Combat Assessment of Non-Lethal Fires: the Applicability of Complex Modeling to Measure the Effectiveness of Information Operations

A Monograph

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AY 01-02

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REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 074-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing this collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	23 May 2002	Monograph

4. TITLE AND SUBTITLE
Combat Assessment of Non-Lethal Fires: the Applicability of Complex Modeling to Measure the Effectiveness of Information Operations

5. FUNDING NUMBERS

6. AUTHOR(S)
LTC Jeffrey J. Goble

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
School of Advanced Military Studies
250 Gibbon Ave.
Fort Leavenworth, KS 66027

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Army Command and General Staff College
Fort Leavenworth, KS 66027

10. SPONSORING / MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE
A

13. ABSTRACT ***(Maximum 200 Words)***

See Attached

14. SUBJECT TERMS

15. NUMBER OF PAGES
52

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
U	U	U	none

SCHOOL OF ADVANCED MILITARY STUDIES

MONOGRAPH APPROVAL

Lieutenant Colonel Jeffrey J. Goble

Title of Monograph: Combat Assessment of Non-Lethal Fires: the Applicability of Complex Modeling to Measure the Effectiveness of Information Operations

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Accepted this 23d Day of May 2002

Abstract

COMBAT ASSESSMENT OF NON-LETHAL FIRES: THE APPLICABILITY OF COMPLEX MODELING TO MEASURE THE EFFECTIVENESS OF INFORMATION OPERATIONS by LTC Jeffrey J. Goble, U.S. Army, 47 pages.

Military forces conduct information operations against one of the most complex, adaptive systems – the human mind. Linear thought processes, prevalent in the military, correspond to, and understand well, the linear mathematics that measure the effects of lethal fires. They do not lend themselves well to the thinking necessary for understanding the effects of non-lethal fires on the complex adaptive system of the human mind. While each of the capabilities of information operations (IO) has individual Measures of Effectiveness (MOE), the cumulative effects they achieve, once integrated and synchronized in IO, are not simply a sum of each of the capabilities' MOE. Nevertheless, these non-lethal systems, synchronized in information operations, must have predictive effects in order for commanders to employ them with confidence. Therein lies the problem; comprehensive MOE for information operations do not exist.

The study of complex adaptive systems is a relatively new field of scientific study. Much of the study to date has been dedicated to developing non-linear mathematical models to measure complex adaptive systems found in nature such as ice, the human genome, and populated inner cities to name a few. The monograph determines that the military can use complexity science to predict and measure the effects of information operations in the same manner as linear mathematical models predict and measure the effects of kinetic weapons.

Complexity science is a body of knowledge whose epicenter is the Santa Fe Institute in Santa Fe, New Mexico. The institute's scientists are the noted experts in the growing field of complexity. The monograph determines that the military must tap into this expert body in order to develop operationalized complexity models for use in planning, executing, and measuring the effects of information operations. It uses the historical analogy of the U.S. Air Force's efforts to establish the RAND Corporation in the 1940s to conclude that capitalizing on expert scientific capability in the non-profit, civilian sector is more efficient, and effective, than building a similar capability resident in the military structure.

Combat Assessment of Non-Lethal Fires: the Applicability of Complex Modeling to Measure the Effectiveness of Information Operations

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CHAPTER 1. INTRODUCTION

"Whoever has the best coup d'oeil will perceive at first glance the weak spot of the enemy and attack him there."
Fredrick the Great[1]

Joint Publication 3.09, Doctrine for Joint Fire Support, defines fires as the effects of both lethal and non-lethal weapons. Lethal fires are the effects achieved by traditional kinetic weapons systems such as aerial bombs, artillery, rockets, and missiles. Non-lethal fires are the effects achieved by weapons systems such as electronic warfare, psychological operations, and other capabilities of information operations (IO) that minimize damage and injury to personnel. The joint force and component commanders must synchronize a variety of fires in time, space, and purpose to mass effects in order to achieve the operational concepts of Joint Vision 2020.

Military forces apply lethal fires through the joint targeting process in contemporary U.S. warfare. This process targets adversary systems studied and mapped using linear mathematical models. The process incorporates similar models to predict the combat effects of kinetic weapons on these adversary systems. Thus, the measures derived from the targeting process tend to be linear. Similarly (and in large part because of), the thinking of commanders employing these weapons tends to be linear in nature.[2] Their thinking tends to focus on how to destroy or defeat the adversary using the kinetic systems at their disposal. Linear thinking has been sufficient in making decisions applying kinetic/conventional weapons systems on linear battlefields. However, the world is becoming more complex, and so is warfare. This more complex environment requires a systems approach to thinking and decision-making. It also requires qualitative judgments from commanders, without the benefit of quantitative data such as correlation of forces estimates or battle damage assessment reports. Because senior leaders, in particular,

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[1] "The Instruction of Frederick the Great for His Generals, 1747," trans. T.R. Phillips in *Roots of Strategy*, ed. T.R. Phillips (Harrisburg, PA: Stackpole Books, 1985), 342.

[2] Chapter 3 explains the concepts of linearity and non-linearity in depth. The properties of proportionality and demonstrability in linearity result in direct cause and effect relationships between variables. In this case, military decision-making skews toward the proportional, and demonstrable, cause and effect relationships between kinetic weapons and their visible effects. For example, if we drop a bomb on a building, then the bomb will destroy it.

have been trained and educated in linear thought processes, it will take time to train, educate, and groom senior leaders who feel comfortable making qualitative decisions in the complex battlespace of the 21st century.

Accurate predictive effects of weapons systems, be they lethal or non-lethal, are necessary in order to build confidence in the minds of commanders employing them. Commanders employ lethal fires with confidence, because of the predictive nature of the effects of the weapons systems. The years of experience they have in employing kinetic systems against myriad adversaries enable them to visualize the cumulative effects of these systems. This is their vision or "coup d'oeil."

Military forces conduct information operations against one of the most complex adaptive systems known – the human mind. Linear thought processes, prevalent in the military, correspond to, and understand well, the linear mathematics that measure the effects of lethal fires. They do not lend themselves well to the thinking necessary for understanding the complex adaptive system of the human mind. While each of the capabilities of IO has individual Measures of Effectiveness (MOE), the cumulative effects they achieve, once integrated and synchronized in IO, are not simply a sum of each of the capabilities' MOE. Nevertheless, these non-lethal systems, synchronized in information operations, must have predictive effects in order for commanders to employ them with confidence. There in lies the problem; comprehensive MOE for information operations do not exist.

The study of complex adaptive systems is a relatively new field of scientific study. Much of the study to date has been dedicated to developing non-linear mathematical models to measure complex adaptive systems found in nature such as ice, the human genome, and populated inner cities to name a few. This monograph determines that the military can use complexity science to predict and measure the effects of information operations in the same manner that linear algorithmic models predict and measure the effects of kinetic weapons.

Complex Environment

From the geopolitical to the local family and village levels of the world's societies, the post cold-war world, of the past 10 years, is incredibly complex. According to Samuel P. Huntington, seven or eight major civilizations typify the contemporary geopolitical landscape, rather than the two major superpowers of the cold war. The cultural commonalties and differences between these civilizations will shape the interests of states within the nation-state system.[3] Major actors on the international scene come from different civilizations: the United States from the western civilization, China from the Sinic civilization, Russia from the Orthodox civilization, and Japan from a distinct civilization of its own. Although there are other contending theories of geopolitical organization of the post cold war world, there is no doubt that the world is, and continues to become, more multi-polar, multicultural, and multi-civilizational. Multiplicity adds to complexity if for no other reason than pure numbers. Understanding multiple cultures and civilizations, in competition on the world stage, is much more complex than understanding two of them.

The U.S. Army calls the complex environment in which it operates the Contemporary Operating Environment. There are many types of actors in the complex, contemporary operating environment. Some of the actors are nation states and some are not. As Huntington points out, civilizations will play a role, albeit in influence alone, in the politics of the globe of the future. Some power is shifting to nontraditional actors and transnational concerns such as international drug cartels, international terrorist organizations, the media, and multi-national corporations. There are many potential challenges to traditional concepts like balance of power, sovereignty, national interest, and roles of nation-state and non-state actors. Of course, not all actors are threats. The capabilities of actors that are a concern to the military are not necessarily purely military, but encompass all the elements of power available to an actor.[4]

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[3] Samuel P. Huntington, *The Clash of Civilizations: Remaking of World Order* (New York: Simon and Schuster, 1996), 29.

[4] Department of the Army, *FM 7-100 Opposing Force Doctrinal Framework and Strategy* (Washington, D.C.: U.S. Government Printing Office, 2001) VI.

One aspect of the contemporary operating environment is certain; the human dimension plays a significant role. Cultures, clans, tribes, families, and even individual people play a defining role in the relationships between actors on the world stage. Whether it be the dynamic personality of a dictatorial leader like Slobodan Milosevic, the misplaced hatred of a teenage fundamentalist resident of the West Bank, or the desperate struggle of a family of refugees in Southern Sudan, military operators will confront the complex adaptive system of the human mind in military operations of the future like never before.

Linear Thinking and Commanders' Confidence

Once committed as an instrument of national power (by political leadership) in the contemporary operating environment, the employment of weapons and forces in military operations is a commander's prerogative. He alone decides when to commit forces to battle and what weapons and firepower to bring to bear on the enemy. How does he know how much, where, and when? Fredrick the Great calls the ability to do so "coup d'oeil": the commander's ability to see the battle before it takes place; to know when and where the decisive point will be. Military leader development almost totally focuses on developing this ability in leaders.

Gen. (Retired) Fred Franks, former commander of VII (US) Corps, describes his constant efforts to develop his coup d'oeil in the book *Into the Storm,* written by Tom Clancy. He describes this vision as "the ability to picture operations in your head, and to judge time/distance factors to get the right units, in the right combination, at the right place, at the right time."[5] He attributes the ability to think this way to a lifetime of experience, education, and training. He also believes that, in a small measure, a leader's ability to think creatively about operations is an inherent natural ability as well as something that must be deliberately developed. "Some commanders are better than others at orchestrating a battle. For some it is a learned skill; for others it comes more easily."[6]

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[5] Tom Clancy with General Fred Franks, *Into the Storm* (New York: G.P. Putnam's Sons, 1997), 15.

[6] Gen. Fred Franks, U.S. Army (Retired), interview by author, 26 February 2002, Fort Leavenworth, Kansas.

During General Franks' command, VII (US) Corps was the main ground effort in OPERATION DESERT STORM, and was ultimately responsible for the defeat of the much-touted Iraqi Republican Guard. The five division, 146,000 man VII Corps attacked on an axis 250 kilometers in length, spanning a front of over 100 kilometers, across the Iraqi desert. In 89 hours of constant combat, it destroyed the better part of eleven Iraqi divisions. To accomplish such a feat, the Corps had to deploy to an austere theater from both Europe and the United States. It deployed, planned, trained for, and rehearsed one of the greatest armored operations in the history of modern warfare in a matter of three months, from a cold start.

