Chapter One

INTRODUCTION

> If I always appear prepared, it is because before entering on an undertaking, I have meditated for long and have foreseen what may occur. It is not genius which reveals to me suddenly and secretly what I should do in circumstances unexpected by others, it is thought and meditation.
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> ——Napoleon Bonaparte, 1812[1]

In an age of abundant, almost limitless, information and communications capabilities, decisionmakers are increasingly faced with the problem of too much information, rather than too little. In today's information-oriented society, winnowing, filtering, correlating, and fusing information have become as important as acquiring the information, or (regrettably) even as important as its content, if not more so. Understanding what information is most essential for decision-making—so that the information being communicated, processed, or displayed can be bounded—is now a major issue in the design of computer-aided decision support systems.

Nowhere has the problem of overabundant information become more apparent than in military command and control, where the accelerating technologies of communications and computers have flooded commanders at all levels with so much information that they sometimes seem no longer able to digest or comprehend it. The prevailing approach to this problem is to apply still more technology, in the form of computers and software, to sort through, filter, and display the information in ways that will assist the commander in focusing on the "right" information. This approach, of course, assumes that the commander and his responsibilities, circumstances, and

[1]The quotations at the beginning of the chapters are taken from Robert Heinl, *Dictionary of Military and Naval Quotations*, Annapolis, Md.: Naval Institute Press, 1966.

decisions are understood well enough for his informational needs to be anticipated.[2] It also assumes that the C2 issues for commanders are acquiring enough information, sorting through it, and then maintaining connectivity with subordinates so that they can be directed.

Excessive reliance on complex command, control, communications, and intelligence (C3I) systems is insidiously dangerous, and counting on the wrong part of command and control (C2)—on a system emphasizing mainly the control rather than the commander—to ensure success in battle can be a prescription for disaster. Yet most current theories of command and control are hierarchical (they represent information as flowing up and down the chain of command) and system-dependent.[3] They envision the commander as using a C2 system to influence events indirectly, at a distance. The commander issues instructions to subordinates, suggestions to commanders of adjacent units, and requests and reports to supporting units and superiors. He develops and maintains a situational awareness of the area of his operations through reports presented by other people or by electronic systems.[4]

Most C2 theories[5] involve information-push processes, in which the design of the system, type of standard messages and their formats, and positioning and capabilities of communication nodes define the type of information available to the commander. Typically, as events in the battle space[6] unfold, descriptive information flows through the hierarchy back to the commander and his staff. As the situation develops, the commander reacts by assessing the situation, developing plans, and issuing orders and reports. According to this view, the

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[2]In this report, we use *he*/*his* throughout for clarity, not to imply gender significance.

[3]System-dependent in the sense that the hardware pieces of the system define it. A more detailed discussion of contemporary command and control modeling approaches is given in the next section and in the Appendix.

[4]Thomas P. Coakley, *C3I: Issues of Command and Control*, Washington, D.C.: National Defense University, 1991, pp. 43–52.

[5]See especially the sections "Communications Connectivity" and "Launch Under Attack" models in the Appendix.

[6]Given the three-dimensional nature of modern warfare, and the fact that many future engagements are likely to be fought on media other than dry ground, this term is probably more apt than *battlefield*.

role of the command and control system is to paint a picture for the commander, and the role of the commander is to make highly interactive decisions.

By placing the commander in the position of a processor of inputs and a generator of messages, traditional approaches to modeling command and control create an ideal commander who is, in a way, a prisoner of events: He must react to developments in the battle space rather than anticipate them. A logical corollary is that real-time information becomes critical to the commander's ability to understand and decide. Because the commander makes decisions in reaction to events as they occur and not in anticipation of them, information—lots of it, painting as complete a picture as possible of the battle space—becomes his most critical need.

This approach to C2 clearly views the commander as a reactor, searching the ebb and flow of situational data for critical pieces of information in real time. It proceeds from the notion that the commander is unlikely to anticipate the development of events with any degree of accuracy. It assumes that the commander, his staff, and his supporting C2 system must sift through masses of data—coming in at ever-increasing rates—to glean the relevant clues that will inform his action. It also assumes that the vast majority of information transmitted will be descriptive, and that the most significant cognitive activity of the commander will be "pattern-matching": recognizing the picture and its significance.

