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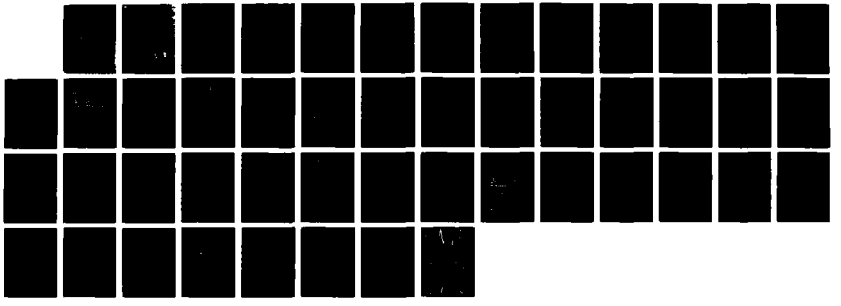

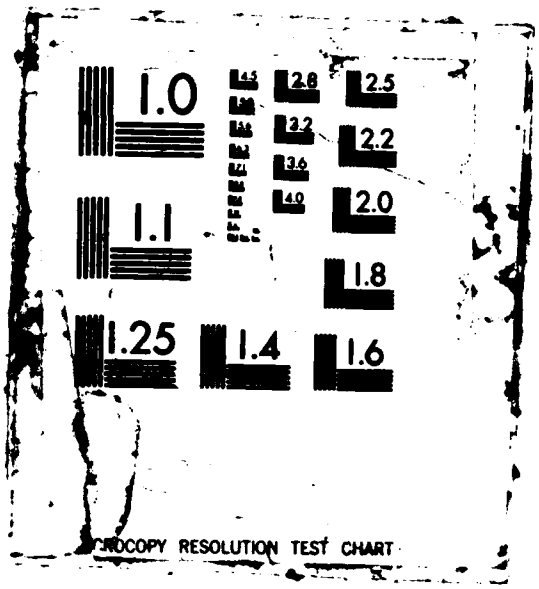
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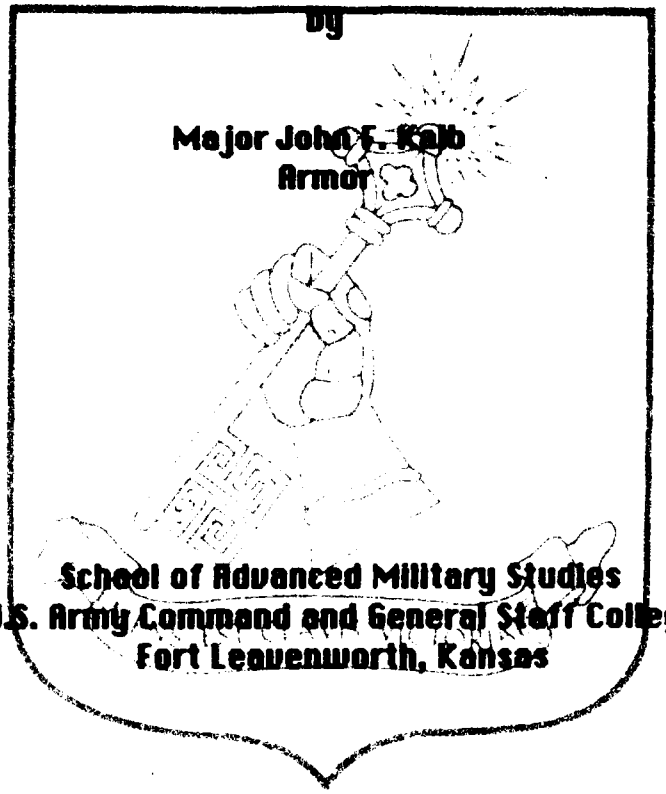
Measuring Command and Control
--Considerations for Force Design

by

Major John F. Kalb
Armor



School of Advanced Military Studies
U.S. Army Command and General Staff College
Fort Leavenworth, Kansas

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Command and control (C2) is an essential element of all combat operations. Measuring the effectiveness of a C2 system is a difficult task. Numerous definitions, the lack of a common vocabulary, and the absence of a prevailing conceptual framework are factors that obfuscate any methodology for assessing the performance or components of a system. The most useful approach produces quantifiable data that measure the efficiency of components within a C2 system. Key to this evaluation technique is the establishment of measurable and meaningful criteria. This monograph examines key aspects of C2 at the tactical level in order to propose a set of criteria for measuring the efficiency of a C2 system.

The study begins with a theoretical and doctrinal analysis of C2 in order to establish a model of the C2 process. Components of the model are then

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translated into general force design requirements to illustrate linkages between process and structure and establish a focus for measuring efficiency. Theoretical and doctrinal insights are explored during the next step in order to establish a set of criteria for measuring the efficiency of a C2 system. An analysis of unit performance at the National Training Center is used to reinforce the validity of the proposed criteria. The study concludes by addressing implications with regard to doctrinal development, future research, and force design.

This monograph suggests that a unit's Table of Organization and Equipment (TOE) is the focus for measuring efficiency in a C2 system. Continuity of operations, accuracy of information, speed of the process, and security of information are criteria that measure the key attributes of an ideal C2 system.

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ABSTRACT

MEASURING COMMAND AND CONTROL -- CONSIDERATIONS FOR FORCE DESIGN
by MAJ John F. Kalb, USA, 40 pages.