The operations of VII Corps in DESERT STORM did not go as smoothly as may be surmised from the description above. In his book, Clancy describes an on going and constant tension between VII Corps and its higher headquarters and leaders, in particular General Schwarzkopf, the Commander of U.S. Central Command and the overall commander during DESERT STORM. While General Franks and VII Corps accounted for the myriad variables in the complex operation they faced, in particular the enemy to their front and their own immense organization, General Franks did not fully account for the influence of, nor completely understand, the relationship between his organization, the other joint and combined components, and the Joint Force Command. He realizes now that these were key variables in the complex system he was dealing with, and understands that they were present at the time, but could not affect them and their impact on the overall success of his operation.[7] One reason for this is that the patterns and experiences of joint operations, which he developed over a majority of his career serving and commanding in Europe, were not applicable to joint operations in U.S. Central Command. He did not possess a fully accurate mental model of the operational environment.

[7] Ibid.

The use of mental models in naturalistic decision-making is a growing field of research into how people in general, and leaders and managers in particular, make decisions.[8] This field of research studies how people use their experience to make decisions. Again, theorists and practitioners of military art and science, such as Fredrick the Great, Carl von Clausewitz, and General Franks, place great emphasis on experience in developing a vision of operations. If this experience develops mental models that are not applicable to, or are incomplete concerning, a certain situation, the vision of the decision-maker will be incomplete. This could lead to poor decisions and unintended outcomes. In the case of General Franks in DESERT STORM, his mental models of joint operations developed in Europe were not applicable to U.S. Central Command fighting in the Iraqi desert.[9]

This leads to the problem of commanders' confidence in synchronized information operations. Until commanders gain experience employing non-lethal fires, and are able to see tangible results, they will not choose to apply them. They will continue to make decisions about the applications of systems at their disposal based on the experiences and mental models they currently possess. This means a continued reliance on lethal fires to achieve desired results. If they do not learn to employ non-lethal fires with confidence, they will not gain the experience and develop the mental models necessary to support their decisions to do so.

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[8] Gary Klein, *Sources of Power: How People Make Decisions* (Cambridge, MA: MIT Press, 1999), 1. Peter M. Senge, *The Fifth Discipline: The Art and Practice of The Learning Organization* (New York: Currency Doubleday, 1990), 17. Senge and Klein are two of the authors/theorists/researchers working in the field of naturalistic decision-making. Klein's work focuses on how people use their experience to make decisions. Senge coin's the term "Mental Models" in reference to his attempt to explain why organizations fail to adapt, change, or implement new ideas. Mental Models are analogous to individual experiences that people use to formulate decisions. Chapter three of the monograph explains how some types of systems/organizations adapt (or fail to do so) using the theories of complexity.

[9] Gen. Fred Franks, U.S. Army (Retired), interview by author, 26 February 2002, Fort Leavenworth, Kansas.

The Need for MOE for IO

Joint Vision 2020 embodies the vision of the future U.S. military force. It envisions a military that achieves and exploits information superiority over adversaries. That is, one that knows more about the adversary and the battlefield than the adversary does, and applies this knowledge to make decisions about operations quicker than the adversary can. An essential aspect of achieving information superiority is conducting information operations. Information operations involve actions taken to affect adversary information and information systems while defending one's own information and information systems.[10] The focus of information operations is the adversary decision-maker. If U.S. forces can deny the adversary decision-maker information relevant to his decision-making, and create or protect the information relevant to its own, through information operations, they will make decisions in battle quicker and ultimately prevail in conflict or war.

Military scientists produced a large body of work concerning information superiority and information operations over the past 10 years. This body of work touts the potential revolutionary results in battle that information operations can achieve. Myriad lessons learned, from the Gulf war, through the peace operations of the 1990s, up to the recent combat experiences in the Former Yugoslavia and Afghanistan praise the effects of the elements of information operations. Despite the praise, analysts did not, or could not, directly attribute combat success to any single element of information operations, let alone the synchronized effects of several of the elements. Take the DESERT STORM vignette of the 10,000-pound bomb dropped on a republican guard unit.[11] Coalition Psyop informed a Republican Guard unit, through leaflets and radio broadcasts, that the coalition was going to drop the largest conventional bomb in the world on its positions, in an effort to have the unit cease resistance and surrender. The

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[10] Department of Defense, *JP 1.02, DOD Dictionary of Military and Associated Terms* (Washington, D.C.: Government Printing Office, 2001) in Joint Electronic Library, Internet, http://www.dtic.mil/doctrine/jel/doddict/data/i/02581.html, accessed 24 February 2002.

[11] The U.S. Army Special Warfare Center and School, Ft. Bragg, NC, uses this vignette in the Psychological Operations Officers Course. The author attended this course in 1994 and obtained knowledge of this vignette from unpublished lectures there.

Coalition eventually dropped the bomb and destroyed the unit after it remained in position. Over the next several days, the coalition delivered similar Psyop leaflets to adjacent units. Soon, the units began to displace. Did the units displace because of orders they received? Were the moves pre-planned, or did the Psyop activities or the initial bombing influence the Iraqi commander? Did the rank and file of the units mutiny because of an effect of their sister unit's destruction? These questions are difficult to answer at best, let alone in a timely enough manner to influence a commander's decision-making.

The lessons learned from this vignette attribute the unit displacements to the cumulative and synchronized effects of the non-lethal Psyop fires and the lethal fire of the 10,000-pound bomb. Nevertheless, the effects of non-lethal weapons, like Psyop and the other elements of information operations, remain secondary in the decision-making and planning processes of military operations. Commanders find it difficult to rely on systems that lack quantifiable measures of effectiveness. The following quote of SSG Edward Fivel, 9th Battalion, 4th Psyop Group in DESERT STORM illustrates this point. "We had to convince the company commander of our parent unit to let us Psyop people [*sic*] try ousting those Iraqi soldiers from their underground bunker."[12] SSG Fivel and his detachment eventually succeeded in convincing 400 Iraqi soldiers to surrender; yet, they had to convince their parent company commander to initiate the Psyop. Once the commander and the rest of his battalion from the 101st Airborne Division saw the tangible results of the Psyop, they continued to employ their Psyop assets with confidence. Without such tangible proof of IO effectiveness, and reliable means to measure it, commanders will continue to default to the application of kinetic weaponry to win decisive engagements.

[12] F.L. Goldstein and D.W. Jacobowitz, "Psyop in Desert Shield/Desert Storm," in *Psychological Operations Principles and Case Studies,* ed. F.L. Goldstein and B.F. Findley (Maxwell Air Force Base, AL: Air University Press, 1996) 352.

> A principle found in the Marine Corps *Small Wars Manual* of the 1930s is now widely accepted. Warfare must transcend material destruction of property and populations to deal with the underlying economic, sociological, religious, and ethnic issues of society at large. The operational objective alluded to in this manual from the 1930s, as today, was not to kill noncombatants but to bend them to our will and prevent them from obstructing the mission.[13]

Future military operations must fully leverage the synchronized effects of non-lethal fires to minimize challenges associated with the use of lethal force. By doing so, military forces can gain myriad effects, including minimized collateral damage and reduced friendly risk, required in the contemporary operating environment. Employing the types of systems capable of achieving such effects and objectives requires a fundamental shift in the thinking of commanders. Until commanders build confidence in the effects of non-lethal fires, achieving this shift in thinking is doubtful. Commanders need something to bridge the gap and break out of this perpetual "do" loop. Quantifiable measures of effectiveness for information operations can bridge this gap. Quantifiable and timely MOE can serve to bolster commanders' confidence in non-lethal fires until they can gain experience in using them and develop their own mental models as to how the effects of non-lethal fires can lead to military success.

[13] Michael M. Smith and Melinda Hofstetter, "Conduit or cul-de-sac, Information flow in civil military operations," *Joint Force Quarterly* 21 (Spring 1999): 101.

CHAPTER 2. THE MILITARY'S EFFORTS TO DATE

Currently, the U.S. military measures the effects of IO on adversaries by measuring the effects of the individual IO capabilities independently. Since most of the individual elements of IO existed before the military developed the integrating and synchronizing function of IO, methods for measuring their effectiveness did as well. IO focuses, however, on the benefit of synergistic effects of the individual elements. As illustrated in the introduction, commanders require comprehensive, quantitative measures of the total synchronized effects of IO to employ them with confidence. This is a difficult task given the disparate nature of the individual capabilities, how they are planned, and the targets upon which they focus. Merely adding up the individual effects does not begin to capture their cumulative and synergistic relationship. In addition, quantitative measures that document IO effects are difficult to develop because effects on the human mind, a complex adaptive system, are better measured qualitatively.

Targeting and the MOE for the Individual Capabilities of IO

Major elements of IO include Physical Attack/Destruction (PD), Psychological Operations (Psyop), Electronic Warfare (EW), and Military Deception (MD). There are also two significant related activities: Public Affairs and Civil Affairs. Although there are many other capabilities and related activities considered, integrated, and synchronized by commanders and IO planners, the first four capabilities listed above are those that contribute the most to military operations through direct offensive employment. To attempt to understand the specific MOE for each of the myriad capabilities and related activities of IO is outside the scope of this monograph. Yet, to understand the difficulty in comprehensively measuring the effects of these activities, once integrated and synchronized together into an information operation, it is beneficial to understand how some of the major IO elements are measured individually.

As stated in the introduction, Joint Force Commanders (JFCs) plan for and employ fires, both lethal and non-lethal, through the Joint Targeting Process. The latest version of Joint Publication 3.60,

Joint Doctrine for Targeting, includes a step in this process for Combat Assessment of both lethal and non-lethal fires.[14] The Combat Assessment step attempts to apply useful measures of effectiveness for all fires, to assess their overall impact on operations; however, it does not delineate assessment tools for non-lethal fires.

There are three major parts of the combat assessment step of the Joint Targeting Process: Battle Damage Assessment (BDA), Munitions Effectiveness Assessment (MEA), and Re-Attack Recommendations (RA). BDA and MEA are the specific parts that deal with applying measurable criteria for the effects of fires. BDA has to do with the damage or effects inflicted on a specific target and/or target system selected for attack during the previous steps of the targeting process. MEA relates to the performance of a particular weapon system in attacking a particular target.

There are three important aspects of BDA. First, physical damage assessment takes place to answer the question: "was the particular target struck with the chosen weapon or not?" Second, functional damage assessment takes place to answer the question: "was the particular target functionally damaged or effected in the manner desired?" Lastly, target system assessment attempts to answer the question "was the adversary system, that the particular target was a part of, effected in the desired manner?" The three important aspects of BDA are logically linked to proceed from a micro-level examination of the damage or effect inflicted on a specific target, to ultimately arriving at macro-level conclusions regarding the functional outcomes created in the target system.[15] Consequently, a critical ingredient for effective BDA is detailed familiarity with all aspects of the analysis performed during the target development that justified the chosen targets.[16]

Physical Destruction

The joint forces possess very effective and useful models to target linear (yet complicated) adversary systems with lethal fires. Therefore, commensurate with targeting these systems effectively,

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[14] Department of Defense, *JP 3.60, Joint Doctrine for Targeting* (Washington, D.C.: Government Printing Office, 2002).

[15] Ibid, II-9.

they also have effective means and processes to assess the effectiveness of attacks on these systems. Targeting, as are most military planning processes, is an intelligence intensive planning activity. Intelligence agencies throughout the joint force dedicate immense time and resources to study potential adversaries from the standpoint of targeting their critical systems.[17] These agencies provide products and services to joint force lethal targeting organizations to assist in lethal fire planning.