The problem is that this approach does not consider the content of what is being transmitted—or what *should* be transmitted. It implies that system designers are able to determine the type and content of the messages that a commander might need and that command and control is simply a function of the hardware, software, and doctrine for its use; if they achieve a master data-fusing system employing the right filters and data-reduction techniques, the commander's decisions can be cued in a timely manner. The system is viewed as a type of magic "bat-signal" that shines in the sky[7] to alert the commander that something important is happening. More significantly,

[7]The metaphor is taken from the Batman comic books and films, wherein the police of Gotham City signal their need for the "caped crusader" by shining a searchlight into the sky with a projected image of a stylized bat.

it implies that the information commanders need and will react to is both knowable and invariant for all commanders. In this approach to C2 design, "one size fits all."

Therefore, whereas most contemporary *discussions* of command and control (and, indeed, much of the current military-journal literature on the *practice* of command and control) pay strong lip service to the importance of the human element, there is little in the *theoretical* literature of command and control that does not have the commander boxed up in a wiring diagram. Much of this literature deals with organizations and communications[8] and explains theories with organizational charts that relate commanders to the people and functions they control, or with network-wiring diagrams that relate nodes and links in terms of informational functions or capacities. Defining the C2 process as a function of how the communications system is wiried together is analogous to considering a particular tank gun as being essential to a general theory of ballistics. However, although better guns shoot better, the properties of a gun do not change the fundamental laws of ballistics, which drive the design of the weapon. The rapidly evolving technology of C2 has shifted our attention from the essence of command and control—the individual, idiosyncratic approach of a commander to command that goes beyond military training and doctrine—to its silicon handmaidens, beguiling us with their siren songs of ever more communications, computing, and displays. It seems that a general theory of C2, if one can be determined, should drive the design of C2 systems, good ones of which are absolutely essential for effective performance on the battlefield but cannot substitute for a general theory of command and control.

In this report, we propose an alternative theory of command and control that focuses not on the sufficiency of bandwidth, interoperability, information overload, and stocks, flows, filters, and transformers, but on the cognitive processes of the commander. Specifically, we mean those processes that develop a concept of

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[8]Two notable exceptions are Martin van Creveld, *Command in War*, Cambridge: Harvard University Press, 1985, especially Chapters 1 and 8; and C. Kenneth Allard, *Command, Control, and the Common Defense*, New Haven: Yale University Press, 1990 (revised 1996). Both of these works are critical of the mechanistic view described above; but they stop short of suggesting a theoretical concept of what C2 *is*. We discuss van Creveld's ideas in Chapter Two.

impending operations that cue the commander (and his C2 system) to look only for certain pieces of information—the substance rather than the means of communications between commanders and their subordinates. To more carefully set our theory apart from the prevailing theories, we briefly describe the most prominent C2 theories here.

THE FOUNDATIONS OF EXISTING C2 THEORY

To qualify as a theory of command and control, a proposed model must explain widely observed properties and behaviors in terms of more fundamental, or deeper, concepts that draw their principles and vocabularies from analogs in other systems or sciences—control theory, cognitive science, organization theory, neurophysiology, and information theory—not merely describe existing command and control systems. In spite of the apparent diversity of analogs informing these approaches, most models in the literature are fundamentally similar in that they can all be reduced to a variant of a *cybernetic approach*, which describes C2 processes within the framework provided by control theory, or mechanical-electrical communications theory.[9] Because of this convergence, it is not unreasonable to refer to the dominant approach to modeling command and control as a *cybernetic paradigm*. This is the term we use in the following discussion to describe the standard approach to modeling C2.

Explaining C2 with Control Theory

The processes of battle—coordinating the activities of multiple independent units and adapting to exogenous changes—are similar to activities encountered in the control of industrial processes. For this reason, control theory provides a powerful framework within which to model the *control* aspect of command and control.

Cybernetic models divide systems into subsystems (components) that exchange signals (inputs and outputs) and that introduce math-