Command and control (C^2) is an essential element of all combat operations. Measuring the effectiveness of a C^2 system is a difficult task. Numerous definitions, the lack of a common vocabulary, and the absence of a prevailing conceptual framework are factors that obfuscate any methodology for assessing the performance or components of a system. The most useful approach produces quantifiable data that measure the efficiency of components within a C^2 system. Key to this evaluation technique is the establishment of measurable and meaningful criteria. This monograph examines key aspects of C^2 at the tactical level in order to propose a set of criteria for measuring the efficiency of a C^2 system.

The study begins with a theoretical and doctrinal analysis of C^2 in order to establish a model of the C^2 process. Components of the model are then translated into general force design requirements to illustrate linkages between process and structure and establish a focus for measures of efficiency. Theoretical and doctrinal insights are explored during the next step in order to establish a set of criteria for measuring the efficiency of a C^2 system. An analysis of unit performance at the National Training Center is used to reinforce the validity of the proposed criteria. The study concludes by addressing implications with regard to doctrinal development, future research, and force design.

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I. Introduction

General Donn A. Starry once commented that "no element of the [AirLand Battle] concept is more essential to the development of a credible warfighting capability than command and control."[1]

Command and control (C^2) is an important part of Army doctrine and a subject of continuing concern. The May 1986 edition of FM 100-5 Operations notes that "Common to all operations- close, deep, and rear- is the necessity for superior command and control."[2] A recent Armor Center White Paper, entitled "Command and Control of the Maneuver Heavy Force in the AirLand Battle," provides a glimpse of the Army's contemporary and future concern with C^2.

> The execution of AirLand Battle and, subsequently, Army 21 doctrine, will be conducted at a greatly accelerated pace, requiring the full use of the lethality and mobility of our fighting vehicles....The commander must make his decisions based upon his ability to "see" the battlefield. This involves not only the physical ability to see the point of main effort but also the use of intelligence to predict enemy probable courses of action. Our planning and execution cycle must be accelerated so that the enemy continually finds himself attempting to react to new offensive operations against his flanks and rear, rather than concentrating on offense, as his doctrine stresses.[3]

But what is C^2 and why is it considered so important? A plethora of sources offer varying definitions of C^2 that tend to confuse rather than enlighten. This paper will use the Army's definition of C^2 found in FM 101-5-1 Operational Terms and Symbols:

> The exercise of command is that process through which the activities of military forces are directed, coordinated, and controlled to accomplish a mission. This process encompasses the personnel, equipment, communications, facilities, and procedures necessary to gather and analyze information, to plan for what is to be done, and to supervise the execution of operations.[4]

A C^2 system is important because it supports the commander in making decisions and carrying out actions in the accomplishment of a mission. Martin van Creveld in his study Command demonstrates the importance of a C^2 system and observes:

> By making possible a faster and clearer reading of the situation, and a more effective distribution of resources, a superior command system may well serve as a force multiplier and compensate for weakness elsewhere....[5]

The effectiveness of a C^2 system is a vital component of combat power.

Measuring the effectiveness of a C^2 system is a difficult task. Numerous definitions of C^2, the lack of a common vocabulary, and the absence of a prevailing conceptual framework obfuscate any methodology for assessing the performance or components of a system.[6] Various approaches produce different results. Evaluation techniques generally fall within two groups: those that focus on mission accomplishment and those that focus on evaluating competing alternatives within a system.[7]

Measuring mission accomplishment is a popular technique. This is not surprising since both Soviet and US doctrine define effectiveness in terms of mission results. The Soviets view measures of effectiveness as follows:

> Based on the performance results of the tactical mission, that is, the effectiveness of employment of men and weapons, and based especially on the number of enemy and friendly losses, it is possible and necessary in the first place to assess the effectiveness of command and control by any commander or control organ.[8]

US Army doctrine recognizes that "the ultimate measure of command and control effectiveness is whether the force functions more effectively and more quickly than the enemy."[9] Techniques that focus on mission accomplishment inevitably include subjective evaluations of human decision making. While this approach provides qualitative data, it does not produce valid quantifiable data because of the variable nature of the human decision maker.[10] Measuring effectiveness in terms of the outcome of battle is not an appropriate technique to support cost effectiveness or other force design decisions.

The second approach evaluates the components within a system that are designed to support the decision maker.[11] This technique examines the technical means that support a C^2 process rather than the human dimension. Results are quantifiable and facilitate the comparison of candidate improvements to evolving systems. The second approach measures the efficiency of components within a

system and is the preferred methodology. Key to this evaluation technique is the establishment of measurable and meaningful criteria.

There is an increasing need for a set of criteria that are a common basis for measuring the efficiency of a C^2 system. The growing sophistication and cost of even low-level tactical C^2 systems make it imperative that decision makers be able clearly to determine the benefits of a particular technological improvement in order to make logical decisions. For example, the value of the Army's new Mobile Subscriber Equipment (MSE) initial contract is $63 million, with annual options totaling $4.3 billion.[12] Equally important, a common set of criteria also facilitates an evaluation of a system with regard to adequacy when threshold levels for the criteria are established.

The purpose of this paper is to establish a set of criteria that provide the framework for evaluating the efficiency of a C^2 system in a tactical combat organization. The methodology for this study is conditioned by a general theory of living systems and historical experience.