Most of these agencies use complicated systems modeling techniques to map critical adversary systems for targeting. The types of systems traditionally mapped/modeled for lethal attack planning include: petroleum, energy, and other power production and distribution systems; transportation systems, including road, rail, and air; and communications systems, including but not limited to command and control and integrated air defenses. Models identify critical nodes and links in the systems that if attacked, will achieve a desired effect on the system as a whole. For example: In a rudimentary telephone communications system there are the telephones themselves (nodes), the lines that connect them (links), and switches to route calls from one device to another within the system (link and node). A military force wanting to affect this system has a choice of targeting any or all of these links and nodes to achieve a desired result. Because of a limited amount of assets available to attack the system, the attack should focus on the minimum number of links or nodes to achieve the effects desired.

The types of information traditionally included in a system model of the example rudimentary telephone system are the locations of as many of the switches, lines, and devices in the system (links and nodes) as possible. It also includes as much detailed information as possible about each link and node, and its relationship to the rest of the system. For example: the capacity of a certain phone line, the capacity of a certain switching station, and the maintenance capability of the adversary to repair each node and link if it is damaged. If there are gaps in the intelligence information available on the links and

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[16] Ibid.

[17] The association of specific intelligence agencies with their respective capabilities and support to Joint Force Targeting is often classified. While it would be more useful (for the reader) to include these classified relationships, it is not necessary for a conceptual understanding of systems modeling in support of lethal fires targeting.

nodes within the system, analysts use predictive modeling techniques to fill the gaps, in an attempt to map out the system in as much detail as possible.

Once the map is as complete as possible, analysis of the system, again using the same or similar modeling techniques, attempts to determine critical links and nodes within the system. This is very similar to the Army planning technique of identifying high value and high payoff targets. Coupling this information with commander's guidance and desired objectives, targeteers working the targeting process identify specific targets within the system to attack in order to achieve the desired results. For example: if a commander wants to disable the telephone system for a certain period, rather than completely destroy it, targeteers can input this desired effect into the system model of the telephone network. The model then determines what specific links and nodes to attack within the system to achieve the desired effect. A complete system model can determine that a certain switch, if destroyed, will disrupt the functioning of the system for the period it takes to either reroute traffic around that switch or repair it. If that period meets the commander's requirements, the system model has identified the appropriate target.

The detailed information about the system, built into the model, also assists in identifying the appropriate capability to employ to attack specific targets. For example: if the selected target is a switching station within a building in a built-up area, this may call for precision-guided munitions. If it is an underground bunker, the model can also develop recommended types and amounts of ordinance using inputs from the Joint Munitions Effects Manual (JMEM).[18]

As stated earlier, detailed familiarity with all aspects of the analysis performed in target development, that justified the chosen targets and their linkage to the JFC's objectives and guidance, is necessary to conduct proper combat assessment. In the telephone system example, targeteers identified the MOE for the physical destruction of targets within the system throughout the target selection process. The commander desired to disrupt the system for a certain period, the target location required precision munitions, and the fortification of the switching station dictated the ordinance type and amount. A

[18] The JMEM is a classified joint reference manual that lists the capabilities of munitions within the U.S. weapons inventory.

significant aspect of using these types of quantitative models in targeting is that they are predictive of physical results.

The pieces of information identified by the system model of the telephone system guide the Combat Assessment Process following the attack on the system. Therefore, the MOE come out of the models used to identify and plan targets in the targeting process. These questions now form the basis for intelligence collection requirements necessary to confirm the results of attacks predicted by the systems models. First, did the delivered munitions strike the targeted telephone switch? The answer to this question often comes from the pilot delivering the munitions or the artillery observer controlling the indirect fires on the target. Second, did the munitions destroy the switch? This intelligence requirement often requires some other intelligence collection asset to answer it. In many cases, aerial imagery provides the answer; in other cases, intelligence such as SIGINT or ELINT must determine whether the switch is still functioning. Lastly, did the attack disrupt the telephone system for the period desired by the commander? This question most assuredly requires an all source intelligence effort to collect on aspects of the complete system performance and analyze whether or not it is functioning effectively or not. Again, the detailed knowledge of the system, provided by the system model, enables intelligence collection managers to focus their assets on specific links and nodes within the system to determine its functionality. Thus, the premise in JP 3.60 that targeting is an intelligence intensive activity. Intelligence support is vital to the analysis performed during target development, to prepare for targeting during the execution of operations (e.g., to pre-task real-time ISR assets), and to support combat assessment of success.[19]

Psychological Operations

"Psychological Operations are planned operations to convey selected information and indicators to foreign audiences to influence their emotions, motives, objective reasoning, and ultimately the behavior

[19] Department of Defense, *JP 3.60, Joint Doctrine for Targeting* (Washington, D.C.: Government Printing Office, 2002), II-3.

of foreign governments, organizations, groups, and individuals. The purpose of psychological operations is to induce or reinforce foreign attitudes and behavior favorable to the originator's objectives."[20] Psyop planners use a planning system, similar to the joint targeting process, to plan and develop Psyop. This process is called the Psyop Cycle.[21] Just as in targeting for lethal fires, the MOE for Psyop derive from information garnered throughout the Psyop Cycle.

The Psyop cycle has three steps: assessing, planning, and executing. All three steps focus on the identification of target audiences of Psyop (Psyop Targets). The Psyop Cycle does much more than just identify target audiences, it develops detailed knowledge of the target audiences necessary to properly plan and execute Psyop. The cycle is not a step-by-step process but a continuous cycle, thus its name – Psyop Cycle. In the Psyop Cycle, Psyop planners use several linked processes to develop their detailed knowledge of target audiences. Using these linked processes, they develop products to reach these audiences with developed messages, identify the means to disseminate these products, and identify the means to measure their effect on the targeted audiences. The processes are Intelligence gathering, Target Audience Analysis, Product Development, Media Selection and Dissemination, and Impact Assessment. Psyop planners need to understand how the Psyop Cycle develops Psyop in order to measure its effects on intended target audiences the same as lethal targeteers need intimate familiarity with how the Joint Targeting Process develops targets in order to conduct combat assessment.

Target audience analysis is an essential part of the Psyop Cycle, and is where planners conceive Psyop MOE. Target audience analysis is a detailed, systematic examination of Psyop intelligence to select target audiences that, if affected, will contribute to accomplishment of the Psyop mission, which

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[20] Department of Defense, *JP 1.02, DOD Dictionary of Military and Associated Terms* (Washington, D.C.: Government Printing Office, 2001) in Joint Electronic Library, Internet, http://www.dtic.mil/doctrine/jel/doddict/index.html, accessed 1 March 2002.

[21] Department of the Army, *FM 33-1-1 Tactics and Techniques for Psychological Operations* (Washington, D.C.: Government Printing Office, 1994) in Training and Doctrine Digital Library, Internet, http://www.adtdl.army.mil/atdls.htm, accessed 13 October 2001. Chapter 3 of this manual explains Psyop planning and the Psyop cycle. Chapter 6 explains the Target Audience Analysis process. The information contained in this section on Psyop Measures of effectiveness summarizes these chapters.

ties to the commander's overall objectives. Target audience analysis identifies the ability, vulnerability, susceptibility, accessibility, and impact indicators present in the target audience.

Audience ability has to do with the ability of the target audience to carry out the behavior desired by the commander. For example, if the commander wants the adversary to surrender, do opposing force soldiers have the ability to surrender or will their commanders shoot them attempting to do so? In this step, planners attempt to answer the question "does the target audience have the means to carry out the behavior desired?" Determining audience vulnerability concerns identifying any physical or moral aspects of the audience, which make them particularly vulnerable to Psyop. For example, if the adversary unit, targeted for surrender, is separated from their supply base for a considerable time, they may be vulnerable because of a lack of food, water, or ammunition. This step attempts to answer the question: "are there vulnerabilities present in the target audience which Psyop can exploit?" Audience susceptibility continues to build on the previous identified aspects of the audience by determining whether (or not) they may be susceptible to Psyop messages. For example: if the unit in question is without food and water, they may be susceptible to promises of food and water if they surrender. This step in the analysis process attempts to answer the question: "how can we take advantage of an audience vulnerability?" Accessibility of the audience has to do with whether, and through what means, Psyop can reach the audience. For example, if the unit in question is separated from their supplies for some time, they may not have battery or generator power to run their radios. Therefore, they would not likely receive or hear radio broadcasts. This step attempts to answer the question: "can we reach the audience through any particular dissemination means."

The final step in the Target Audience Analysis Process concerns impact indicators. In short, impact indicators are MOE for Psyop on a particular audience. They are the expected changes or events with respect to the target audience that can then be collected on and analyzed to determine whether the Psyop was effective. Since the process used in target audience analysis is much more subjective than the systems modeling used in kinetic targeting, so to are the impact indicators resulting from this process. Nevertheless, when properly identified, collected on, and analyzed, impact indicators resulting from the

Target Audience Analysis Process provide reliable judgments as to the effectiveness of Psyop activities. When possible, analysts attempt to express impact indicators as a percentage of increase or decrease in a specified activity. As an example, refer again to the surrendering unit. If the unit in question had safe conduct pass leaflets airdropped to them, what percentage of surrendering soldiers had these passes in their possession when surrendering. Alternatively, what percentage of soldiers in the unit actually surrendered? Impact indicators can be either positive or negative in nature. "A positive impact indicator correlates directly with the Psyop effort. A negative impact indicator is an event or a change opposite that desired by the Psyop."[22] The example just used seeks a positive indicator. An example of a negative indicator might be fewer defectors despite a massive program to convince them of the benefits and advantages of surrendering. Analysts must be aware, however, that the defectors might be surrendering because of factors other than the Psyop program. Therein lies the subjectivity of measuring Psyop effectiveness.

In addition to traditional intelligence collection, Psyop units also post-test their products with members of selected target audiences. Psyop interrogators may question defectors from the example unit specifically about the leaflets dropped to them. Post-testing may uncover why the target audience responded in a certain way. Impact assessment and post-testing allow Psyop units to determine the effectiveness of Psyop products by using a deliberate and systematic evaluation process.

Electronic Warfare

In military operations, the term electronic warfare (EW) refers to any military action involving the use of electromagnetic or directed energy to control the Electro-Magnetic (EM) spectrum or to attack the enemy.[23] EW includes three major subdivisions: Electronic Support (ES), Electronic Attack (EA), and Electronic Protection (EP). Electronic Support covers exploitation of the EM spectrum to support military operations. SIGINT and ELINT are ES products. Electronic Attack targets adversary

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[22] Ibid.

[23] Department of Defense, *JP 3.51, Joint Doctrine for Electronic Warfare* (Washington, D.C.: Government Printing Office, 2000), vii.

information, communications, and non-communications systems to deny them the use of the EM spectrum. Jamming is an example. Electronic Protection relates to activities in the EM spectrum that protect friendly information and information systems. Electronic Counter-Countermeasures (ECCM) is an example. Planning for these functions runs across staff responsibilities in planning staffs. The intelligence staff is primarily responsible for planning ES, the operations staff is primarily responsible for EA, and the communications staff is primarily responsible for EP. Because of this, planning EW operations requires detailed and constant synchronization and deconfliction, primarily concerning the use of the EM spectrum.

Unlike the two previous descriptions of Physical Destruction and Psyop, there is no unique planning process for planning EW. Instead, Electronic Warfare Officers (EWO) use the operations planning process for their particular organizations to derive EW plans.[24] Regardless of the process used, EW planners derive MOE through a process. In a similar manner as PD and Psyop, EW planners use models, as tools, to depict friendly and adversary capabilities and determine courses of action to conduct EW activities in support of commander's objectives. With the help of these tools, planners identify MOE for the courses of action they plan.

