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The Analytic Representation of Sensemaking and Knowledge Management within a Military C2 Organization

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FOR THE COMMANDER

// Signed //

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A review of current research from the fields of organizational psychology, management science, cognitive work analysis, and social network analysis provides a number of useful paradigms and constructs for explicitly representing the processes of sensemaking and knowledge management within military Command and Control (C2) organizations. This report summarizes those findings in the form of a proposed modeling framework for explicitly representing the process by which battlespace information is combined with appropriate staff expertise to generate actionable knowledge for the commander. The proposed model provides a theoretical framework for addressing the cognitive, social, organizational, doctrinal, and operational aspects of sensemaking and knowledge management. The utility of this framework is then illustrated by a case study that examines effects-based targeting operations during recent military operations in Afghanistan and Iraq.

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EXECUTIVE SUMMARY

INTRODUCTION AND OVERVIEW

Recently operations in Afghanistan and Iraq have demonstrated the growing complexity and emergent nature of decision making within the modern battlespace. The asymmetric nature of the adversary, the merging of high intensity combat with stability and security operations (SASO), the desire to employ both maneuver and a range of both lethal and non-lethal effects to achieve specific outcomes, and the involvement of both Joint and coalition forces each contribute to this trend. No longer are military operations simply a matter of optimizing the application of combat power against a traditional array of enemy forces or installations. Rather, military planning and decision making is more concerned with achieving the right effects against an adversary's centers of gravity while avoiding unanticipated negative consequences that might arise when military actions are not carefully coordinated with other aspects of the operation. At the same time, military decision makers now have access to an almost overwhelming amount of information –either from battlespace sensors and reporting systems or by means of networked reach back via the Global Information Grid (GIG). Yet, the capacity of the military staffs to process and transform this information into actionable knowledge for the commander is both limited and subject to a variety of obstacles and impediments. It is in this context that the attention of military analysts has recently turned to the study of sensemaking—the ability of a commander and his staff to "make sense" out of an evolving situation and to develop a shared framework for intelligence decision making.

Sensemaking within a military context can be defined as the multidimensional process of developing operational understanding within a complex and evolving battlespace. *Cognitively*, it can be seen as the process of collecting, filtering, interpreting, framing, and organizing available information into actionable knowledge for command decision making. *Operationally*, it can be seen as an active and dynamic process in which the commander is attempting to construct and impose a specific intent or reality against a reactive adversary. *Socially*, it can be seen as the process of reconciling and integrating multiple stakeholder perspectives into a common operational vision that is driven by command intent. *Organizationally*, it can be seen as the process of building up appropriate bodies of staff expertise, equipping those bodies with effective information systems and collaboration technology, and efficiently structuring the

knowledge management and decision making battle rhythms of those bodies. *Doctrinally*, it can be seen as the process of utilizing these bodies of staff expertise, information and collaboration technology, and battle rhythms to effectively plan and execute actions in accordance with the military's future concepts of operation.

Given the multidimensional nature of sensemaking, it is only natural that the modeling and analysis of sensemaking be approached from an interdisciplinary point of view. In this regard, recent advances within the fields of cognitive psychology, organizational psychology, social psychology, and management science provide analysts with a range of useful paradigms, constructs, and theories. And, although the topic of sensemaking is often described within these other fields of study by means of different constructs (*e.g.*, situation awareness, knowledge creation, knowledge management, shared understanding), the essential elements of the process reduce to those dimensions described above. Unfortunately, to a large extent, most of this work has remained beyond the purview of systems analysts and has yet to influence the development of more effective modeling approaches. By contrast, much of the present modeling and analysis of military command and control (C2) systems continues to be rooted in classic control theory that—while relevant to the industrial age—is no longer adequate for expressing the complex and emergent nature of decision making within the modern battlespace. As a consequence, military analysts need a new generation of modeling tools and paradigms to both explore the nature of sensemaking within the battlespace and to identify ways of improving this process.

To address this concern, Evidence Based Research, Incorporated (EBR), undertook a study to review the broader literature related to sensemaking and to extract from this literature useful paradigms, constructs, theories and methods for analytically modeling sensemaking and knowledge management as these processes occur within a military C2 organization. Accordingly, this report summarizes the results of this research and illustrates their application to a current problem of interest. Specifically, the report is structured in terms of four chapters:

- Chapter 1 provides a discussion of how to best represent actionable knowledge within a military C2 organization—not as a commodity, but as a meaningful state of information organization.