A general theory of living systems provides the foundation for studying a C^2 system. Among various studies, a master theory presented by James Miller in his book Living Systems is perhaps the most comprehensive. Miller's central thesis is that

> ....systems at all these levels (cell, organ, organism, group, organization, society, supranational system) are open systems composed of subsystems which process inputs, throughputs, and outputs of various forms of matter, energy, and information.[13]

Miller identifies nineteen subsystems that are essential for life, nine of which are concerned with information.[14] His general theory of systems has several implications with regard to this paper. First, structure and process are the basic components of a system.[15] Information oriented subsystems are rooted in the natural laws of the universe. This implies that the information process is unchanging, while structure is variable. Second, a general theory "provides common measurement units that make research at different levels comparable."[16] This suggests the existence of common measurement criteria.

History has also illuminated a path for study. The evolution of command and control over the last thousand years has demonstrated that leadership, communications, and organization are essential elements for establishing and maintaining unit control.[17] Man is the focus of the control process. As one study put it, "the control of military units means simply -- the control of men."[18] Leadership is the central principle upon which the command and control process rests because man is the perpetual component in all military operations.[19] While this study seeks to exclude the variable nature of the human element, the effects attributable to the nature of leadership are relevant.

Experience during war demonstrates that a supreme leader is the preferred form of authority on the battlefield.[20] This suggests that a hierarchical form of organization (the physical manifestation of authority) is the best structure for force design. Command is the functional aspect of military leadership that rests on authority. Experience also demonstrates that "there is a limit to the number of

principle subordinates a leader can effectively command."[21] This is the functional reason for the evolution of a staff system and limiting a commander's span of control. A hierarchical structure, a staff system, and a limited span of control are elements of force design ascribed to the influence of leadership.

The evolution of command and control also illustrates that communications is a key ingredient because it allows a commander and his staff to exercise control.[22] Indeed, communications has increased in importance during the last century. An extract from A History of The U.S. Signal Corps illustrates the key role communications played during WW I :

> The Signal Corps troops maintain their nets with telephone, telegraph and buzzer-phone instruments. Projector service, which is a means of visual signaling, supplements the wire circuits during the period of their interruption by the enemy's shellfire and other activities....The extensive radio net, throughout which each division on the front uses numerous types of radio equipment designed to meet the special needs of the regimental, brigade, division and corps headquarters....The systems are further augmented....by the pigeon service....special forms of fireworks....signaling panels used with airplanes and the "runners" (soldiers) to preclude an interruption in communication.[23]

WW II commanders relied on technical communications means more than ever before.

> Units, at all levels, were controlled and directed toward their missions by fragmentary verbal orders. Given over the radio by the voice of the commander, these orders were as pertinent and direct as they were personal and human.[24]

People and equipment form the means for communications and are in reality components of force design. Force design provides a means to achieve C^2. Thus the "Composition of a military formation has direct bearing upon how it can be controlled in combat."[25] The Army Lineage book illustrates the significance of this point with an example from the American Civil War:

> In the heat of the conflict, no changes were made in regimental organization, despite the fact that it was soon recognized as unsuitable. Improved firearms forced regiments and their companies to disperse to such an extent that officers could not effectively exercise control over them. Once a regiment deployed, it was too big for one man and his staff to control. This fact helped to cause a high casualty rate among general officers, since the only way they could influence an assault, or rally a broken line, was to place themselves where everyone in the command could see them. At such times the enemy's sharpshooters saw them equally well.[26]

Theory and history have provided an azimuth to guide investigation. This study begins with a theoretical and doctrinal analysis of C^2 in order to establish a model of the C^2 process. Components of the model are then translated into general requirements for people and equipment to demonstrate linkages between process and structure and establish a focus for measures of efficiency. Theoretical and doctrinal insights into measures of efficiency are then explored in order to propose a set of criteria for measuring the efficiency of a C^2 system. An analysis of unit performance at the National Training Center (NTC), with a focus on C^2 issues, is used to reinforce the validity of the proposed criteria.

The study concludes with recommendations for doctrinal development, future research, and force design.

The scope of this paper is limited to the tactical level of war although the conclusions offered may have relevance in the operational and strategic realms. The J-Series tank battalion provides a relevant focus for examination because of its central position in the Army of Excellence Heavy Division.

II. The C^2 Process

An appreciation for the C^2 process is the first step in establishing criteria for measuring the efficiency of a C^2 system. Although theoretical and doctrinal perspectives differ with regard to the exact components of the C^2 process, common concepts are discernible and provide a means to construct a model of the military C^2 process.

A.M. Wilcox and his associates at the Royal Military College of Science depict C^2 as a cybernetic process. A commander commands and controls his forces "through a number of cybernetic or feedback loops."[27] Cybernetics refers to the theory of control and communications in animals and machines. It also indicates that the C^2 process has its roots in the deeper theory of living systems.[28] The steps in each cybernetic loop occur sequentially and are interpreted as follows:[29]

- Surveillance. The search for available intelligence.

- **Communications.** The transfer of information to the commander and staff.

- **Data Processing and Management.** The filtering and processing of raw data into a suitable format for the commander.

- **Decision Making.** Selection of a course of action by a commander aided by his staff and decision aids.

- **Communications.** The conveyance of orders that result from decisions.

- **Action.** The purpose and end product of the process.

Wilcox' C^2 theory depicts one or more loops as necessary to achieve the desired action and recognizes that subordinate organizations execute their own cybernetic loops. This is consistent with a hierarchical command structure whose basic purpose is to accomplish a military action.