Digital models and simulations are essential tools in the evaluation of EW and related systems. Because of the plethora of EW systems across the services, and the differences in EW employment perspectives of each of the services, there are numerous government agencies and contractors involved in EW modeling.[25] Each of these agencies has numerous models that EWOs can use in EW planning. Selection of a particular model depends on the level of operations involved, and the systems and capabilities required or employed. Numerous databases also exist to support EW modeling and planning.

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[24] The person responsible for planning and deconflicting EW in military operations is the operations staff EW Officer (EWO). Each of the services has its own planning processes as well as its own EW capabilities and perspectives on how to employ them. The planning processes used by EWOs are organization dependent. For example, if the EWO is on a joint staff they use JOPES, if on an Army staff they use the MDMP.

[25] Department of Defense, *JP 3.51, Joint Doctrine for Electronic Warfare* (Washington, D.C.: Government Printing Office, 2000), E-1. The Joint Staff Director for Force Structure, Resource, and Assessment periodically publishes the "Catalog of Wargaming and Military Simulation Models." This is the most comprehensive catalog of models available and identifies most agencies involved in EW.

Databases include doctrinal, order of battle, parametric, signature, antenna pattern, C3 networks, and topographic information for use in EW modeling and planning.[26]

Because of the vast number of models available to assist EWOs in planning, the ability to derive MOE from these models is dependent on the knowledge and expertise of the EWO. This is particularly noteworthy concerning the EWO's knowledge of the existence and applicability of models that can assist in planning. While many of these models are complicated mathematical constructs that quantitatively measure the systems they are concerned with, the EWO still makes subjective decisions at key points in the EW planning process. This subjectivity concerns selecting applicable models to use in planning, as well as databases to propagate the models. Once chosen, applicable EW models assist EW planners in targeting adversary vulnerabilities with EW, selecting friendly systems to use in attacking those vulnerabilities, then deriving measures to evaluate the effectiveness of EW. Again, to do this, EW planners use their respective organizational planning processes in the same manner Targeteers use the Joint Targeting Process or Psyop planners use the Psyop Cycle.

Military Deception

Military deception is defined as actions executed to deliberately mislead adversary military decision-makers as to friendly military capabilities, intentions, and operations, thereby causing the adversary to take specific actions (or inaction's) that will contribute to the accomplishment of the friendly mission.[27] The particular focus of military deception is the adversary military decision-maker. This person is the sole target of deception. While there may be many intermediate targets of deception activities, such as adversary intelligence collection assets, deception planners only target these in order to paint a deceptive picture about friendly intentions and operations in the eyes of the adversary decision-maker. Since the adversary decision-maker (normally the commander) is the sole target of deception,

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[26] Ibid, E-3. One of the most comprehensive database catalogs available is the directory of DOD-Sponsored Research and Development databases produced by the Defense Technical Information Center.

[27] Department of Defense, *JP 3- 58 Joint Doctrine For Military Deception* (Washington, D.C.: Government Printing Office, 1996), I-1.

deception planners consider this person the "target audience" of the deception in much the same way Psyop planners consider their targets. Similarly, deception planners analyze and develop detailed knowledge of their deception target in much the same way Psyop planners conduct Target Audience Analysis.

Deception operations have a unique planning process that parallels the JOPES planning process. The deception planning process has six steps: Mission Analysis, Planning Guidance, Staff Estimate, Commander's Estimate, Plan Development, and Plan Review and Approval. Again, as in the previous elements of IO described, the MOE of deception operations come from information developed throughout this process. In particular, the plan development step is where deception planners derive the specific MOE for the deception operations they plan.

In the first four steps of deception planning, planners determine such things as whether deception is even possible given the friendly and enemy situation. They also compile detailed information on the adversary (especially concerning the deception target) and develop a tentative deception story. In effect, deception planners attempt to tell a story about friendly actions contrary to those actually planned. To do this, deception planners use many of the same types of tools PD, Psyop, and EW planners use. In plan development, planners produce a detailed deception plan following five major actions: complete the story, identify the means, develop the event schedule, identify feedback channels, and develop the termination concept.[28] Identification of feedback channels is where the MOE for the deception fit into the plan. It is a deliberate and separate step in the process focused on identifying indicators of whether the deception is working and effective in accomplishing its goals.

> Deception planners require two major types of feedback about their operations. Operational feedback identifies what deception information is reaching the deception target. Analytical feedback identifies what actions the target is taking because of that information. All-source intelligence and counterintelligence about the adversary's intelligence interests and activities provide indications of the receipt of deception information. Observations by friendly intelligence provide information about changes in the adversary's dispositions and actions. Those dispositions are normally the essential determinant of the success of the deception. Once operations commence, the adversary's

[28] Ibid, IV-4. JP 3-58 Chapter IV contains a detailed description of each of the steps of the deception planning process as well as descriptions of the five actions taken in plan development.

reactions to friendly initiatives are indicators of whether the deception story is still being believed by the deception target.[29]

Planners provide intelligence collection requirements to intelligence planners in the form of questions related to the feedback required. These requirements are then the operational and analytical MOE for the deception. The operational feedback requirements determine whether (or not) the adversary is collecting the information being depicted by the deception. For example, if part of the deception were an amphibious demonstration, the operational feedback intelligence requirement would be to determine whether (or not) the enemy saw the demonstration. The analytical feedback requirements determine whether (or not) the deception caused the adversary to act in the manner desired by the deception plan. For example, if by using an amphibious demonstration the commander wanted the adversary to deploy in defensive positions along a coast, the analytical feedback intelligence requirement would be to determine whether the adversary did so.

MOE, or feedback, for deception operations are critical to the integration of deception operations into the overall plan or operation because of the risk associated. If a friendly course of action is dependent on whether a deception succeeds or fails, the risk associated with executing that course of action is directly dependant on determining the success or failure of the deception. In the amphibious demonstration example, the commander of the overall operation wanted the adversary to deploy in coastal defenses in order to prevent those forces from influencing friendly actions elsewhere. If the demonstration did not work to deploy the adversary in coastal defenses, then the actual friendly course of action may not work, requiring a change to the plan. Therefore, commanders must have effective MOE for deception in order to have confidence in its contribution to the overall operation. The deception planning process identifies feedback mechanisms and intelligence requirements to measure the effectiveness of deception operations during execution. These feedback mechanisms are not, however, predictive in nature. The predictive assessment of deception success or failure is still a qualitative judgment on the part of the commander and his deception planners.

[29] Ibid, IV-7-8.

Existing Comprehensive Works within the Military

As stated previously, IO is an integrating function designed to achieve synergistic effects from the elements of IO. To do so, IO planners use planning processes and tools in the same way individual element planners use their respective planning processes. There are myriad planning processes and tools available to IO planners depending on the level of operations planners are working at, what organizations they work for, or what services they represent.[30] Despite the disparity among them, there are common aspects of each of these processes and tools. First, they all seek to integrate the elements of IO to achieve synergistic results. Therefore, they are comprehensive in nature with respect to integrating the individual elements of IO. Second, while the tools are unique to the organizations that use them, they generally follow a systematic process very similar to the Joint Targeting Process or the Psyop cycle. Third, the processes, in one way or another, identify feedback requirements used to measure the effectiveness of the IO plans they produce. While many of the processes and tools use quantitative modeling techniques to achieve their desired purpose, they still require qualitative analysis by planners and commanders to be predictive of the results of IO. Nevertheless, it is useful to understand how some of these tools and processes work, to conduct synchronized IO planning, in order to ascertain how difficult it is to develop predictive, quantitative MOE for IO.

The Joint Information Operations Center (JIOC) is a joint force organization that provides IO planning, execution, and support to warfighting Commanders-in-Chief (CINCs). As such, it primarily plans and conducts IO at the strategic or operational level. The JIOC uses a planning tool called the Information Operations Navigator (ION).

> The ION planning tool provides its users with the ability to plan, develop, synchronize, and manage an integrated Information Operations campaign. ION implements the structured Joint Information Operations Attack Planning Process

[30] Major IO agencies include: Joint Information Operations Center (JIOC), Land Information Warfare Activity (LIWA)(Army), Air Force Information Warfare Center (AFIWC), and the Fleet Information Warfare Center (FIWC)(Navy). Each of these agencies has its own unique planning processes and tools reflective of its individual organizations' requirements. Additionally, many intelligence agencies provide unique intelligence support to these IO organizations. As such, these agencies also have their own systems and tools to provide this support, dependant on the agencies' particular area of expertise.

(JIOAPP) methodology to generate the IO portions of an OPLAN in JOPES format and to identify targets for a Candidate Master Target List.

The JIOAPP is a five-step method for conducting IO attack planning. It facilitates planning at two levels-the CINC level and Component level. CINC level planning usually has as its goal the identification of IO tasks. These tasks are provided to the components for further planning. Component level planning strives to determine the optimum target/asset match(es) to accomplish the IO task. Since the IO process is information intensive, a high level of collaboration is usually beneficial.

ION facilitates these planning efforts by bringing all of the necessary elements together in a single, structured, software-planning environment in which planners can collaborate.

ION goes beyond Strategies-to-Task methodology to include more refined processes for deriving IO objectives from CINC objectives, to decompose IO objectives into IO tasks, and to identify target-asset pairs to accomplish IO tasks.

IO objectives are derived from CINC objectives by first identifying all of the implied, specified, and subsidiary tasks the CINC must accomplish in order to meet his objectives. These ISS tasks are then evaluated for how well IO can help their accomplishment.

IO tasks are derived from IO objectives by analyzing where in the opposition force structure friendly IO efforts should be focused (e.g., center of gravity) to achieve the IO objective. The planner identifies the areas – called Opposition Activities and Functions – where friendly IO efforts should focus and the effects IO must induce on those Activities/Functions in order to accomplish the objective. Also identified at this point is the general element of IO (EW, Computer Network Attack, etc.) that should be used. This information is used to write the corresponding IO tasks.

The IO task is assigned to one or more organizations that are responsible for executing the task. One organization is identified as the primary for the task, others as supporting. The assigned organization(s) then identify, evaluate, and select target/weapon pairs necessary to accomplish the IO task. The completed analysis results in IO subtasks And Candidate Targets which are forwarded to the Joint Target Coordination Board at the CINC.[31]

Through the detailed planning and analysis aided by ION, as well as collaboration with subordinate components and supporting agencies, JIOC planners derive MOE for each of the IO tasks and subtasks. The MOE then become the intelligence requirements necessary to conduct combat assessment of the IO planned through ION. Measuring the cumulative, synergistic effects of the tasks planned using ION remains a subjective judgment on the part of planners, analysts, and commanders even though they are supported by quantitative data derived from ION and other models used to feed information into the process. Further, since planners develop the MOE to conduct combat assessment after the IO tasks occur,

[31] "ION Overview," *JIOC Homepage*, DOD Secret Internet Protocol Router Network (SIPRNET), http://www.jioc.smil.mil/prodserv/planning/ION/pages/home/ion_overview.html, accessed 12 March 2002. The referenced document is an unclassified description of the ION planning tool accessed through the JIOC Homepage on the DOD SIPRNet.

they are not predictive in nature. They merely measure whether or not an IO task or set of tasks accomplished their intended purpose after execution.