- Chapter 2 explores the nature of the organizational process used to combine available information with tacit experience and expertise to produce actionable knowledge in accordance with command intent.
- Chapter 3 reviews the development of two methodological threads—cognitive task analysis and social network analysis—and demonstrates how these methods can be combined to build richer and higher fidelity models of sensemaking within a military C2 organization.
- Chapter 4 combines these concepts and theories with illustrations from recent operations in Afghanistan and Iraq to address the modeling of effects-based targeting operations conducted within a Joint operational environment.

CHAPTER 1: THE REPRESENTATION OF ACTIONABLE KNOWLEDGE

In order to identify appropriate structures and constructs for representing actionable knowledge within a military C2 organization, EBR undertook an extensive review of research literature from several fields. Research areas (and their major theories and authors) addressed in this review included

- The decomposition of the battlespace problem domain (as motivated by Jens Rasmussen's abstraction hierarchies);
- The construction of a commander's vision or pathway from current state to desired end-state (as motivated by Leroy Beach and Terrence Mitchell's image theory);
- The characterization of knowledge state dimensions in terms of uncertainty, complexity, ambiguity and equivocality (as motivated by Michael Zack's theory of organizational ignorance);
- The representation of actionable knowledge as both a top-down and bottom-up mental construction process (as motivated by the Joint Directors of Laboratory's definition of intelligence fusion and Ralph Giffin's constructivist model of operational knowledge);
- The characterization of knowledge as a distinct concept from data and information (as motivated by the knowledge definitions of Dick Stenmark and Keith Devlin); and
- The framing of shared actionable knowledge in terms of issues, competing hypotheses, and supporting empirical evidence (as motivated by Alison Kidd's concept of *wicked problem domains* and Horst Rittel's development of an *issue-based information system*).

From a synthesis of these various theories, Chapter 1 presents a modeling framework for representing the construction of actionable knowledge within a military C2 organization. Central to this model is the representation of the commander's "running estimate"—a series of operational issues that must be addressed and resolved in order to achieve the desired end-state. In a Joint or coalition force environment, various functional experts or stakeholders reflecting different perspectives posit different hypotheses for each of these issues—expressed in terms of an abstract hierarchy of goals, priorities, constraints, influencing factors, functions, means-ends models, and battlespace objects. These hypotheses are generally the product of past experience, areas of expertise, and parochial cultures. In turn, this structure of competing hypotheses provides a framework for assembling and organizing empirical evidence that either supports or contradicts specific views. Thus, it is the issue-hypothesis-evidence framework that provides the conceptual means for combining the *know what*—current information available from the Common Operating Picture (COP) or GIG—with the *know how*—tacit experience and expertise –available within a military C2 organization.

Ideally, a military staff combines its possessed *know how* with its possessed *know what* to produce actionable knowledge for the commander. However, the relative lack (or surplus) of either information or experience/expertise gives rise to certain forms of organizational ignorance that can be characterized as *uncertainty*, *complexity*, *ambiguity*, or *equivocality*. Each of these specific states of knowledge deficiency, in turn, will lead the organization to initiate remedial actions such as (1) collecting additional information from the battlespace, (2) breaking down a planning problem into simpler elements, (3) seeking additional types of staff expertise or stakeholder input, or (4) resolving expert or stakeholder disagreements via command decision. Thus, sensemaking within a military C2 organization can be characterized as a continual process of collaboration, negotiation, integration, and reconciliation of perspectives.

CHAPTER 2: THE REPRESENTATION OF ORGANIZATIONAL PROCESS

Next, the research study turned to the representation of key process elements associated with sensemaking and knowledge management in a military C2 organization. Again, EBR undertook an extensive review of current literature from several fields of research. Specifically, the review of literature from the field of sensemaking research focused on the construction of understanding

in a social context. Research areas (and their major theories and authors) addressed in this review included

- The identified occasions for sensemaking (as motivated by the work of Karl Weick, Donald Schön and Michael McCaskey);
- The basic structures of codified and tacit knowledge within an organization (as defined in the work of Karl Weick , Charles Perrow, Gary Klein, Paul Feltovitch, and Herbert and Stuart Dreyfus);
- The basic cognitive and social elements of sensemaking (as described in the work of data/frame theory of Gary Klein and sensemaking processes of Karl Weick); and
- The basic mechanisms of maintaining sensemaking reliability when an organization faces emergent or novel situations (as characterized in the case studies of Karl Weick and Kathleen Sutcliffe and the military writings of Martin Van Creveld).