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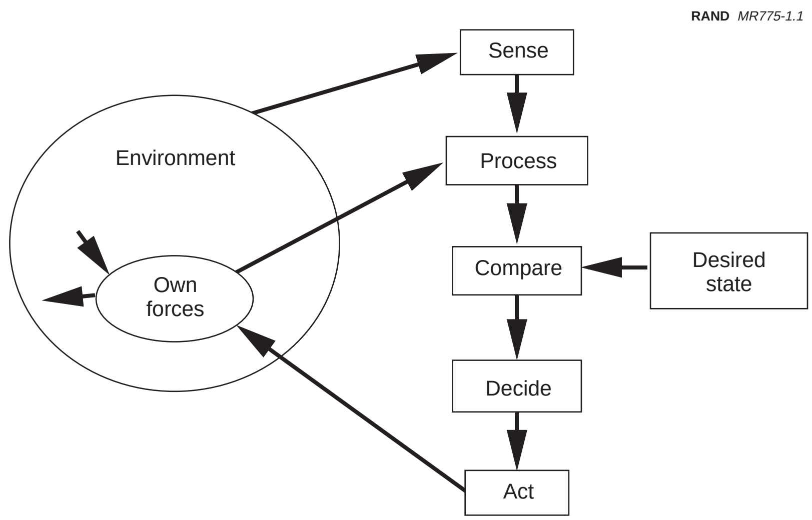
[9]Alexander H. Levis and Michael Athans, "The Quest for a C3 Theory: Dreams and Realities," in Stuart E. Johnson and Alexander Levis, eds., *Science of Command and Control: Coping with Uncertainty,* Washington, D.C.: Armed Forces Communications and Electronics Association (AFCEA) International Press, 1988, pp. 4–9.

ematical transformations of those signals. When this approach is applied to C2, it results in models consistent with the cybernetic paradigm. A frequently cited model of this type is that of J. S. Lawson, shown in Figure 1.1.[10] The influence of cybernetics and control theory on Lawson's model is quite clear. Terms such as "desired state" and "sense" are not native to the military lexicon. Indeed, the diagram of Lawson's model could apply equally well to a thermostat as to an industrial control system. Lawson's model is typical of the reactive, picture-painting view of C2 described earlier in this chapter, in which the entire environment provides signals that must be "sensed," evaluated, and compared with a desired state so that their relevance can be determined. In Lawson's world, the commander reacts to signals rather than anticipating them.



SOURCE: J. S. Lawson, "Command and Control As a Process," *IEEE Control Systems Magazine*, March 1981, p. 7. Copyright © 1981 IEEE.

Figure 1.1—Lawson's Model

[10]J. S. Lawson, "Command and Control As a Process," *IEEE Control Systems Magazine*, March 1981, pp. 5–12.

Organization Charts and C2 Modeling

Organizing military forces into a hierarchy of "units" may be among the most ancient of command and control techniques. Modeling the command and control of any particular armed force certainly requires representing its organizational structure, which encompasses both unit identities and chains of command.

Understanding the functions performed by various units in a military organization can be complex and challenging. However, when viewed as an information-processing mechanism, a military organization operates by exchanging messages (orders, directives, status reports). When flows of information are added to the chart, the result is a model based on flows of information and its transformations at various nodes (Army forces/Joint Force land component, Navy forces/Joint Force maritime component, for example). Figure 1.2 displays an example of such a model (arrows indicate sample nodes).

MODELING C2 WITH COGNITIVE SCIENCE

Purely cybernetic models—with their numeric signals and transforms—inadequately represent the complex and idiosyncratic activities of humans in C2 systems. To overcome this deficiency, cognitive constructs representing human decisionmaking have been inserted into, or overlaid upon, cybernetic models. Modeling the command part of C2 clearly requires some model of command decisionmaking. Cognitive science provides a rich portfolio of such constructs. A variety of cognitive techniques has been used to model command decisionmaking—in particular, rule-based expert systems and subjective expert utilities with Bayesian updating.[11] Petri nets have been used to model data-flow and decisionmaking structures.[12]

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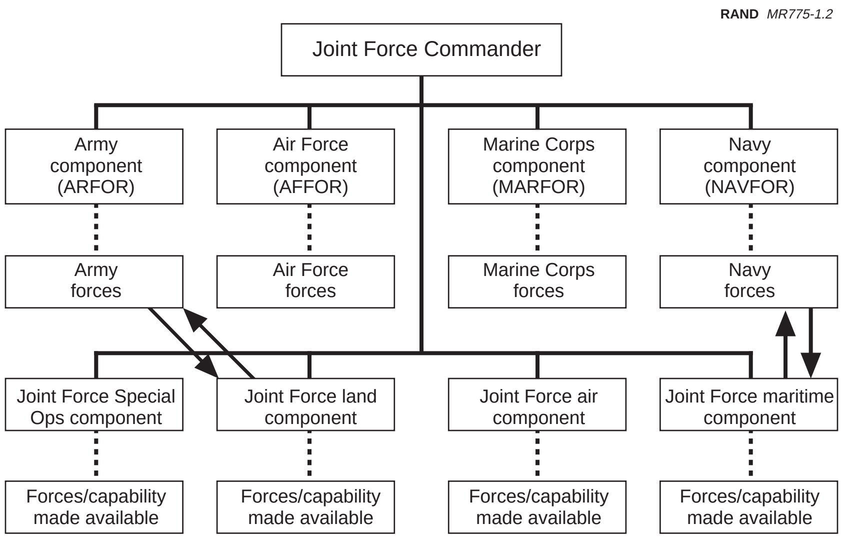
[11]Rex V. Brown, "Normative Models for Capturing Tactical Intelligence Knowledge," in Stuart E. Johnson and Alexander H. Levis, eds., *Science of Command and Control: Coping with Complexity*, Fairfax, Va.: AFCEA International Press, 1989, pp. 68–75; Gary A. Klein, "Naturalistic Models of C Decision Making" and Karen L. Ruoff et al., "Situation Assessment Expert Systems for C3I: Models, Methodologies, and Tools," in Johnson and Levis, 1988, pp. 86–92 and 118–126.