One of the intelligence agencies that support IO planning conducts Influence Net Modeling using an automated modeling tool called SIAM – Situation Influence Assessment Model.[32] SIAM is a commercially available tool that assists analysis of high level, complex, strategic problems in an organized, holistic fashion. "Influence Net Modeling [assisted by SIAM] is a structured process that allows those responsible for strategic planning and decision-making to investigate complex issues of cause and effect in order to determine optimal courses of action to influence outcomes."[33] "The modeling technique incorporates a mathematically robust algorithm to compute the cumulative effects of all influences on a specified event. This algorithm, called Belief Propagation, automatically "rolls-up" the complex, and possibly contradictory, influences to determine the likelihood of the event's occurrence."[34] Since IO focuses on influencing adversary decision-makers, influence net modeling is a powerful tool to use in planning IO. IO planners can use Influence Net Modeling to map the influence net of a certain adversary decision-maker and the influences of real or planned events on that decision-maker.

A significant aspect of this modeling technique is Pressure Points Analysis. The SIAM tool identifies critical initial events with the greatest potential to increase or decrease the likelihood of occurrence of a specified (desired) event.[35] For example, if a primary desired event input into the model is to convince an adversary to surrender, the model assesses which influencing IO task (influencing events) are most likely to produce the desired event (surrender). "If a manageable number of such influences (IO tasks) can be identified, then the friendly decision-maker has the beginnings of a course of

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[32] The SIAM software tool is owned and marketed by Science Applications International Corporation (SAIC), 10260 Campus Point Drive, San Diego, CA 92121 U.S.A. SIAM is a registered trademark of Science Applications International Corporation (SAIC), 10260 Campus Point Drive, San Diego, CA 92121 U.S.A.

[33] "Introduction to Influence Net Modeling," *Influence Net Modeling for Strategic Planning* (San Diego, CA.: Science Applications International Corporation, 2002), Internet, http://www.inet.saic.com/inet-public/, accessed 13 March 2002.

[34] J.A. Rosen, and W.L. Smith, "Influencing Global Situations: A Collaborative Approach," *Influence Net Modeling for Strategic Planning* (San Diego, CA: Science Applications International Corporation, 2002), Internet, http://www.inet.saic.com/inet-public/, accessed 13 March 2002, 9.

action, without spreading available resources beyond their effectiveness. In this sense, *Influence Net* [*sic*] Modeling supports the "what if" analysis necessary to identify potential actions."[36]

Building an influence net model of a particular adversary requires expert knowledge about the adversary. The quality of the model is directly dependent on the information, in the form of events and influences, which planners input into the model. Therefore, while the modeling tool is extremely beneficial in planning IO, especially with regard to predictability of effects, the model, and decisions derived from it, is still completely dependant on the subjective judgment of "experts" who input data into the model. Nevertheless, automated Influence Net Modeling facilitates the JIOAPP by documenting the data, conducting expert mathematical reasoning, and producing assessment results. Planners can use SIAM to produce graphical results that, when incorporated into an OPLAN or briefing, offer the commander the "picture that's worth one thousand words."[37]

Processes like JIOAPP, and modeling tools like SIAM, make great strides towards deriving comprehensive IO plans, and consequently, measures of effectiveness. Viewing these two tools in terms of the disparate nature of the individual capabilities' processes and measures, one can see the difficulty in deriving comprehensive tools to synchronize and measure the synergistic effects of IO capabilities. The four individual capabilities of IO listed here each have systematic processes to plan their activities, and thus derive MOE. Two of these capabilities (PD and EW) lend themselves well to quantitative measurement. The other two (Psyop and Deception) are best measured qualitatively and are almost completely dependent on planners' subjective analysis for MOE. This is because they target the human mind. The complexity of the human mind, coupled with the inability of traditional tools to integrate the individual processes and IO models, generates the question: do non-traditional tools exist which can comprehensively measure the synchronized effects of IO? The answer lies in the complexity community.

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[35] Ibid, 14.
[36] Ibid.
[37] Ibid, 18.

CHAPTER 3. THE COMPLEXITY COMMUNITY

Where It Is and What It Does

M. Mitchell Waldrop, in his 1992 book "*Complexity: The Emerging Science at the edge of Order and Chaos,"* describes the genesis of the scientific movement called complexity.

> The movement's nerve center is a think tank known as the Santa Fe Institute (SFI), which was founded in the mid 1980s and which was originally housed in a rented convent in the midst of Santa Fe's art colony…The researchers who gather there are an eclectic bunch, ranging from pony-tailed graduate students to Nobel laureates such as Murray Gell-Mann and Philip Anderson in physics and Kenneth Arrow in economics. However, they all share the vision of an underlying unity, a common theoretical framework for complexity that would illuminate nature and humankind alike. They believe that they have the mathematical tools to create such a framework, drawing from the past twenty years of intellectual ferment in such fields as neural networks, ecology, artificial intelligence, and chaos theory. They believe that their application of these ideas is allowing them to understand the spontaneous, self-organizing dynamics of the world in a way that no one ever has before –with the potential for immense impact on the conduct of economics, business, and even politics.[38]

From the nerve center in Santa Fe, the study and understanding of complexity, Complex Adaptive Systems (CAS), and their associated theories, has grown to world wide acceptance in explaining how single elements, such as people or a company stock, spontaneously organize into complicated structures like societies and economies. The science of complexity has made great strides since 1984 in explaining how these spontaneous systems act and interact with each other to provide order to our complex world.

An underlying principle of SFI's research is that it is trans-disciplinary. SFI's eclectic and noted scientists "undertake topics of interest that transcend any single scientific discipline and cannot be studied adequately in traditional disciplinary contexts" such as physics, computer science, or sociology.[39] The institute's scientists work collaboratively to build computer simulations (models) of the complex systems they study. The list of simulations they have developed is immense and ever growing. Examples include

[38] M.M. Waldrop, Complexity: The Emerging Science at the Edge of Order and Chaos (New York: Simon and Schuster, 1992), 12.

[39] Santa Fe Institute, "Vision of the Santa Fe Institute," *SFI Homepage* (Santa Fe, NM: Santa Fe Institute) Internet, http://www.santafe.edu/sfi/organization/vision.html, accessed 13 March 2002.

mathematical models of molecular and cellular biology, computer simulations of stock market performance, and the dynamics of human societies.

From the potential of studying complex systems, recognized by the founders of SFI, was born a new science that now works throughout the world to solve real problems. In order to draw conclusions as to complexity theory's usefulness to developing IO MOE, it is important to understand some of the basic principles of complexity theory. Some examples of how the institute's work has helped solve real problems then follow to reinforce its potential usefulness.

Basic Complexity Theory

The science of complexity deals primarily with the mathematical concept of non-linearity. Since humans tend to think in a linear fashion, it is easier to understand non-linearity by contrasting it with a linear mathematical construct.[40] There are four features of linearity: proportionality, additivity, replication, and demonstrability. These four features typify linear mathematics, which forms the basis of how most people think about the world around them.

Proportionality, in linear terms, means that the outputs of a system or equation are proportional to the inputs. The additivity feature of linearity simply means that the whole system is equal to the sum of its parts. Replication, in linearity, means that the same action, carried out by the same system, will achieve the same results if it happens under the same conditions time after time. Finally, linearity is demonstrable with respect to cause and effect, meaning that a linear equation or system can demonstrate a direct cause and effect relationship between variables, inputs and outputs, etc…

[40] Tom Czerwinski, *Coping with the Bounds: Speculations on Nonlinearity in Military Affairs* (Washington, D.C.: Institute for National Strategic Studies, 1998), 8. Czerwinski uses a method of explaining non-linearity by first reviewing linear mathematical principles. His description is a compilation of generally accepted mathematical principles of linear and non-linear functions in mathematics. His work is one of the best sources for a simplified yet complete description of basic complexity theory. As such, the monograph uses his description as a basis for this section on complexity theory. Other thorough yet simple descriptions written for a lay understanding of basic complexity theory include: J.N. Rosenau, "Many Damn Things Simultaneously: Complexity Theory and World Affairs," 73-100, and R. Jervis, "Complex Systems: The role of Interactions," 45-72 in *Complexity, Global Politics, and National Security,* ed. D.S. Alberts and T.S. Czerwinski (Washington, D.C.: Institute for National Strategic Studies, 1997).

Non-linearity, on the other hand, does not embrace these features. In fact, non-linear systems perform contrary to linear principles. Inputs in a complex system are not proportional to the outputs. An essential characteristic of complex systems is that small changes in system inputs often lead to large or disproportional results. The variables in non-linear systems are not additive. The whole system does not equal the sum of its parts. Actions within complex systems are often not replicable, even if undertaken under the same conditions. Finally, cause and effect relationships are usually ambiguous within non-linear systems. "A contributing cause to this condition [a lack of linear features in non-linear systems] is the phenomenon of non-linear dynamics, whereby outcomes are arbitrarily sensitive to small changes in initial conditions."[41]

The reference to systems in describing non-linearity is deliberate because the world comprises an infinite number of interrelated systems. The science of complexity, and its underlying principles of non-linearity, centers on systems called Complex Adaptive Systems (CAS). Czerwinski, in his book "*Coping with the Bounds"* calls CAS the "engines" that drive non-linearity.[42] These systems are complex because they perform in a non-linear fashion. The attributes of non-linearity describe their behavior in a much more thorough manner than do linear features. They are adaptive because while performing in a non-linear fashion, they adapt and change themselves to fit the world in which they exist. There are seven basic attributes of Complex Adaptive Systems, comprised of four properties and three mechanisms. The four properties are: aggregation, non-linearity, flows, and diversity. The three mechanisms are: tagging, internal models, and building blocks. All of these attributes describe how CAS adapt and exist in the world.

Aggregation is a property where large-scale outputs or actions within a system come from the aggregate actions of smaller parts. Once joined together, these smaller parts can then act together as individual agents at a higher level within the system. In short, because of the property of aggregation, CAS become systems of aggregated systems. CAS aggregation is not a random occurrence. Variables

[41] Ibid, 10.
[42] Ibid, 13.

within CAS aggregate in order to serve some purpose – for example to protect themselves from predators or to ally in defeat of a common enemy. Agents within a CAS use a mechanism called tagging to recognize each other for aggregation. Agents in the CAS have certain tags that other agents can use to recognize them. A much-used example in complexity study is the flock of birds or the school of fish. Each bird or fish is recognizable to the others because of its color or scent. The colors and scents are tags.

This simple description of aggregation and tagging can seem linear in terms of additivity. Yet, another property of CAS, the second one, is non-linearity. Simply stated again, non-linearity means the whole is not equal to the sum of its parts. Refer once more to the bird flock example. The visible size of the flock is not equal to the visible surface area of each individual bird, but a larger whole that seemingly moves together as one. The CAS property of non-linearity makes aggregation of the flock complex because the aggregate whole is greater than a mere sum of its parts.

"The third property of CAS is the idea of flows."[43] Think of CAS in terms of the rudimentary telecommunications system from Chapter 2. Flows have to do with how information moves through the system. Because CAS are self-adapting, flows within the systems change over time. The flow of information through the system constantly changes as the links and nodes adapt (or fail to adapt) to myriad influences on the system. If a military force destroys a routing switch, information then flows through the system to a different switch, or out of the system into another mode of communication. Tags allow agents in the system (operators for example) to recognize other links or nodes that can carry the information to its destination.