John R. Boyd, a maneuver warfare theorist, offers a more compact but similar theory of a C^2 process. Boyd reduces the C^2 process to a series of cycles that are composed of the following events: observation, orientation, decision, and action.[38] Observation is the process of collecting information; orientation and decision represent a consideration of the information and a selection of a course of action; and action is the execution of a decision. Boyd's theory also emphasizes that his process applys to all living things.

> Life is conflict, survival, and conquest. In addressing any questions about conflict, survival and conquest one is naturally led to the Theory of Evolution by Natural Selection and the conduct of war, since both treat conflict, survival,

and conquest in a very fundamental way.[31]

Martin van Creveld in his study Command provides a third theoretical point of view.[32] He believes an ideal C^2 process:

- Gathers information.
- Presents alternatives in decision making.
- Produces decisions that are adhered to in principle.
- Generates orders.
- Transmits orders.
- Monitors developments.

Van Creveld introduces the concept of monitoring as a step similar in function to gathering information but different in purpose. Gathering information relates directly to a command decision on a course of action, while monitoring provides information for a control decision that keeps an action consistent with achieving an end goal. Van Creveld believes monitoring is absolutely essential, citing several uses of what he calls a "directed telescope" to accomplish the task.[33]

The Soviets provide a final sample of C^2 theory that is very similar to those already discussed. Soviet C^2 theory recognizes the following "functions" in the C^2 process:[34]

- Acquisition and processing of information on the situation.

- Commander's adoption of the decision and his planning of combat operations.
- Disseminate the tactical missions to the troops and to organize their coordination.
- Organization of comprehensive support of combat actions.
- Preparation of troops for combat operations.
- Organization of command and control.
- Monitoring of the readiness of troops for combat operations.

Although the Soviet model appears more complicated, the process is essentially the same.

> Of all the functions mentioned, the main, always mandatory, fixed functions and those constantly repeated in practice are the acquisition and processing of information on the situation, making a decision based on this information, and disseminating the missions to those who will perform them.[35]

A doctrinal perspective is also useful in examining the C^2 process. The US Army recognizes many of the previously discussed concepts. TRADOC Pamphlet 525-2 Tactical Command Control acknowledges the following tasks as making up the C^2 process:[36]

- Find out what is going on.
- Decide what to do about it.
- Issue necessary instructions.

- Keep track of how well instructions are being carried out.

Field Circular 71-6, Battalion and Brigade Command and Control, describes the C^2 process at the lower end of the tactical level:

> Each time information requiring action is received, the commander goes through a decision-making process. He collects and analyses information, decides what to do, organizes his force to do it, orders someone to do it, and supervises the execution of the decision.[37]

C^2 theory and Army C^2 doctrine share the same basic concepts with regard to process. All examples included the requirements to collect information, communicate the information to a decision maker, perform a subordinate decision making process, and transmit the decision in order to accomplish a mission. Action seeks some goal and is the foundation of the process. Finally, the C^2 process is representative of the informational subsystem found within all living organisms. This suggests that the process is not evolving; it is a stable component within a C^2 system. The diagram at Figure 1. represents a synthesis of the previous examples into a model of the C^2 process.

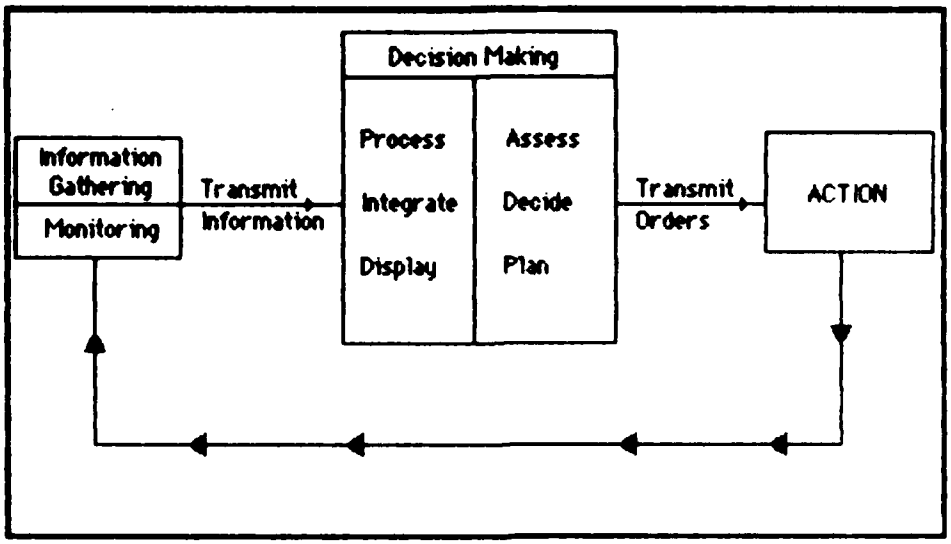

Figure 1. The Command and Control Process.

III. Process and Structure

The definition of C^2 describes a system that includes the elements of a process and a structure. A C^2 structure exists to support the C^2 process and includes doctrine and a unit's Table of Organization and Equipment (TOE). Doctrine includes the C^2 system of the superior headquarters, and any principles, policies, or standard operating procedures accepted by an authority.[38] Structure is shaped by factors in the environment. These include the unit's mission, friendly and enemy capabilities, terrain and weather, and time. Doctrine provides the framework for how to accomplish a mission in the environment and thus acts as a link in the C^2 structure that connects force design with external conditions.