Additionally, the review of literature from the field of knowledge management examined the utilization of expertise and the flow of information within an organization. Research areas (and their major theories and authors) addressed in this review included

- The characterization of an organization as a marketplace of knowledge sources, users, and gatekeepers that can be hampered by various structural and process obstacles to sensemaking (as motivated by the knowledge marketplace theory of Thomas Davenport and Laurence Prusak); and
- The characterization of an organization in terms of a knowledge base, a set of business rules, and the dynamic formation of *ad hoc* project teams for knowledge creation (as motivated by the *organizational amplifier theory* of Ikujiro Nonaka and Hirotaka Takeuchi).

Finally, the review of literature from the field of organizational psychology focused on roles, actors, and the division of work responsibilities and activities within a military C2 organization. Research areas (and their major theories and authors) addressed in this review included:

- The partitioning of sensemaking responsibilities according to the top, middle, and lower levels of an organization (as motivated by Dennis Leedom's structural modeling of operational headquarters);
- The characterization of top level visionary and decision making roles (as outlined by the executive role definitions of John Kotter, Russel Honoré, and Martin Van Creveld);
- The characterization of middle level problem-solving and coordination roles (as defined by Karl Weick's improvisation model, Alison Kidd's knowledge worker model, and Horst Rittel's concept of wicked problem spaces); and
- The characterization of lower level information management and analyst roles (as motivated by the definitions of expertise levels by Herbert and Stuart Dreyfus and the *cognitive capability model* of Elliot Jaques).

From a synthesis of these various theories and models, Chapter 2 presents a conceptual model of sensemaking and knowledge management within a military C2 organization. A key proposition underlying this model is that that decision makers generally operate within a constructed frame of reference or problem space, not the physical battlespace. These mental problem spaces will correspond in certain ways to the physical battlespace, with the degree of correspondence being highest at the tactical level of decision making. However, at higher and more abstract levels of reasoning and decision making, these constructed problem spaces are likely to differ in significant ways among individuals, depending upon their experience and functional responsibilities. From a modeling viewpoint, the complexity of this sociocognitive process implies the need to represent the organization in terms of several dimensions and the various obstacles and impediments that might arise along each dimension. Thus, in contrast to representing military C2 organizations in terms of a simple *observe-orient-decide-act* feedback control model, it is best represented in terms of the structures, elements, and factors that frame the abstract reasoning and decision making process.

As outlined in Chapter 2, a military C2 organization is comprised of specific actors that each contributes to the creation of understanding and meaning. Actors at the top and middle levels of the organization perform a *knowledge worker* role in the sense that (1) they contribute value to the process by interpreting or framing available information according to possessed experience and expertise and (2) their work activities are influenced by the nature and content of the

information they receive to act upon. While it is exceedingly difficult to codify their possessed expertise in explicit rule-based form, useful process models can be developed which consider the areas and levels of expertise associated with each individual. When compared with the emergent issue demands of the battlespace problem domain, such characterization provides the analyst with a means for representing and assessing the placement and interaction of specific experts within the organization.

From a second perspective, military C2 organizations are seen to deal with various classes of knowledge inputs and outputs. Inputs can be characterized in terms of three different classes of information and expertise: (1) *codified information and expertise* in the form of doctrine, Common Operating Picture, existing military databases, standard operating procedures, plans and orders, and other documents; (2) *tacit experience and expertise* in the form of prior military training, specific assignments, and on-the-job experience; and (3) *social experience and expertise* in the form of informal working relationships, trust, and interpersonal familiarity. Each class of information and expertise is essential to the sensemaking process. On the output side of the organization, two classes of knowledge products represent the value-added contribution of a headquarters: (1) *command directives* that are typically expressed in terms of command intent, plans, and orders; and (2) a *shared codified knowledge base* that reflects the value-added interpretations and framing of information contributed by the headquarters staff, and that provides the context for subsequent sensemaking and decision making by subordinate headquarters.