[12]D. Tabak and A. H. Levis, "Petri Net Representation of Decision Models," *IEEE Transactions on Systems, Man, and Cybernetics*, Vol. SMC-15, No. 6, 1985.



NOTES:
1) A joint force contains Service components (because of logistic and training responsibilities), even when operations are conducted through functional components.
2) All Service and functional components are depicted; any mix of the above components can constitute a joint force.
3) There may also be a Coast Guard component in a joint force.

Arrows indicate sample nodes (see text).

Operational control (OPCON)
Command relationship(s) determined by JFC

SOURCE: Adapted from Joint Chiefs of Staff, *Doctrine for Joint Operations*, Washington, D.C.: Office of the Joint Chiefs of Staff, Joint Pub 3-0, February 1995.

Figure 1.2—Possible Components in a Joint Force

These compound approaches ultimately rely on chains of command and communications paths for connections between nodes. Therefore, they end up being driven by cybernetic formalisms. Moreover, the human behaviors at all of the nodes are reduced to a common, rational actor: The “human” transformer at one node is the same as that at any other node. The advance, if any, is really one of inserting a more complex mechanical processor at each node.

Thus, regardless of whether the original inspiration comes from control theory or cognitive science, the process of seeking a "deep" theory of command and control produces convergent evolution toward a common destination: a collection of information flows and transforms—boxes and arrows—with the boxes representing processing nodes and the arrows representing information flows. Although cognitive science should be able to generalize the information flows from the real numbers of control theory to arbitrary data structures, the modeling emphasis has remained *not* on the content of the information flow but on the architecture of the boxes and arrows.

In describing C2 systems in this fashion, the content of the information that moves throughout the system and the transformations of that information are secondary to the representation of the nodes and links themselves, and can be represented only in the context of a particular architecture. J. G. Wohl's SHOR (Stimulus-Hypothesis-Option-Response) paradigm, shown in Figure 1.3, is an example. Similar to Lawson's model, this paradigm divides C2 processes into boxes, but its use of such concepts as "hypothesis" indicates that it draws inspiration from cognitive science as well as control theory.[13]

The ability to construct cognitive models that are descriptively accurate is much more poorly established than it is for models drawn from communications or control theory. Still relatively immature, cognitive science provides tools for modeling only certain aspects of command. In particular, the reactive aspect of human decision-making—e.g., picking from a list of preplanned options based on a situation estimate—is much better understood than the leadership aspects of command. Thus, while cognitive science has provided a basis for modeling command beyond the representations used in control theory, the resulting models remain primarily cybernetic in character, neglecting those aspects of command that are not reactive.