Just as doctrine links structure to the environment, a TOE links structure to process. Each step in the flow of information within the cyclic C^2 process requires the accomplishment of certain tasks. The first task is to gather information. This involves various subtasks at the battalion level that are a reflection of the sources of information. Primary sources of tactical information are: higher, adjacent, and supporting headquarters, personal observations, direct reports from subordinates, reports from the local populace, captured enemy soldiers and documents, air reconnaissance, signal intercept, electronic sensors, topographic maps, technical references, and the commander's own knowledge.[39] Force design provides the commander with a means to tap sources of information. General requirements for information gathering include: an organizational structure with communication pathways that connect pertinent headquarters, a means for the commander personally to see any part of the battlefield under his direction, people to observe and collect information, vision equipment, sensors, maps, and a tactical library.

The next task is to transmit information. This is also functionally the same as the fourth task (transmit orders). A communication system functions to pass information from one place to another.[40] The information source transmits a message either orally or visually. A transmitter converts the message to a signal best suited for transmission via the communications channel. The channel, such as radio or wire, is the means used to send the signal. The receiver then changes the signal back into a message, completing the transmission of information. Transmitting information involves subtasks that are a function of the type of communications system used. Force design

provides the commander with the channel or means of communication. These include: equipment operators, radio transmitters and receivers to operate on required nets, devices for visual and audio signals, material and devices to facilitate written messages or orders, and messengers with appropriate transportation.

FC 71-6 Battalion and Brigade Command and Control notes that the C^2 "process is a cycle that begins and ends with the commander."[41] The third task, decision making, is thus the essence of the C^2 process. This step requires the processing of data into a form that is relevant and easily understood, assessment of the data, consideration of courses of action, a decision, and further amplification into a detailed plan if time permits. Force design provides the position of Commander as the focus for decision making. A staff in battalion and larger organizations is provided to the commander to assist him in his decision making duties. Various types of aids/devices are provided to track and display information that facilitate the commander's and staff's efforts.

The previous discussion establishes a sequence of linkages that illustrate the key role a TOE plays in a C^2 system. The diagram at Figure 2. is a model of a typical C^2 system. The components of a C^2 system are a process and a structure. The process is composed of distinct steps. Each step in the C^2 process is a task that generates a requirement for a piece of supporting design. The C^2 structure is composed of a TOE and doctrine. A TOE represents a summation of force design requirements that provides the means to accomplish the tasks and satisfy doctrinal requirements. Process provides the task or the "what" for force design, while doctrine provides the "how." A TOE links the two. Since the efficiency of a C^2 system is variable and the process

within the system is fixed (the constant), then one or more elements in the structure are variable and thus determine the efficiency of the system. If the TOE represents the link between process and structure that acts to harmonize process with doctrine, then the TOE determines the efficiency of a C^2 system.

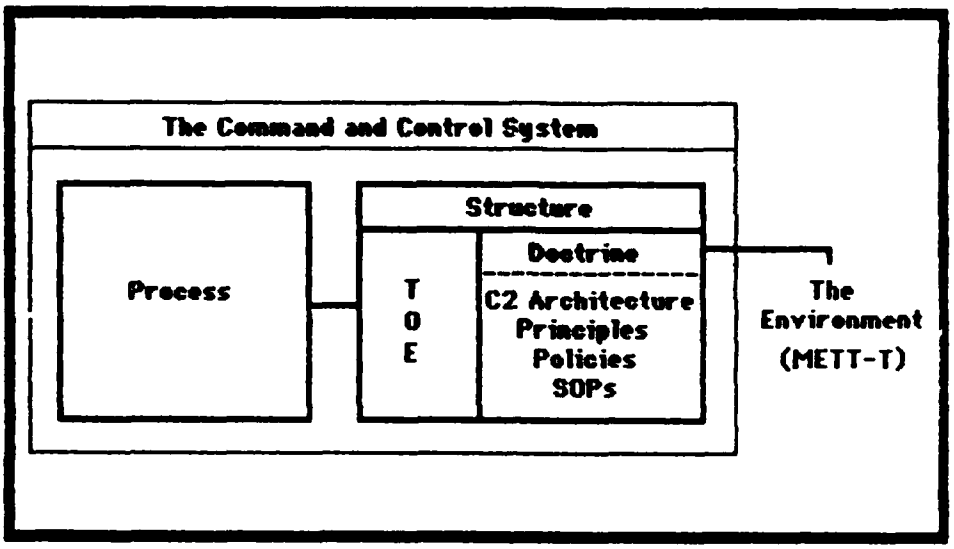

Figure 2. The Command and Control System.

III. Criteria for Measuring Efficiency in a C^2 System

A TOE provides a level (quality and quantity) of means that should mesh with doctrine to maximize the efficiency of a C^2 system. Both theoretical and doctrinal perspectives provide insight into establishing criteria that measure efficiency in a C^2 system.

The cybernetic process discussed in the theory by A.M. Wilcox and his associates views communications as the essential part of the

process. The theory depicts selected attributes of the communications component of the C^2 process as the best measurement criteria:

> It is clear from the analysis of command and control that communications are the vital element in the loop.... The communications systems themselves must be survivable, flexible, reliable, secure, and interoperable if they are to contribute positively to effectiveness in battle.
>
> ....The measure of the effectiveness of a communications system is its efficiency in passing information .... described by the following parameters: accuracy....quantity of information passed....(and) speed of passing information. These parameters are measurable and are specified as the basic design criteria of a system, and the final form of the system depends on the emphasis placed on each.[42]

Martin van Creveld in his study Command offers similar descriptors but addresses them to the entire process:

> An ideal command system, then, should be able to gather information accurately, continuously, comprehensively, selectively, and fast. Reliable means must be developed to distinguish the true from the false, the relevant from the irrelevant, the material from the material. Displays must be clear, detailed, and comprehensive at one and the same time.... Orders should be clear and unambiguous. Once formulated, orders must be rapidly, reliably , and securely transmitted.[43]

John Boyd's theory focuses on speed as a primary means of disorganizing and defeating an opponent.