From a third perspective, military C2 organizations are seen to reflect an emergent, adaptive process of collaboration among various functional experts and stakeholders. It is through the emergent and nonlinear process of collaboration that available information and expertise are combined to produce actionable knowledge. However, this emergent and non-linear process of knowledge development generally operates within the linear or cyclical framework of a battle rhythm. The battle rhythm consists of a repetitive cycle of information or coordination briefings, formal group/cell meetings, decision briefings and other scheduled staff events that serve to synchronize the sensemaking and knowledge management activities of an organization. Thus, the modeling of organizational sensemaking and knowledge management must account for both

the linear/cyclical and nonlinear/emergent work activities that occur within a military C2 organization.

Finally, it is important to represent the sensemaking and knowledge management processes of an organization in terms of their agility to perform in the face of varying conditions and changing situations. Here, organizational agility can be operationally defined in terms of the ability of the organization to overcome or minimize the influence of specific types of impediments or obstacles identified in the knowledge management research literature. At the same time, multidimensional nature of these impediments and obstacles suggest the importance of representing (at least in terms of first-order effects) the influence of information technology, training and standards of performance, personnel management, and staff process and battle rhythm on the overall sensemaking and knowledge management performance of a military C2 organization.

CHAPTER 3: MODELING AS A FRAMEWORK FOR INTEGRATING COGNITIVE AND SOCIAL RESEARCH METHODOLOGIES

Accurate modeling of military C2 organizations requires effective methods for observing and documenting key structures and processes associated with sensemaking and knowledge management. Accordingly, a third aspect of the research undertaken by EBR focused on the historical development and current state-of-art of two methodological areas: cognitive task analysis (now also referred to as cognitive work analysis) and social network analysis. Specifically, this review focused on the potential application of these methods to the study of sensemaking and knowledge management. In the area of cognitive task analysis, historical developments addressed in this review included (1) the early development of *knowledge elicitation methods* by Wilhelm Wundt; (2) the development of *manual task analysis methods* by human factors engineers during the middle part of the 20th century; (3) the subsequent evolving of these task analysis methods during the 1950s and 1960s into methods for studying operator procedures and decision tasks; and (4) the emergence of *cognitive task analysis methods* during the 1980s that focused on supporting training development, job design, and the engineering development of cognitive work aids.

By the 1990s, there emerged a variety of different approaches to cognitive task analysis. Four specific theoretical perspectives included:

- The general *goal-operator-method approach* of Stewart Card and his associates that conceptualizes work in terms of goal decomposition, problem-solving, and agent activity—thus resulting in modeling frameworks such as GOMS and MHP;
- The seven-stage cognitive model of Donald Norman and his colleagues that, while similar to the work of Card, focuses primarily on human-computer interactions and partnerships;
- The work-in-context triad model of David Woods and associates that reflects three important determinants of work performance: the external world or task domain, the human or machine agents that perceive and act upon this domain, and the artifacts or information representations that convey meaning about the task domain to the agents; and
- The hierarchical study approach of Jens Rasmussen and his associates that addresses work domain, control tasks, control *strategy*, *social/organizational structure*, and *worker competencies*.

More recently, there have emerged methods more suited to studying cognitive processes in the more unstructured context of wicked problem domains. Referred to under the newer term *cognitive work analysis*, principal examples of these methods include:

- The *situation awareness-oriented design method* of Mica Endsley that attempts to document different levels of situation awareness and their commonly associated patterns of error;
- The decision-centered method of Gary Klein and his associates that focuses on naturalistic decision making in situations that are dominated by subjective human goals and intents, rather than by physical laws and objective processes;
- The worker-in-context method of Robert Eggleston that is particularly tailored to studying work processes that evolve as a function of unexpected situations and disruptions; and

- The applied cognitive work analysis method of Bill Elm and his associates that employs a cycle of several steps to systematically transform an analysis of work domain demands into the identification of specific information visualization and decision aiding concepts that can support the decision maker.

Finally, a model-centered, bootstrapping strategy has emerged from the work of Scott Potter, Emilie Roth, David Woods, and William Elm. In this approach, analysts iteratively move back and forth between building better models of the problem domain and better models of the structures and processes that characterize the field of practice. Coincident with the interests of the military C2 modeler, this approach views analytic modeling as the integrating architecture for employing the various methods of cognitive work analysis.