The fourth property of CAS has to do with the diversity of variables within the system. This property speaks to the cooperative adaptability of the system as a whole, even though it is comprised of a diverse set of variables. Within the telecommunications system, each line and switch are different in some way, and each system operator or maintenance person has different levels of education and experience. Yet, the system works to reroute information after losing a switch by looking for other switches to fill the void. Although the new switch may have a different capacity or be in a different

location, its tag as a "switch" allows other agents in the system (operators) to recognize it as a switch and reroute information through it.

This now relates to a second mechanism of CAS called internal models. CAS use internal models to anticipate and adapt. These can be overt models, such as standing operating procedures, or tacit models, such as immediate action drills. In the case of the telecommunications system, system operators may have standing procedures (overt model) to route information to specific nodes if a certain switch is damaged. They may also use these procedures to predict that other switches may be lost in an attack and re-route information around those switches before they are destroyed. If there are no procedures in place, an operator may use his experience from a previous attack (tacit model) to decide where to reroute information. This operator may also use this experience to predict where another attack might occur within the system and act to reroute information around that location ahead of the attack.

The third and final mechanism of CAS, building blocks, is what enables agents within the CAS to develop internal models for use in anticipating changes and adapting. Say, for example, this was the first hostile attack on the telecomm system in its history, and therefore there are no standing procedures for reacting to such an attack. The operators, however, probably experienced losses of switches due to maintenance problems or losses of lines due to adverse weather in the past. The attack is by no means a rainstorm or a routine maintenance problem. Nevertheless, the operators break down the new problem into smaller problems that they recognize from previous, seemingly unrelated experiences. These smaller problems serve as building blocks for the internal model the operators build to adapt to the attack.

The continuing use of the telecommunications system vignette to describe systems and attacks thereon is deliberate. Note that Chapter 2 described the telecommunications system as a typical system that lethal fires targeteers model using linear mathematical algorithms. They use these models to plan attacks on the chosen adversary systems. Chapter 3, however, describes the same system as a non-linear CAS that is best modeled using the attributes described above. The resulting system is not the same as it

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[43] Ibid, 18.

was in Chapter 2. The latter description adds a new variable to the system – the human decision-maker. The system operator made decisions concerning how to re-route information through the system. These decisions made the system adaptive. IO focuses on the adversary decision-maker and the system of systems surrounding it. The decision-maker causes these systems to be complex and non-linear. Since the attributes of CAS best describe these systems; modeling, attacking, and measuring effects on them requires the non-linear science of complexity.

Complexity science provides a new tool for planners to use that can model non-lethal effects in the same way that linear models aid lethal fire targeteers. The characteristics of CAS mirror the seemingly immeasurable factors related to non-lethal IO elements. Cause and effect relationships are difficult to measure, inputs do not necessarily equal outputs, and current planning tools do not pinpoint aggregation and relationships between myriad variables. Complexity scientists, at SFI and elsewhere, postulate that these aspects, though difficult, are not impossible to identify and model. Clearly, the gifted and accomplished scientists at SFI can provide value to studying and modeling the CAS related to planning and measuring IO effects, but is SFI the best type of organization to assist with the problem of IO MOE. That is the subject of Chapter 4.

CHAPTER 4. SUITABILITY OF USING THE COMPLEXITY COMMUNITY

Scientists, from SFI and elsewhere, apply complexity science to solve real problems in medicine, social sciences, and business. If complexity science works in these fields, it can work for the problem of IO MOE in the military. It is the only tool not yet applied to this problem – and it works. SFI is a likely candidate, within the complexity community, to develop tools and models of CAS that can enable the military to measure the effects of IO. A historical analysis of the formation of a similar organization – RAND – demonstrates the success of employing an organization like SFI to help solve scientific military problems.

Practical Application of Complexity Science

By no means is complexity science, the work done at SFI and elsewhere, a panacea for explaining the infinite number of inter-related complex adaptive systems of the world. The science is still very new and very complicated in itself. Since it is very new, complexity scientists are still developing it as a pure science. The task of simultaneously developing a new science, exploring practical applications for it, and using those applications to solve real problems is an immense undertaking. One of the founding members of SFI, Nobel Laureate Murray Gell-Mann states that "the modeling that's been done [at SFI] is very useful, and some day mathematicians will take a hand in it and there will be a whole mathematical theory of these very simple sets of rules that give rise to apparent or real phenomena. But what we need for applications is to move toward the middle of the spectrum, where quite a bit of information about real life and real societies is put in."[44] Since Gell-Mann made this statement in 1995, scientists working at, and with, SFI have made great strides in taking their complexity models from the abstract, pure science form, into a condition of using real world data to model real world situations.

[44] Janet Stites, "SFI's Next Generation of Models Tackles the Real World," *SFI Bulletin* 10, no.1, (Spring 1995) Internet, http://www.santafe.edu/sfi/publications/Bulletins/bulletin-spr95/spring95.html, accessed 23 March 2002.

The efforts of Gell-Mann and others to become more practical in their science not withstanding, even a cursory survey of the thousands of titles and abstracts of the studies emanating from SFI indicates the continuing struggle with the practicality of using these works in everyday life. For example, the 2002 list of SFI working papers contains titles such as: "Discovering Planar Disorder in Close-Packed Structures from X-Ray Diffraction: Beyond the Fault Model,"[45] "Network Topology and Species Loss in Food Webs: Robustness Increases with Connectance,"[46] and "Mutational Robustness and Asymmetric Functional Specialization of Duplicate Genes."[47] The jargon of the titles alone rivals that of the U.S. Military, let alone the language in the bodies of the working papers themselves. While scientists involved in nuclear medicine, ecological study, or gene technology may be able to understand and use these studies (in their present form) for their everyday work; city managers, farmers, or military planners most assuredly cannot. This does not mean to say that complexity science has not produced tangible results from a practical standpoint. The following examples illustrate some of the many ways in which complexity science has recently contributed to solving real world problems.

An article published by Paul Plsek and Tim Wilson in the September 2001 issue of the British Medical Journal "describes the application of complexity thinking in the organization and management of health care."[48] The authors describe the British National Health Service (NHS) as a Complex Adaptive System. Using examples of current practices in budgeting, purchasing, and administering care within the NHS, the authors recommend concrete changes in the management practices of the service. The recommendations are very practical in nature. If implemented, the recommendations can seemingly

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[45] Dowman P. Varn, Geoffrey S. Canright, and James P. Crutchfield, "Discovering Planar Disorder in Close-Packed Structures from X-Ray Diffraction: Beyond the Fault Model," *Working Papers of Santa Fe Institute* (Santa Fe, NM: Santa Fe Institute) Internet, http://www.santafe.edu/sfi/publications/wpabstract/200203014, accessed 23 March 2002.

[46] Jennifer A. Dunne, Richard J. Williams, and Neo D. Martinez, "Network Topology and Species Loss in Food Webs: Robustness Increases with Connectance," *Working Papers of Santa Fe Institute* (Santa Fe, NM: Santa Fe Institute) Internet, http://www.santafe.edu/sfi/publications/wpabstract/200203013, accessed 23 March 2002.

[47] Andreas Wagner, Mutational Robustness and Asymmetric Functional Specialization of Duplicate Genes," *Working Papers of Santa Fe Institute* (Santa Fe, NM: Santa Fe Institute) Internet, http://www.santafe.edu/sfi/publications/wpabstract/200202006, accessed 23 March 2002.

[48] Paul E. Plsek and Tim Wilson. "Complexity, Leadership, and Management in Health Care organizations." *British Medical Journal* 323, no. 7315 (29 September 2001),746.

achieve results at both a systemic level as well as the individual patient level in the NHS. It is unknown whether Plsek and Wilson used a computer generated complexity model of the NHS in their research. What is clear is that the study displays a thorough and in depth understanding of all of the aspects of complexity science, and the features of complex adaptive systems, on the part of the authors. Much more importantly, the authors apply this knowledge to formulate solutions to real life problems in the NHS.

Since its inception, SFI has established a close working relationship with business and industry through its Business Network. "The SFI Business Network furnishes its members with key information and access to leading-edge research, and provides the Institute with a source of unrestricted revenues to support its core research. Through this mutually supportive relationship, the Business Network helps to ensure the fulfillment of two of the Institute's missions: to set new directions for science; and to encourage the dissemination and application of its research results."[49] The SFI's list of 42 Business Network members includes such Fortune 500 companies as Intel, State Farm Insurance, and Deere. Through this network and other information means, businesses from around the world have latched onto, and used, complexity science in their everyday business practices. Citibank used complexity algorithms to search for patterns in its huge volume of customer call records. The mathematics of complexity helped predict when calls were most likely to occur, for example, after an interest rate increase. The bank then used the information to staff its telephone banks more efficiently at critical times.[50]

In 1997, SFI scientist Dr. Roger Jones began working on the problem of risk analysis in the insurance industry. His work, centered on a software program (computer model) called the Insurance World Simulator, which uses complexity theory to simulate the entire insurance industry.[51] This work proved so fruitful and profitable that he and another SFI colleague, Professor John L. Casti, formed their

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[49] Santa Fe Institute, "Business Network," *SFI Homepage* (Santa Fe, NM: Santa Fe Institute) Internet, http://www.santafe.edu/sfi/indexBusnet.html, accessed 23 March 2002.

[50] Shannon Brownlee. "Complexity Meets the Business World: a New Business Science is Shedding Light on Commerce," *U.S. News and World Report* 121, no. 13, 30 September 1996, 57.

[51] Dana Mackenzie, "The Science of Surprise: Can Complexity Theory Help Us Understand the Real Consequences of a Convoluted Event Like September 11?" *Discover* 23, no. 2 (February 2002) Internet, http://www.discover.com/recent_issue/index.html, accessed 16 March 2002.

own for-profit company – Complexica.

> Complexica is a scientific hatchery of innovation and the authority in the science of complexity (the science of surprise). Complexica uses data mining and other mathematical applications that provide solutions to some of the most complex problems faced by business and industry. Developing advanced and proprietary algorithms and applying them to industries as diverse as lumber, equities trading, oil and automobile manufacturing has positioned Complexica as the world leader in Complexity Science.[52]

Now, Insurance World, a consortium of insurance companies, has taken the commercialized computer model developed by Dr. Jones to build "competitive advantage and market focus" within their industry.[53]

Complexica is one of many start-up commercial ventures born from the complexity community in Santa Fe. Another such company is BiosGroup Inc., "a Santa Fe-based consulting and software development company, [that] pioneered the use of complexity science to solve complex business problems and is now the world leader in applying the techniques of this emerging science to large commercial applications."[54] BiosGroup "has done more than 50 projects for Fortune 500 clients."[55] One of these companies is Proctor and Gamble. BiosGroup developed a computer model of Proctor and Gamble's complex product distribution system that lead to reducing the company's delivery times from 65 days to 30 days, resulting in a 20 percent reduction in distribution costs.[56]

As evidenced by these few examples, complexity scientists have applied their science to solve problems for both profit and the greater good. While complexity science is new and still developing as a science, and its complicated technical jargon may seem intimidating to most people with even an undergraduate degree, its practical applicability to solve real world problems is proven. Many in the military recognize the proven performance of complexity science. However, the military faces a similar challenge to that of SFI and other complexity scientists – how to operationalize the science to its greatest

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[52] Complexica, "About Complexica," *Complexica Homepage* (Santa Fe, NM: Complexica) Internet, http://www.complexica.com/, accessed 28 March 2002.