> The idea of fast transients suggests that, in order to win, we should operate at a faster tempo or rhythm than our adversaries -- or, better yet, get inside our adversaries Observation-Orientation-Decision-Action time cycle or loop. Such activity will appear ambiguous (unpredictable), and thereby generate confusion and disorder among our adversaries -- since our adversaries will be unable to generate mental images or pictures that agree with the menacing as well as faster transient rhythm or patterns they are competing against.[44]

Although Clausewitz did not directly address the command and control issue in On War, he alluded to the importance of speed:

> If the enemy decides on a simpler attack, one that can be carried out quickly, he will gain the advantage and wreck the grand design. So, in the evaluation of a complex attack, every risk which may be run during its preparatory stages must be weighed. The scheme should only be adopted if there is no danger that the enemy can wreck it by more rapid action. Wherever this is possible we ourselves must choose the shorter path.[45]

LTC Dale E. Fincke in a paper titled Principles of Military Communications for C^{3}I believes that "communications more than any other combat related element directly effects the ability of the commander to turn information, ideas, and plans into reality."[46] He suggests that the principles of continuity, homogeneity, versatility, security, and simplicity "form the qualitative foundation against which current and future communications methods, architectures, and equipment should be assessed."[47] Subordinate elements that support each basic principle are also postulated as follows:

- **Continuity - survivability, reliability, redundancy, and self repairability.**
- **Homogeneity - modular commonality, network syathesis, integration.**
- **Versatility - agility, flexibility, decentralization, autonomy.**
- **Security - indeterminacy, digital transmission, communications security, stealth.**
- **Simplicity - technological sophistication, human factors.**

Soviet C^2 theory stresses that subordinate criteria indexes (after mission results) are: speed of the system, survivability, continuity, security, accuracy and reliability of data, and the carrying capacity of communications channels.[48] The Soviets emphasize speed as their basic measurement.

> **Consequently, the basic quantitative criterion (index) of operativeness in control may be the time spent by the commander and staff of a given element on one control cycle, that is, on acquiring and studying the situation data, making a sound decision on this basis, and assigning the missions to those who will carry them out. This time, of course must be as short as possible in order to provide maximum time for troop preparations to carry out the mission, to ensure striking before the enemy....This maximum admissible duration of one cycle is customarily called the critical control time.[49]**

A doctrinal point of view may also help in the development of criteria that measure the efficiency of a C^2 system. US Army doctrine recognizes measures of system efficiency. FM 100-5 details the essential ingredients of an efficient C^2 system as follows:

> The system must be reliable, secure, fast, and durable. It must collect, analyze, and present information rapidly. It must communicate orders, coordinate support, and provide direction to the force in spite of enemy interference, destruction of command posts, or loss and replacement of commanders.[50]

FC 71-6 Battalion and Brigade Command and Control reflects current doctrine.

> The system must function with such efficiency, accuracy, and dispatch that the information--decision--action--follow up cycle works faster than that of the enemy.
>
> The system must be responsive to the demands of higher headquarters, and must provide for continuous planning, coordination, and assessment in every situation.[51]

The previous sampling of C^2 theory and current US Army doctrine suggests that the following criteria measure efficiency in a C^2 system:

- continuity of operations.
- accuracy of information gathered.
- speed of the process.
- security of information.

Continuity of operations is a distinct feature in both theory and doctrine and is influenced by the following factors: survivability, redundancy, reliability, sustainability, mobility, and interoperability.

Accuracy of information is also frequently discussed and reflects what van Creveld refers to as "the endless quest for certainty."[52] The

subdimensions of accuracy are: the number, availability, and adequacy of collection sources; the speed of collection and transmission of information; and the degree of distortion during transmission.

Security of information is the capability of an organization to deny the enemy knowledge of one's orders or plans. Communications security is the most obvious dimension of this criterion.

Speed of the process is the most frequently discussed criterion and perhaps the most important. Speed is measured in increments of time and is influenced by the following variables: the number of command levels, the span of control, the degree of decentralization in the decision making process, and automation.[53] The speed of each component or the entire process is measurable in time. For example, the time it takes to detect an enemy activity is measurable, as is the total time for a unit to detect an activity and issue orders for action.

The proposed criteria measure attributes of a perfect C^2 system that are a reflection of the C^2 process. The ideal C^2 system: functions all the time regardless of environmental conditions; totally denies the enemy information regarding friendly plans or orders; collects all relevant information and passes it through the system without distortion; and operates with such speed that information is real-time, and the decision cycle always turns faster than the enemy's.

The established criteria by themselves are only a measure of efficiency; they do not guarantee adequacy with regard to the enemy. The force designer achieves adequacy in a C^2 system by raising the threshold of one or more criterion until a war-winning level is reached. For example, he increases the degree of continuity in operations by providing a heavier armored C^2 vehicle which increases survivability.

Unfortunately, adequacy in the design of a C^2 system is relative to the capabilities of an enemy, and actual combat experience is the only true test. Actual combat experience would also provide a means to reinforce the validity of the proposed set of measurement criteria.