In a second area of review, Chapter 3 turns to the historical development and current state-of-art of social network analysis methods. Historically, this area is marked by (1) the development during the early and middle 20th century of sociometric methods that used various mathematical methods to analyze meaningful patterns associated with informal social structures, cliques and communities; (2) the application during the 1970s of multidimensional scaling methods and algebraic set theory to extract and analyze meaningful social dimensions from sets of social data; and (3) the publication of various influential studies that demonstrated the importance of informal social networks for gathering relevant information in novel situations.

As defined in recent literature, social network analysis currently reflects a broad spectrum of algebraic and statistical methodologies that can be used to map and measure relationships and flows among people, groups, organizations, computers, and other information/knowledge processing entities. These analytic techniques range from simple counting and frequency distribution procedures, through various graph-theoretic and statistical programs such as multidimensional scaling, to integrated software packages that support the analysis and graphic visualization of social network databases. Key themes reflected in this current research include

- The development of various relational measures that reveal important linkages within a social group,
- The analysis of interlocking relationships between specific types of actors,
- The definition of structural equivalence between different networks,

- The analysis of duality where individuals occupy roles in more than one network,
- The examination of equilibrium and social influence in creating the conditions for self-synchronization within a group, and
- The development of graphical *methods* for visualizing network structures.

In large part, the field of social network analysis has presumed a certain level of stability or "steady-state" conditions regarding the structure and behavior of social groups and organizations. However, more recently, attention has shifted to the study of dynamic social networks—motivated, in part, by a desire to understand how social networks respond to changing or novel conditions. As with cognitive work analysis, much of the current work in dynamic social network analysis employs modeling to provide a central architecture for building research findings. This emphasis is reflected in a number of research efforts:

- The study of collaborative social networks in high-reliability settings such as military C2 organizations;
- The study of scale-free networks that are characterized by uneven patterns of connectivity—e.g., large number of nodes connected to a central hub;
- The study of social networks and agent behavior in the context of other organizational variables such as human capital, physical resources, task distributions, and inter-organization linkages;
- The study of how changes in individual agent behavior manifests in more global changes across a social network; and
- The impact of organizational structure and network-centric information systems on the flow of knowledge within an organization.

As cognitive task analysis and social network analysis have evolved over the past several decades, they have each led to comparable types of understandings, developments, and recognitions. First, cognitive task analysis has led to greater understanding of how information technology, training, organizational structure, and work environment influence the cognitive performance of the individual. Likewise, social network analysis has led to greater understanding of how informal social networks, actor roles, and weak contacts influence the cognitive performance of groups. Second, cognitive task analysis has led to the development of a wide

range of data collection and research methods that can be employed in an iterative, bootstrapping fashion to represent cognitive structures and functions of the individual. Likewise, social network analysis has led to the development of a wide range of data collection and research methods, metrics, and visualization techniques that can be employed to explore the structure and functioning of social networks. Third, cognitive task analysis—as it has developed into the broader domain of cognitive work analysis—has led to the recognition that one must simultaneously understand both problem domain and field of practice in order to link cognition with meaningful action in the real world. Similarly, social network analysis has led to the recognition that the empirical validation of theory and the mathematical exploration of possible outcomes reflect two essential sides of the research coin.

The present project extends this convergent trend by placing modeling activities in the context of an overall research campaign—one that uses modeling as a framework for integrating cognitive and social research methodologies. Looking to the future, the integrated findings and insights developed from a review of current sensemaking and knowledge management literature enhance the theoretical foundation that can inform and focus the application of existing cognitive task analysis and social network analysis methodologies. Specifically, this literature provides a theory-driven model of knowledge creation that (1) addresses both positivist and constructivist modes of cognition and sensemaking; (2) identifies unique actor roles at different levels within an organizational sensemaking process; (3) identifies critical work tasks and work task differences specifically associated with wicked problem spaces; and (4) explicitly defines codified knowledge, tacit knowledge, and social knowledge as three essential inputs to collaborative sensemaking.

At the same time, the current literature suggests that actionable knowledge is best represented as a state of information organization, rather than as a finite commodity to be managed. Knowledge state, in turn, is defined in terms of a networked set of goals, hypotheses, and organized evidence –a network that, in the case of shared knowledge, is socially defined by various functional experts and stakeholders. State deficiencies can be defined in terms of specific metrics such as ambiguity, uncertainty, complexity, and equivocality regarding these elements. Finally, the current literature on sensemaking and knowledge management provides a new set of paradigms for organizing our thinking about cognition and social networks. The *organizational amplifier*

paradigm usefully directs modeling attention to the importance of *ad hoc* project teams in the knowledge creation process. The *information and knowledge marketplace* paradigm offers a way of visualizing the impact of various cognitive, social, and technological obstacles on the flow and exchange of information within a group or organization.