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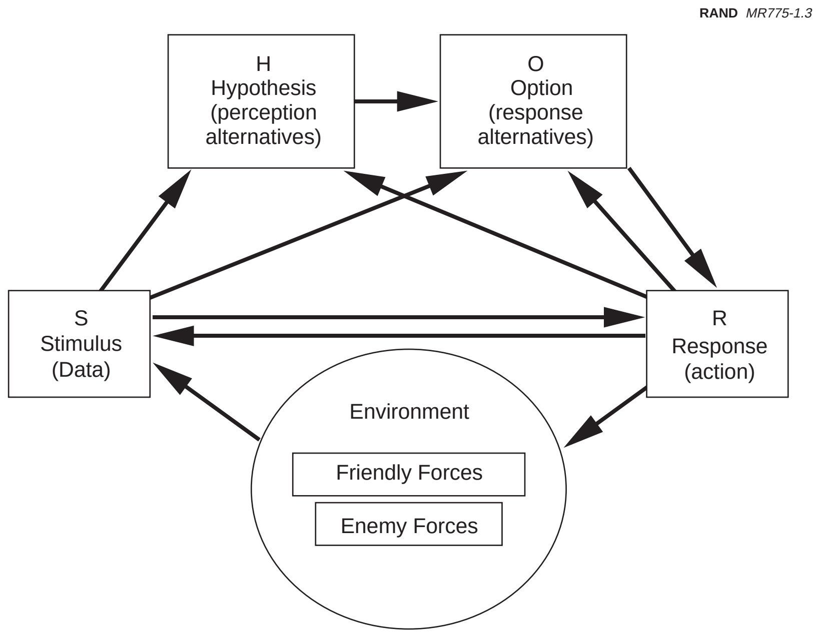
[13]J. G. Wohl, "Force Management Decision Requirements for Air Force Tactical Command and Control," *IEEE Transactions on Systems, Man, and Cybernetics*, Vol. SMC-11, No. 9, September 1981, pp. 618–639.



SOURCE: Adapted from J. G. Wohl, "Force Management Decision Requirements for Air Force Tactical Command and Control," *IEEE Transactions on Systems, Man, and Cybernetics*, Vol. SMC-11, No. 9, September 1981, p. 625. Copyright © 1981 IEEE. Adapted by permission.

Figure 1.3—Wohl's SHOR Model

Viewing a military organization primarily as an information-processing mechanism neglects many aspects of command but enables C2 models to be constructed without confronting these difficult aspects. Again, this is essentially a cybernetic paradigm. The chief problems with this representation are that the system defines the roles of the humans and that message formats, the type and frequency of messages, and connectivity define what information is available to the commander.

In order to solve the problems of contemporary and future command and control—problems that, for the most part, are unexplained by cybernetic theories of C2—a new theory of command and control that addresses those phenomena neglected by cybernetic models must be considered. This new theory must explicitly apply across multiple time scales of battle, from readiness and preparation to maximum combat intensity. It must address the social and cultural aspects of C2, and not reduce commanders to atomized information processors. Most of all, it must focus on the creativity of commanders.[14]

A THEORY OF COMMAND CONCEPTS

Thus, cybernetic models are incomplete: Although they provide a robust basis for understanding *control* functions, they are inadequate to properly descibe *command*, whose human elements cannot be captured in a computer program. Kenneth Allard, in commenting on the following definitions of *command*, *command and control*, and *command and control system* in the *Department of Defense Dictionary of Military and Associated Terms,* notes that "one of the most striking characteristics of these definitions is the extent to which they evoke the personal nature of command itself, especially the fact that it is vested in an individual who, being responsible for the 'direction, coordination, and control of military forces,' is then legally and professionally accountable for everything those forces do or fail to do":[15]

> *Command:* "The authority vested in an individual of the armed forces for the direction, coordination, and control of military forces."
>
> *Command and control:* "The exercise of authority and direction by a properly designated commander over assigned forces in the accomplishment of the mission. Command and control functions are performed through an arrangement of personnel, equipment, communications, facilities, and procedures which are employed by a commander in planning, directing, coordinating, and controlling forces and operations in the accomplishment of the mission."

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[14]*Creativity* encompasses a wide range of thought processes and behaviors. The case histories of successful command concepts such as MacArthur's at Inchon and Nimitz's at Midway illustrate individual aspects of creativity.

[15]Allard, 1996 rev., pp. 16–17.

> *Command and control system:* "The facilities, equipment, communications, procedures, and personnel essential to the commander for planning, directing, and controlling operations of assigned forces pursuant to the missions assigned."[16]

When we use these three terms, the above definitions are implied in them.

Going beyond personality alone, our theory suggests that the essence of command lies in the cognitive processes of the commander—not so much the way certain people do think or should think as the ideas that motivate command decisions and serve as the basis for control actions: Ideally, the commander has a prior concept of impending operations that cues him (and his C2 system) to look for certain pieces of information. Rather than seeing the commander and his C2 system as omnivorous consumers of all available information, we see the commander's ideas as generating an information-pull process: a selective searchlight in a sea of information.[17] His technical systems may provide warnings, but they do so primarily because of the contrast of pertinent information against the background of his expectations, which are rooted in a prior, *expressed* concept of operations. If the commander has shared that concept with others, then the warnings can be provided by a strategically positioned subordinate, by a logical conclusion his staff deduces from the presence or absence of a key piece of expected data, or by the commander's own intuitive sense that events are developing either as he had expected or contrary to his expectations.