V. Measuring Efficiency in a Tank Battalion C^2 System

Short of actual combat, the most realistic battlefield environment available to the US Army is the National Training Center at Ft Irwin, California. Brigade-size units conduct live-fire and force-on-force operations against a Soviet-style opposing force over rugged terrain that can exceed 40 kilometers from start to finish. Both sides are equipped with MILES systems that simulate personnel and vehicle destruction and position location designator systems that track the movement of combat vehicles and dismounted elements. Both the MILES and position designator systems as well as remote video cameras are tied into a computerized instrumentation system that provides data and a video representation of the battle for analysis. A team of on-site Observer/Controllers conduct a close evaluation of each unit's performance.[54] C^2 is one of the eight operating systems that form the basis for evaluation of unit performance. Written findings are coupled with instrumented data to provide a thorough analysis and critique of performance.[55] The realistic training environment, instrumented data, and first-hand observations concerning C^2 make unit performance at the NTC an ideal laboratory to test the validity of criteria for measuring

the efficiency of a C^2 system and to examine how well a particular TOE satisfies C^2 requirements.

Data on unit performance at the NTC was gathered from nine different rotations including a special C^2 assessment team after action report. Both doctrinal and TOE observations relating to C^2 were sifted from the sources and categorized according to their effect on the C^2 process.[56] A final analysis was then conducted by category to isolate one or more common attributes. For example, battalions routinely publish operation orders (OPORDs) to transmit plans to subordinates. Observations noted that the reproduction of OPORDs by hand (the cause) consumed a great deal of time and invariably produced inaccurate overlays (effects on the C^2 process).

Continuity of Operations

Unit performance indicates that many C^2 problems are due to insufficient personnel, insufficient radios, and survivability of facilities.[57] Observations clearly relate to the ability of a unit to maintain continuous C^2. Comments are centered on the capability of C^2 facilities to perform doctrinal tasks. The following observations illustrate common problems:

- Insufficient personnel in the Mortar Platoon FDC impaired 24-hour operations.
- Insufficient personnel in the TOC Fire Support Element impaired 24-hour operations.
- The physical configuration of the Commander's vehicle (working space, radios) detracted from his C^2 capability.

- Insufficient personnel in the combat trains impaired 24-hour operations.
- Insufficient communications equipment and personnel in the combat trains detracted from the capability to act as the alternate TOC.
- Insufficient personnel in the TOC impaired 24-hour operations.
- The TOC was very vulnerable to interdiction because of the visual signature of the M577 and the number and length of radio transmissions.

Accuracy of Information

The quality of decisions made by a commander is frequently degraded because an inaccurate picture of the battlefield is formed. This is a result of false information collected from various sources, a distortion of accurate information after collection, or the inability to determine when information is too old.[58] This is both a process and design problem that relates to the accuracy of information as it flows from the sender to the intended receiver. The following observations illustrate the contemporary version of an age-old problem:

- Map reading errors, particularly in scout platoons and M-1 equipped units, are the root of many problems.
- Reproduction of operations overlays by hand results in graphical errors.
- Inadequate or inaccurate administrative and logistical information frequently distorts the commander's estimate of his combat power.

Security of Information

A unit's plan is frequently revealed to the enemy before battle, stripping the friendly force of the key element of surprise. This is rarely the result of breaches in signal security; poor physical security is usually to blame. A common observation is that the scout platoon is inadequate to counter the enemy's mounted reconnaissance, and that doctrine does not address the issue.[59]

Speed of the Process

Perhaps the most frequently noted attribute of a C^2 system is speed. Positive comments noted that successful units are able to react quickly to situations and tend to allow their subordinates the maximum amount of time possible to prepare for an operation. These same units shorten the decision cycle time by continuously anticipating enemy moves, knowing the status of available resources, judging accurately time and space relationships, relying on SOPs, decentralizing activities to the maximum possible extent, and maintaining a rapid and reliable means of communications.[60] Observations also noted the following common problems related to speed:

- The reproduction of OPORDs by hand consume an inordinate portion of available time.
- Lack of permanently task organized units coupled with a high personnel turnover requires detailed coordination (and hence more time) to accomplish routine tasks .

- Standard reports take up too much radio transmission time.
- Battalions frequently attach a maintenance team permanently to each company in order to simplify and speed up maintenance operations.
- Inadequate communications capability in the Maintenance Platoon delays maintenance operations.
- Inadequate communications capability in the field trains delays supply operations.
- Inadequate or inaccurate administrative and logistical information frequently delays resupply operations.

Unit performance at the NTC further substantiates the importance of an efficient C^2 system, the role a TOE plays with regard to efficiency in a C^2 system, and the validity of the proposed set of criteria that measure efficiency in a C^2 system. A breakdown in C^2 may result in loss of the battle, while a superior C^2 system is a significant combat multiplier that may provide the edge for victory. The efficiency of a tank battalion's C^2 system is less than maximal when force design does not fully support the C^2 process. Continuity of operations, accuracy of information, security of information, and speed of the process are criteria that measure efficiency in a C^2 system.

VI. Implications

This study has addressed the issue of C^2 from a theoretical, doctrinal, and practical viewpoint. Each perspective raises implications with regard to recommendations for doctrinal development, future research, and force design actions.