CHAPTER 4: SENSEMAKING AND KNOWLEDGE MANAGEMENT ASPECTS OF JOINT, EFFECTS-BASED TARGETING OPERATIONS (CASE STUDY)

The final chapter addresses the application of modeling concepts developed in the first three chapters to the study of Joint, effects-based targeting operations. This term derives its name from the newly emerging topic of effects-based operations (EBO). While several characterizations have been proposed for EBO, this chapter adopts the following definition: "*Effects-based operations are operations conceived and planned in a systems framework that considers the full range of direct, indirect, and cascading effects, which may—with different degrees of probability—be achieved by the application of military, diplomatic, psychological, and economic instruments.*" In terms of operational strategy, EBO implies the need to coordinate and synchronize lethal combat actions with intelligence operations, information operations, psychological operations, humanitarian operations, civil-military affairs operations, economic aid and rebuilding programs, legal constraints, criminal investigations, and other instruments of national security policy. EBO also reflects the need for new leadership and thinking skills, new models of decision making, new information support tools, new organizational structures, and new command and staff procedures. Accordingly, there exists the need for a new generation of analytic models that can support the design and development of future C2 systems that can effectively plan and execute effects-based operations and targeting.

The chapter begins with a historical review of Service efforts to evolve from the traditional targeting doctrine, organizations, and procedures employed prior to Operation Desert Storm. Highlighted within this review are

- The movement of the Air Force toward the concepts of parallel warfare and effects-based operations during Operation Desert Storm;
- The emerging complexity of targeting operations exhibited during Operation Allied Freedom in Kosovo and Operation Enduring Freedom in Afghanistan;

- The Air Force's modernization of the Air Operations Center (AOC) prior to Operation Iraqi Freedom;
- The remaining challenges to building an effective targeting process –as characterized in terms of the inadequacy of personnel training, the disruptive effects of personnel turnover on informal social networks and collaboration, and the disjointed nature of intelligence processes from operational strategy and decision making.

This initial discussion concludes by noting that future models need to address a number of relevant influences on such operations: information technology, leadership and training, personnel management, staff process and battle rhythm.

Discussed in the second section of Chapter 4 is a proposed method for representing actionable knowledge within an effects-based targeting process. Here, the concept of an abstraction hierarchy is used to decompose an adversary into meaningful centers of gravity, relevant functions that are classified along several dimensions (*e.g.*, physical, social, cultural, political, economic), and actual objects within the battlespace. Additional considerations include (1) the need to link targetable objects and functions with command intent so as to maximize operational impact; (2) the need to consider various legal, political and other types of constraints so as to avoid producing unintended negative consequences from the targeting operations; and (3) the need to accommodate different levels of time-sensitivity. The resulting model reflects a sensemaking process by which a military planning staff attempts to use available cues, indications, and other information collected from the battlespace to reconstruct a meaningful abstraction hierarchy that (1) links potential objects within the battlespace to adversary centers of gravity, (2) prioritizes these objects in terms of their contribution to command intent, and (3) deconflicts these objects from potential unintended negative consequences.

The second section of Chapter 4 concludes by demonstrating an application of this modeling framework in the context of a hypothetical scenario. Examples elements of command intent are developed for each phase of the operation, and an actual abstraction hierarchy is developed that links objects, work processes, operational effects, employment principles, and adversary centers of gravity. Target elements are then associated with specific types of intelligence cues (*e.g.*, SIGINT, IMINT, HUMINT) available from tactical, theater, and national collection systems.

Likewise, a matrix is developed illustrating the areas and levels of staff expertise required for interpreting, assessing, and identifying each class of battlespace object as a potential EBO-based target. Finally, several examples are given that describe different sensemaking pathways and levels of collaboration that might be needed to transform available battlespace information into actionable targeting knowledge.