[53] Ibid.

[54] BiosGroup, "About BiosGroup," *BiosGroup Homepage* (Santa Fe, NM: BiosGroup) Internet, http://www.biosgroup.com/company/company.html, accessed 28 March 2002.

[55] Dana Mackenzie, "The Science of Surprise: Can Complexity Theory Help Us Understand the Real Consequences of a Convoluted Event Like September 11?" *Discover* 23, no. 2 (February 2002) Internet, http://www.discover.com/recent_issue/index.html, accessed 16 March 2002.

[56] Ibid.

benefit. The following analogy, using the formation of RAND, provides insight into how to do this.

The Rand Analogy

In March 1946 the U.S. Air Force, under the command of Gen. H.H. "Hap" Arnold entered a contract with Douglas Aircraft Corporation to form Project Rand.[57] The idea for the project was the result of the monumentally successful relationship established between the military, academia, and industry during WWII. General Arnold and others within the military and industry realized that once the war ended, so would the relationship that proved so successful in defeating the axis powers. They also realized that at the dawn of the nuclear age, an advisory relationship between government and industry, particularly with regard to science and technology, was necessary in order to maintain the peace won and the U.S. position as a world leader, established during the war. The situation faced by the U.S. military at the dawn of the nuclear age is not unlike its current position at the nascent stages of the information age. The reasons for establishing Rand and the criteria for selecting how it should be organized and chartered provide historical insight into how to establish a similar relationship with the civilian complexity community.

Through his relationship established with leaders in the aircraft industry, General Arnold negotiated the basic terms of, and entered the contract of March 1946 with Douglas Aircraft Corporation. The necessity to establish Rand was due to several underlying factors with respect to the scientific and technical research requirements envisioned for the future by General Arnold and his colleagues. This meant, primarily, the need for an organization with expert, yet broad, technical and scientific knowledge, and one capable of interdisciplinary work on a wide range of research projects associated with the security of the U.S. Another essential aspect of the organization, required to capitalize on the free-thinking of its members, was that it must be unencumbered by both the bureaucracy of the military and

[57] The capitalized term RAND began its use as the abbreviation for the name of the Rand Corporation after RAND became a private, non-profit corporation, separate from Douglas Aircraft. The use of the uncapitalized term Rand, in the body of the monograph, refers to Project Rand, or the Rand subsidiary of Douglas Aircraft, before its incorporation as a private, non-profit organization.

the bottom-line business requirements of industry. The founders of Rand thought "an independent and objective organization, with a reputation for independence and objectivity [*sic*], can command attention when others can't."[58]

Several other practical factors led to establishing Rand at Douglas Aircraft Corporation, rather than building a scientific and technical research capability within the military or eliciting the continued support of academic institutions. Initially, the thought was that a university would not want to be encumbered by the security requirements associated with the classified programs that the Air Force wanted researched. While this did not prove to be the case, as the U.S. continued its nuclear and space programs, it directed the project founders away from academia as a base for Project Rand. They also rightfully suspected that it would be impossible to "build such a high talent scientific group within the government itself because of the poor salaries and inflexible personnel practices" present at the time.[59] These factors led to the establishment of Project Rand as a separate division of Douglas Aircraft, under exclusive contract to the U.S. Air Force.

Over the next two years, other factors emerged that resulted in Rand becoming a completely independent, private, nonprofit research corporation. First, the hard science researchers brought in by Douglas to form Project Rand quickly realized that interdisciplinary research on topics, such as the future of nuclear warfare and space exploration, required not only hard science but also social science expertise. The statement of work in Rand's contract stated it was to "recommend *preferred* [author's italics] instrumentality's and techniques."[60] The term preferred implied optimal solutions with respect to political and economic constraints, among others. Political and economic analysis required social science capability, as well as hard science, within Rand. While this did not prove to be a problem within Project

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[58] J.R. Goldstein, "Rand: The History, Operations, and Goals of a Non-Profit Corporation" (paper presented to the Harvard Business School Alumni in Los Angeles on 23 February 1961), Santa Monica, CA: Rand Corporation, 1961, 21. A footnote to this speech, published by Rand in 1961, states, "Rand has been described as an experiment in multidisciplinary attacks on complex problems."

[59] Bruce L.R. Smith, *The Rand Corporation: Case Study of a Nonprofit Advisory Corporation, (*Cambridge, Massachusetts: Harvard University Press, 1966), 42.

[60] J.R. Goldstein, "Rand: The History, Operations, and Goals of a Non-Profit Corporation" (paper presented to the Harvard Business School Alumni in Los Angeles on 23 February 1961), Santa Monica, CA: Rand Corporation, 1961, 8.

Rand, it did create friction within the corporate body of Douglas Aircraft. Social scientists hired by Project Rand, mainly academics, simply could not work within the very structured business environment of Douglas Aircraft. Secondly, researchers at Rand received unfettered access to all classified and unclassified programs sponsored by the Air Force. This included the research and development efforts of Douglas Aircraft competitors Boeing and Northrop. The appearance of favoritism within military contracting processes and the fear of Douglas Aircraft, as a whole, having access to competitors' work eventually made the relationship between Rand and Douglas Aircraft untenable. By 1948, the leaders of Project Rand, Douglas Aircraft, and the Air Force realized the untenable position of Rand at Douglas and decided to form RAND as a stand alone, nonprofit research corporation.

Reading the history of RAND is like reading the history of the Santa Fe Institute in many ways. Both were founded under the principles of interdisciplinary research, independence, and non-profit status. They also both have a goal of solving real problems through scientific research. RAND developed out of the scientific application of operations research and systems analysis, which contributed greatly to the allied victory in WWII. The founders of Rand recognized that "although systems analysis normally deals with a range of problems to which there are no unambiguous solutions, specialized research techniques can sometimes clarify important aspects of a broad problem and reduce the uncertainty confronting the analyst and policy maker."[61] The founders and scientists of Rand, in 1948, did not, nor could not, anticipate the future development of complexity science. Nevertheless, their intent to make the ambiguous, complex world more explainable is also the intent present at SFI. While operations research and systems analysis, as known in 1948, were based on complicated linear mathematics, they still made significant impacts in explaining parts of the complex world. The science of complexity now takes that construct one step further by combining disparate pieces together, using non-linear mathematics and sophisticated computer modeling techniques, to develop working models of CAS that better explain the complex world.

[61] Bruce L.R. Smith, *The Rand Corporation: Case Study of a Nonprofit Advisory Corporation*, (Cambridge, Massachusetts: Harvard University Press, 1966), 10.

The applicability of complexity science to solve the problem of IO MOE is clear. The Complex Adaptive Systems of the adversary decision-maker, and information operations against them, can be modeled and measured using the same science that solves problems in the insurance industry, medical services, and financial markets. The role of the private, non-profit organization in solving military scientific and technical problems is also clear. The independence, and resident expertise, of an organization like SFI is best suited to develop models and tools necessary for planning, executing, and measuring the effects of IO against the Complex Adaptive Systems of military adversaries.

CHAPTER 5. CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The Complexity Community as the Answer

There is no doubt that today's world is complex. Contemporary, post cold war literature is rife with the term "complex." It is often used synonymously with the term complicated, without a complete understanding of a literal difference in the two words. The relatively new science of complexity can make a clear distinction between complex and complicated. Complexity delineates a non-linear construct of the world. Complex Adaptive Systems (CAS) models, using non-linear mathematics, better explain natural phenomenon having to do with life than do models using linear, physical sciences.

Researchers in the 1980s, striving to understand complexity, recognized the potential of non-linearity to better explain the world around us, and set out to perfect a science to do so – complexity science. These scientists did much more than develop, and begin to perfect, complexity science. Their goals included making it practical. They have yet to make complexity science simple and useable in everyday life. Nevertheless, they have made great strides, in a relatively short period of time (16-20 years), in gaining worldwide scientific acceptance of complexity as a science that accurately depicts the world as an infinite number of inter-related, complex adaptive systems.

Again, many in the military recognize this worldwide acceptance. More than several noted military scholars, theorists, and scientists have written about complexity and its theoretical applications to military science during the past several years.[62] One recent recommendation to the

[62] D.S. Alberts and T.J. Czerwinski, ed., *Complexity, Global Politics, and National Security,* (Washington, D.C.: Institute for National Strategic Studies, 1997), is a collection of papers presented to the Complexity, Global Politics, and National Security Conference held 13-14 November 1996. Part three of the collection contains five papers dealing specifically with complexity in relation to military strategy and operations. This work also contains an extensive working bibliography dealing with chaos, complexity, and military affairs. Tom Czerwinski, *Coping with the Bounds: Speculations on Nonlinearity in Military Affairs* (Washington, D.C.: Institute for National Strategic Studies, 1998) has a stated purpose of directly engaging the defense establishment along the lines of non-linear thought and understanding. David Alberts and Tom Czerwinski conduct their research at The National Defense University under the auspices of the DOD Command and Control Research Program (CCRP). They are but two examples of the plethora of noted military researchers who have produced theoretical works dealing with the

SECDEF, related to military transformation, was to broaden the Joint Warfare Analysis Center's (JWAC) capability to depict adversaries as complex adaptive systems.[63] Knowledge of complexity theory is not the issue. The military also needs focus in order to benefit from the science of complexity. Just as the scientists at SFI, and the community surrounding Santa Fe, are attempting to go beyond the theoretical, so too should the military. The time has come to not only study and embrace complexity science and non-linearity, but to operationalize it. The problem of measuring the effects of information operations is one area of military affairs where real opportunities exist to do so. How to do so is the question.

The historical analogy of the situation presented to Gen. Hap Arnold and the founders of Rand offers a way. After witnessing first hand the immense contributions that operations research and systems analysis made to the allied victory in WWII, the founders of Rand established a new organizational construct for a mutually beneficial relationship between science, industry, and the military – the non-profit advisory corporation. As described in Chapter 4, there were definite reasons and criteria for establishing a non-profit corporation to conduct independent, scientific, military research. Most notable was the inefficiency and impracticality of building a resident capability within the military.

Since the formation of RAND in 1948, countless non-profit and for profit contractors have sprung up in support of military and national security objectives. While many corporations focus mainly on the strategic and the theoretical in recommending "preferred instrumentalities and techniques,"[64] SFI (non-profit) and companies like Complexica Inc. and BiosGroup Inc. (for profit) work seriously at applying the new science of complexity to operational type problems. They develop usable models that, if developed and refined for military use, can take the theories of complexity and turn them into useable tools for planning, executing, and measuring the effects of IO.

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application of complexity theory in national security and military affairs.

[63] Department of Defense Transformation Study Group, *Transformation Study Report: Transforming Military Operational Capabilities* (27 April 2001), open file report, in Scientific and Technical Information Network (Washington, D.C.: Defense Technical Information Center) Internet, http://handle.dtic.mil/100.2/ADA392289, accessed 3 March 2002, 11.

[64] J.R. Goldstein, "Rand: The History, Operations, and Goals of a Non-Profit Corporation" (paper presented to the Harvard Business School Alumni in Los Angeles on 23 February 1961), Santa Monica, CA: Rand Corporation, 1961, 8.