Theoretically, the C^2 process is a representation of the information subsystem that is common to all living organisms. An open information system allows the subsystems within an organism to interact and adapt to changes in the environment. Conversely, a closed living system that inhibits or shuts out external information eventually suffers disorganization that results in death.[61] A functioning C^2 system is an open information system that should produce decisions that maximize an organization's survival in combat. Destroy (or perhaps just degrade) a unit's C^2 system and the subordinate parts of the unit suffer disorganization, making it more vulnerable to destruction by an enemy force. This suggests that an enemy's C^2 system (at any level) is a high priority target, and that protection of one's own C^2 system is equally important.

The proposition that a C^2 process has its conceptual roots in a general theory of living systems[62] has significant doctrinal implications. If a TOE must satisfy the requirements of both the C^2 process and doctrine, and efficiency is measured by the degree a TOE supports the C^2 process, then maximum efficiency is possible only when process and doctrine are in complete harmony. If the C^2 process is the stable component of the C^2 system, then the essence of doctrine must lay within the same origins of the process. This suggests that a set of

eternal principles, analogous to a natural law, exist. There is certainly a need for research into the military aspects presented in Miller's Theory of Living Systems.

This study also has implications with regard to future improvements in tactical C^2 systems and the force design process. A 1986 Armor Center White Paper, "Command and Control (C^2) of the Maneuver Heavy Force in the AirLand Battle," and an Armor Center - Infantry Center Concept Paper, "K+ Organizational Concept," provide a look at proposed future changes in the C^2 system of a tank battalion.

> Probably the greatest deficiency impacting on the commander's C^2 system today is the lack of time available to effectively coordinate the intelligence, fire, maneuver, and support to the battlefield systems and organization. This deficiency is further compounded by lack of accurate and timely battlefield information. Many of the tasks required of leaders are difficult or impossible by time-pressure, sensory overload, and some of the degraded conditions of NTC operations....
>
> The lack of accurate administrative and logistical support information is especially acute under the difficult and fast-paced operations of NTC.... This suggests that we transition from slow voice communications, paper maps, acetate, grease pencils, slow target acquisition, and inaccurate land navigation to something better....[63]
>
> AirLand Battle doctrine requires that we be able to fight on a sustained basis. Since human beings have a requirement for sleep and rest, it is incumbent on us to develop a system which will meet these requirements. The K+ organizational design recognizes the need for conducting sustained operations....We need to "hide" our commanders in combat vehicles with a common visual signature and, at the same time, we need to have redundancy in the command element.

> In order to have continuous, alert, and responsive command, we need two command groups with redundant command and control capabilities....
>
> The current concept of S-1, 2, 3, and 4 is replaced in K+ by the formation of the battle management section. This section is designed to operate out of three large, tracked command and control vehicles, probably modeled on the same chassis as the armored maintenance vehicle .... Sufficient redundancy is built into the section to rotate personnel.[64]

The proposed future improvements indicated in the papers correct many C^2 shortfalls in force design noted in NTC observations. The Army's methodology with regard to force design is pragmatic; doctrine and field experience are used to correct design shortcomings. Indeed, it seems that C^2 requirements as well as shortcomings in the TOE are almost a surprise. Unfortunately, a great deal of effort and expense has been spent fielding organizations with design flaws, shortcomings that might have been detected prior to fielding.

The papers illustrate a defective hidden logic behind the Army's approach to force design. The logic behind this approach treats the C^2 process as evolving; the process is shaped by factors within the C^2 system and the environment. A standard set of criteria that measure C^2 efficiency is not part of the force designer's kit because the Army does not recognize the C^2 process as the stable foundation of a C^2 system.

An examination of the problem areas indicated in NTC observations suggests that the principle of economy was used in the design of the tank battalion's TOE. Indeed, a further examination of the AOE force design reveals an austere organization that lacks robustness

and redundancy in people and equipment. A logical set of criteria was not used in the force design process to maximize the efficiency of a tank battalion's C^2 system.

VII. Conclusion

This study suggests that a set of force design criteria exists which serve to maximize the efficiency of a C^2 system. Theory and doctrine provide a foundation for establishing criteria. Process and structure are the components of a C^2 system. The C^2 process is representative of the informational subsystem found within all living organisms and is the stable portion of the C^2 system. Structure is the variable portion in a C^2 system that interacts with the environment. Structure is composed of a TOE and doctrine. The linkage between process and structure within a C^2 system is a unit's TOE, and the linkage between structure and environment is doctrine. Efficiency within a C^2 system is a measure of the degree a unit's TOE satisfies process requirements. An analysis of theoretical and doctrinal sources illuminates a set of common criteria that measure the key attributes of a C^2 system. The performance of J-series tank battalions at the NTC provides a basis to evaluate the validity of the proposed criteria from a perspective of reality. An analysis of observations indicates that the efficiency of a tank battalion's C^2 system is less than maximal when a TOE does not fully support the C^2 process. The analysis further suggests that continuity of operations, accuracy of information, speed

of the process, and security of information are measures of efficiency in a C^2 system.

Application of the proposed criteria within the force design process would result in several benefits. Decision makers could optimize choices between C^2 systems or components of systems based on a realistic approach to measuring cost-effectiveness. The probability of fielding an organization with a flawed C^2 system would decrease, while the chances for successive improvements in tactical C^2 systems would increase. Any increase in the efficiency of a C^2 system would produce the most important benefit....an increase in tactical combat power.

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[36] HQ US Army Training and Doctrine Command, Pamphlet 525-2 Operational Concept - Tactical Command and Control, (Fort Monroe, Virginia, 1980), p. 3.

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