Sharing is the operative word in this concept, and in this way is similar to what FM 100-7 terms the *commander's intent,* which is "a concise expression of the commander's expected outcome of an operation."[18] But even more than the expression, we focus on the evidence of the cognitive process—the *command concept*—that

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[16]U.S. Joint Chiefs of Staff, *Department of Defense Dictionary of Military and Associated Terms,* Washington, D.C.: Office of the Joint Chiefs of Staff, JCS Pub. 1, January 1986, p. 74 (quoted in Allard, 1996 rev., p. 16).

[17]Van Creveld calls this the "directed telescope" (1985, p. 75).

[18]Headquarters, Department of the Army, *Decisive Force: The Army in Theater Operations,* Washington, D.C.: FM 100-7, May 31, 1995, p. 5-16.

underlies that expression. Looking across the history of military operations, from antiquity to the present, and considering the substance rather than the means of communication between commanders and their subordinates, what comes through most consistently is a vision of a military operation—what could and ought to be done in the application of military force against an enemy. We find renowned commanders mostly concerned with explaining and asking after their vision or expectations of possible and desirable operations: "Are things going as we planned (envisioned)? If not, what is broken and needs fixing? Why and where are things going wrong? Is the plan (vision) wrong, or does it simply need some adjustment?"

Evidence of command concepts is found most often in war and battle plans, sometimes in the setting of military objectives, less often in the deployment and commitment of forces, and perhaps least often in the issuance of direct orders. Here, we define a *command concept* as a vision of a prospective military operation that informs command decisions made during that operation. As such, a command concept may provide an important clue to the minimum essential information that must flow within C2 systems.

Not only should a comprehensive theory of C2 be able to explain how to organize, connect, and process information, it should also

- explain how the quality of commanders' ideas and the expression of those ideas can be assessed and, indeed, duplicated
- explain how C2 systems, including commanders, *should* work, and the *ideal* circumstances in which that work can occur
- provide measures of performance for commanders and their staffs, as well as for the communications and computers that support them.

The motivation behind the theory is a need to separate the *intellectual* performance of the commander from the *technical* performance of the C2 system. By demonstrating this difference, we demonstrate that the evaluation of C2 systems can finally be separated from the responsibilities of commanders.

Taken to the extreme, the notion of command concepts invites the following hypotheses:

- The most essential functions of command and control are conveying (to subordinates) and altering (for superiors) command concepts.
- All other information in the C2 system is likely to be superfluous—even detrimental if it diverts attention or effort away from those essential functions.

Ideally, then, battle commanders need only convey their vision of the operation to their subordinates. And the only information subordinates need provide their superiors is what would alter their superior's vision of the operation. In theory, therefore, if a commander's vision of battle was sound and was fully conveyed to subordinates beforehand, there would be no need for information to be in the C2 system during the ensuing battle. Conversely, needing a given amount of information in the C2 system during the battle relates directly to failures associated with the validity or completeness of the command concept or its clear conveyance to subordinates.

Decisive Force indicates how the *design*, or concept, enables this limiting of information:

> The commander's intent is the central goal and stand-alone reference that enables subordinates to gain the required flexibility in planning and executing. It is the standard reference point from which all present and future subordinates' actions evolve.
>
> Commanders and leaders—guided by their commander's intent—who can make decisions can better ensure the success of the force as a whole when conditions are vague and confusing and communication is limited or impossible. *The design of commander's intent is not to restrain but to empower subordinates by giving them freedom of action to accomplish a mission*.[19]

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[19]Headquarters, Department of the Army, 1995, p. 5-16. Emphasis added.

ORGANIZATION OF THE REPORT

In this report, we present a theory of C2 that cuts through the technological overlay[20] that now burdens the subject and attempts to reconcile some familiar instances of C2 success and failure from military history with intellectual performance—with what Napoleon refers to in the quotation at the beginning of this chapter as "thought and meditation." We examine whether empirical patterns can be derived from the structure and content of historical command concepts.

In the next chapter, we describe why we chose historical battles, the criteria we used to select the six battles from military history, and the process we used to synthesize the ideal command concepts that would have been appropriate to those battles. In each of Chapters Three through Eight, we present one case history. In Chapter Nine, we present conclusions and recommendations for further study. The Appendix describes C2 theories in addition to those described earlier in this chapter.

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[20]The technological overlay is mostly from communications and computers, which are changing at a remarkable pace. Command and control is conducted mostly in and through human minds, which change much more slowly.