There may be inherent problems with soliciting the direct assistance of these organizations that are contrary to those encountered by the founders of RAND. Although the U.S. Air Force initiated and funded Rand, Hap Arnold and others quickly realized that it needed independence in order to be effective. They also realized that it could not be associated with a specific "for profit" contractor – Douglas Aircraft Corporation - because of the perceived appearance of favoritism by Douglas's competitors in its core aerospace business (namely Boeing and Northrop). To ensure impartiality, Douglas Aircraft and the U.S. Air Force transformed Rand into an independent, non-profit corporation focusing on research issues associated with national security. RAND's commitment to this purpose remained (and still does) even after becoming a non-profit, independent corporation. SFI is already a non-profit, independent entity, but not directly associated with the U.S. Government or any particular national security contractor. Although many of the scientists of SFI have worked for, and/or closely with, the U.S. Government, the primary loyalty of the institute appears to be to its science.[65] While it is the stated purpose of SFI to work to improve our world as a whole, establishing the closeness in purpose, embodied in the founding principles of RAND, may prove more difficult. A relationship between the non-profit SFI and the military would develop much later in the lifecycle of the organization as compared to that between the military and RAND in 1948. Establishing a contractual relationship with a "for profit" company, like Complexica or BiosGroup, may present similar problems to the ones encountered by establishing Rand within the "for profit" contractor – Douglas Aircraft. Namely, the problems associated with proprietary knowledge of competitors' work in the field, as well as access to the plethora of classified programs currently associated with information operations in the military.[66]

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[65] SFI coordinates collaborations among researchers affiliated with universities, national laboratories, and industrial research organizations throughout the world. Los Alamos National Laboratory is located very near Santa Fe, NM. Many of the visiting scientists and external faculty of SFI have, or still do, work at Los Alamos. Sandia National Laboratory/New Mexico is located in Albuquerque, NM. Sandia provides research grants to SFI to conduct some of its research on complexity.

[66] See the later section having to do with the problems of classification and compartmentation within the information operations functions in the military. Many of the non-linear algorithms developed and used by the start-up complexity companies in Santa Fe are proprietary.

Bruce Smith wrote in 1966: "it is a curious irony that the military services themselves, in sponsoring organizations like RAND, have greatly strengthened the civilian's role in defense management and policy formation."[67] This statement may prove useful in establishing a military relationship with the complexity community, specifically for IO, in that it bolsters the position of the community in its relationship with DOD. That is, while there may or may not be a reluctance on the part of some in the community to become a "contractor" of DOD for fear of subordination and loss of independence, the true fact is that they have something DOD needs – expertise in complexity. Civilian control of the military, a founding principle of our republic, is actually reinforced by extending this expertise to guide information operations.

History proves the role and value of the non-profit advisory corporation in national security and military affairs. Since the founding of RAND, and the myriad similar organizations thereafter, the advisor/client relationship with the U.S. military has evolved into almost an automatic understanding. The military is very comfortable with outsourcing scientific functions, and military scientific contracting is a lucrative, vibrant industry. Military to contractor type relations are such that the opportunity now exists to formulate solutions beyond theoretical, strategic recommendations to practical working constructs capable of directly influencing operations and tactics; in this case, planning, executing, and measuring the effects of IO.

Bruce Smith added: "The advisor's influence is necessarily limited to a portion of the full spectrum of problems and choices that the policy maker faces…. No amount of research and advice can ever definitively treat all of the variables that go into a complex decision."[68] Smith wrote this statement in the scientific context of linear operations research and systems analysis, which was state of the art at the time. The entire premise of the non-linear science of complexity, and the incredible computing power now possible, are close to doing just what Smith and the founders of RAND said was impossible.

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[67] Bruce L.R. Smith, *The Rand Corporation: Case Study of a Nonprofit Advisory Corporation, (*Cambridge, Massachusetts: Harvard University Press, 1966), 25.

[68] Ibid, 27.

Collateral Problems Hampering MOE for IO

Despite the best results of tapping into the scientific capability resident in the complexity community, the problem of commanders' confidence in information operations remains. The introduction of a very new and complicated scientific solution may even exacerbate this problem. Nevertheless, the concrete qualitative, as well as quantitative, potential of CAS models can serve two purposes to instill confidence in IO. First, linking measurable effects to IO capabilities (cause and effect relationships) builds confidence in IO. Second, they can develop the decision-makers' ability to understand non-linearity, beyond its theoretical constructs, to optimally integrate and apply non-linear thinking into military decision-making. As stated in the introduction, once military decision-makers develop the ability to think in non-linear terms about the complexity of warfare, and specifically about the application of information operations, the necessity for quantifiable MOE will dissipate. Again, computer generated CAS models, used to plan, execute, and measure IO can bridge the gap between now and when the military develops leaders who more readily think in non-linear, qualitative terms.

Examining the MOE of individual capabilities of IO indicates that measuring their individual effects is a difficult prospect, let alone measuring their combined effects. Recall the example of SSG Fivel and his Psyop detachment in Operation DESERT STORM from Chapter 1. The planners and commanders of organizations like his, possessing individual capabilities such as Psyop or EW, are comfortable with their current, ambiguous, qualitative measures. This comfort comes from years of training and experience working with these capabilities, and seeing the capabilities employed with success on the battlefield. Building a similar confidence in commanders not closely associated with the individual capabilities remains difficult.

The combined effects of the individual capabilities exacerbate the problems of commanders' confidence and the difficulty of developing comprehensive MOE for IO because of the aggregation principle of non-linearity. Even if each IO capability had existing, quantifiable MOE (which they do not), the whole effect of a synchronized information operation is not equal to the sum of its parts. The

aggregated effects of an information operation may be greater or less than the sum of the individual effects. They can be greater because the aggregated IO capabilities work in concert to achieve cumulative effects. Recall the vignette of the 10,000-pound bomb for example. They may be less because IO success may never reach complete certainty. Because the individual capabilities of IO do not have quantifiable MOE, aggregating them in a CAS model is more difficult than if combining multiple, linear, single variable MOE. Nevertheless, a computer generated CAS model is the best hope for developing a useable, unified IO MOE predictor.

Another problem dealing with confidence in IO, collateral to the central thesis of this monograph, has to do with compartmentation of IO efforts. The military often compartments IO work from conventional operations.[69] Because of this, commanders gain little or no experience or exposure to IO during standard professional development and education. It is not unusual for senior commanders to be exposed to certain IO capabilities for the first time when having to make decisions concerning their operational employment. While this is not a new problem, unique to IO, it is an experiential learning deficiency in officer professional development as a whole.

Recommendation

The U.S. military should solicit the support of the civilian complexity community to develop CAS models to assist in planning, executing, and measuring the synchronized effects of IO. IO targets one of the most complex, adaptive systems in the world – the human mind. In this case, meaning the mind of the adversary decision-maker; including his decision processes and their inter-related Complex Adaptive Systems. Since target system models are an integral part of the targeting process, models of the

[69] Special Technical Operations are doctrinally compartmented, as are military deception plans and operations. Many of the capabilities resident in the intelligence community, specifically tailored for support to IO, are also compartmented or classified above the SECRET level. The author has worked with, and has specific knowledge of, many of these capabilities. Because of their classification, these capabilities could not be addressed in the body of this monograph.

adversary's decision systems are integral to effective IO targeting. Computer generated CAS models, of the type used and developed in the complexity community, can model the adversary for IO planning, targeting, and combat assessment.

Rather than build a body of complexity expertise in the military, alluded to by the statement from the report to the SECDEF on military transformation, it is much more efficient to capitalize on the efforts already underway within the private sector. Specifically, the military should sponsor directed research at the Santa Fe Institute, a private, non-profit research institute that specializes in complexity science, as opposed to contracting a for-profit company to do so or attempting to build a similar capability resident in the military structure. The research should focus on developing computer based tools to generate adversary complexity models for IO planning and targeting. As demonstrated by the RAND example, an independent, non-profit organization is best suited to develop unbiased, complete products of this nature.

Four reasons support the selection of the Santa Fe Institute for this task. First, contract specifications (or lack there of), cost over-runs and profiteering, and the necessity for meeting contractual deadlines would not encumber the freedom of scientific discovery, imbedded in the founding principles of SFI. The founders of Rand realized these types of problems exist in for-profit contracting companies and determined that non-profit, private organizations are best suited to overcome them. SFI is not a contractor. It is a non-profit research institute that is dedicated to multi-disciplinary research in the field of complexity.

Second, all of the scientific disciplines necessary for developing tools to model adversary CAS are already resident at SFI. "In addition to the small faculty in residence and external faculty members on site, SFI hosts a wide variety of visiting faculty at any given time--from undergraduate interns to postdoctoral fellows to Nobel Laureates."[70] The resident and non-resident faculty represents disciplines from throughout the hard and social sciences. The multi-disciplinary and trans-disciplinary nature of research at SFI is what enabled it to develop complexity science into what it is today. The early hard

[70] Santa Fe Institute, "People," *SFI Homepage* (Santa Fe, NM: Santa Fe Institute) Internet, http://www.santafe.edu/sfi/indexPeople.html, accessed 3 April 2002.

science researchers at RAND quickly realized that answering the research questions of their day required not only multiple scientific capabilities in physics, mathematics, and chemistry, but also economics and political science. Recreating such an extensive, multi-disciplinary capability in a for-profit contractor would be both costly and inefficient compared to the capability already resident at SFI. Developing CAS models for use in IO undoubtedly requires input and expertise from military IO experts. The addition of visiting military researchers should not present a problem; SFI already integrates the use of visiting faculty and researchers. Military researchers could even lead, or at least participate in, IO research projects at SFI under a "Training with Industry" or "Advanced Civil Schooling" arrangement.

Third, the proprietary nature of the work in for-profit complexity contracting firms hinders access to aspects of complexity work that might otherwise be available at SFI. Many of the start-up complexity companies in Santa Fe develop proprietary CAS models for use in their business ventures. Competition for contracts among these firms is the same as there was among Douglas Aircraft, Boeing, and Northrop in the 1940s. Competition that leads to exclusive use of thoughts and models will hinder access to complexity work useful in CAS modeling for IO. This same issue of competition in the aerospace industry in 1948 was a significant contributing factor in the decision to split RAND from Douglas Aircraft. Because of the non-profit and open research environment at SFI, proprietary competition among researchers does not exist. Seemingly unrelated work on stock market analysis, advertising trends, or municipal planning at SFI may, and probably will, contribute to research efforts to develop CAS models for IO.

The most significant reason for sponsoring IO CAS modeling at SFI is SFI's expertise and independence. SFI developed the science of complexity. It is what they do all day, everyday. Building a commensurate capability within the military requires an unjustifiable amount of effort and expense. Additionally, given the rapid technological advances of the information age, the military cannot afford the time it would take to build a resident capability. The reasons why its founders established RAND as an independent entity, separate from the military, in 1946 remains valid today. The founders realized that creative scientific discovery could not take place to its fullest potential in the bureaucratic military

environment. Policy makers should take a lesson from this bit of history before attempting to build a resident complexity capability in the military at JWAC, DIA, JIOC, or elsewhere.

The requirement for operationalized complexity science for military application is clear. Commanders, across all services, at all levels from strategic to tactical, lack confidence in gauging the effects of information operations. Their lack of confidence leads to reduced use of the IO capabilities so necessary for success on the modern battlefield. Synchronized information operations create qualitative effects within the minds of adversaries that only complexity models can address. An independent, non-profit organization, like The Santa Fe Institute, is most likely to produce the most accurate and complete tools to develop adversary CAS models. DOD must take advantage of SFI's expertise to create complexity tools to effectively plan and measure the effects of information operations.

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