Chaos." *Scientific American*. Dec 1986.

Gaddis, John Lewis. "International Relations Theory and the End of the Cold War." *International Security*. Vol 17 No 3. Winter 1992/93

Goldberger, Ary L., Rigney, David R., and West, Bruce J. "Chaos and Fractals in Human Physiology." *Scientific American*. Feb 1990.

Grebogi, Celso. Ott, Edward. and Yorke, James A. "Chaos, Strange Attractors, and Fractal Basin Boundaries in Nonlinear Dynamics." *Science*. Vol 238. 30 Oct 1987.

Holden, Arun. "Chaos in Complicated Systems." *Nature*. Vol 305. Sep 1983.

Izzo, Lawrence L. "The Center of Gravity is Not an Achilles Heel." *Military Review*. Jan 1988.

Kauffman, Stuart A. "Antichaos and Adaptation." *Scientific American*. Aug 1991.

Mandelbrot, Benoit. "How Long is the Coast of Britain? Statistical Self-Similarity and Fractional Dimension." *Science*. Vol 156. 5 May 1967.

Mann, Steven R. "Chaos Theory and Strategic Thought." *Parameters*. Vol XXII No 2. Autumn 1992.

- May, Robert M. "Biological Populations with Nonoverlapping Generations: Stable Points, Stable Cycles, and Chaos." *Science*. Vol 186. 15 Nov 1974.
- Metz, Steven. and Downey, Frederick M. "Centers of Gravity and Strategic Planning." *Military Review*. April 1988.
- Olson, Mancur Jr. "The Economics of Target Selection for the Combined Bomber Offensive." *Journal of the Royal United Service Institution*. Vol CVII, No 628. Nov 1962.
- Ruthen, Russell. "Adapting to Complexity." *Scientific American*. Jan 1993.
- Sander, Leonard M. "Fractal Growth Processes." *Nature*. Vol 322. 28 Aug 1986.
- Schneider, James J. and Izzo, Lawrence L. "Clausewitz's Elusive Center of Gravity." *Parameters*. Sep 1987.
- Smarr, Larry L. "An Approach to Complexity: Numerical Computations." *Science*. Vol 228 No 4698. 26 Apr 1985.
- Winton Harold R. "A Black Hole in the Wild Blue Yonder. The Need for a Comprehensive Theory of Air Power." *Air Power History*. Vol 39 No 4. Winter 1992.
- Wolf, Alan. "Simplicity and Universality in the Transition to Chaos." *Nature*. Vol 305. Sep 1983.
- Zabusky, Norman J. "Grappling with Complexity." *Physics Today*. Oct 1987.

Documents, Studies, and Miscellaneous

- AFM 1-1, *Basic Aerospace Doctrine of the United States Air Force*. Vol 1. Wash D.C.: Department of the Air Force, March 1992.
- Boyd, John R. "A Discourse on Winning and Losing." collection of unpublished briefings and essays, Air University Library, Doc No MN 43947. Aug 1987.
- Barlow, Jason B. "Strategic Paralysis: An Airpower Theory for the Present." unpublished thesis, School of Advanced Airpower Studies, Air University. May 1992.
- Cecchine, Meg. and Hoyer, Mark. "Applying System Dynamics to Effective Air Campaigns." RAND, PM-106-A7. Jan 1993.

FM 100-5, *Operations*. Wash D.C.: Department of the Army, May 1986.

FMFM-1, *Warfighting*. Wash D.C.: US Marine Corps, 6 Mar 1989.

Hoapili, Evan J. "Carl von Clausewitz: Hope and Fear." unpublished paper, Naval War College. 3 February 1992.

Joint Pub 1, *Joint Warfare of the US Armed Forces*. Wash D.C.: US Government Printing Office, 11 Nov 1991.

Kaysen, Carl. "Note on Some Historic Principles of Target Selection." RAND, RM-189. 15 July 1949.

Lambeth, Benjamin S. and Lewis, Kevin N. "Economic Targeting in Modern Warfare." RAND, P-6735. July 1982.

Lewis, Kevin N. "Strategic Bombing and the Thermonuclear Breakthrough: An Example of Disconnected Defense Planning." RAND, P-6609. April 1981.

Mark, Edward. *Case Studies in Air Interdiction*. unpublished draft, Office of Air Force History, n.d.

Sallagar, F.M. "Operation 'STRANGLE' (Italy, Spring 1944): A Case Study of Tactical Air Interdiction." RAND, R-851-PR. 1972.

Shlapak, David A. "Exploring Paralysis: An Introduction to the Study." RAND, PM-107-AF. Dec 1992.

United States Congress, Senate. Committee on Armed Services. *Situation in Bosnia and Appropriate U.S. and western Responses*. Hearings before the Committee on Armed Services, Senate. 102nd Congress, 2nd sess. 11 August 1992.

Warden, John A. III. "Strategic Warfare, The Enemy as a System." Draft Manuscript. 1993.