The third section of Chapter 4 reviews the current organizational structures, procedures, staff activities, and battle rhythms associated with Joint targeting operations. This section of the chapter draws heavily on current Joint and Component Service publications to define a doctrinal view of the Joint targeting process. Specifically addressed are

- The general planning and execution steps in the Joint targeting cycle;
- The distribution and interaction of staff responsibilities between the Joint Force Command level and the Component Service level;
- A focused look at the staff structure, targeting activities, and battle rhythm reflected within a Joint Task Force (JTF) headquarters;
- A focused look at the staff structure, targeting activities, and battle rhythm reflected within a Joint Force Air Component Command (JFACC) headquarters; and
- A focused look at the staff structure, targeting activities, and battle rhythm reflected within a Joint Force Land Component Command (JFLCC) other component command headquarters.

Finally, the last section of Chapter 4 examines Joint targeting operations as they have unfolded in recent military operations in Operation Iraqi Freedom. As part of this real-world description, the chapter summarizes a range of lessons-learned regarding obstacles, inefficiencies, and disconnections within the Joint targeting process as it currently exists. Specifically, lessons-learned are developed from several units and organizations that directly participated in the planning, coordination, and execution of targeting operations in Iraq: the 3rd Infantry Division, the 1st Marine Division, and the Army's 1st Battlefield Coordination Detachment that coordinated air/land targeting operations within the Coalition Air Operations Center at Prince Sultan Air Base, Saudi Arabia. Issues highlighted in this review include

- The inability of the current targeting process to support fast-moving ground operations,

- The lack of information system compatibility between air and ground forces, and
- The lack of effective staffing and management of target planning personnel.

As concluded in the summary of this chapter, advanced technology—either in the form of battlefield sensors or precision weapons—does not, by itself, constitute an EBO-based targeting process. Careful attention must also be given to

- The role, design, and functioning of information technology in support of the targeting process;
- The critical knowledge, skills, and experience provided by leadership and training;
- The impact of personnel management on maintaining the needed skill sets and social networks within the targeting process;
- The design and flow of the staff procedures, staff collaboration, and battle rhythm that define the targeting process; and
- The division and sharing of task responsibilities, key staff elements, decision authorities, and informal social networks that comprise the network of organizations contributing to the Joint targeting process.

Here, many of the issues and improvisations associated with recent targeting operations in Iraq provide a roadmap for future modeling and experimentation. Indeed, the dynamic systems, processes, and procedures used currently for engaging time sensitive targets in Iraq and Afghanistan might very well become the model for all Joint targeting operations in the future.

Clearly, then, the analytical and modeling community faces a significant challenge if it is to contribute to future deliberations and force planning regarding EBO-based targeting operations. As suggested in the earlier chapters of this report, the analytic modeling of EBO-based targeting operations must address each of the problem dimensions listed above. This will require both (1) the explicit representation of the EBO problem domain in terms of how informational cues from the battlespace are filtered, interpreted and organized relative to command guidance and constraints into actionable knowledge and (2) the explicit representation of the sociocognitive staff elements, processes, systems, and obstacles that define the Joint targeting process. In this regard, it is hoped that the present report provides both motivation and insight regarding the next step in responding to this challenge.

CHAPTER 1: KNOWLEDGE REPRESENTATION FOR MILITARY C2 TEAMS AND ORGANIZATIONS

INTRODUCTION

To properly model the sensemaking and knowledge management processes at the individual or collective level in a military C2 team or organization, it is important to be able to explicitly define data, information, and knowledge in objective and precise ways. Explicitly defining data, information, and knowledge leads, in turn, to the development of an acceptable ontology. This chapter summarizes a number of relevant bodies of literature on knowledge representation and syntheses various concepts and ideas into an integrated ontology that can support subsequent modeling efforts.

In the most basic philosophical sense, an ontology is a systematic specification of how to represent objects, concepts, and other entities that are assumed to exist in some area of interest, together with the relationships that hold among them. In a modeling sense, an ontology defines—perhaps, at different levels of abstraction—the computational objects and their properties that are represented and manipulated in a model to represent some corresponding real world phenomena of interest. In a cognitive sense, an ontology reflects ways people think about the world by subcategorizing objects, concepts, and other entities according to their essential and relevant properties. The use of the term ontology in this project reflects all three of these definitions

Technical Goal

A technical goal of the present research is to develop an ontology that is meaningful and useful for describing knowledge relevant to military operations—that is, how such operations are viewed or thought about by individual decisionmakers and collectively by C2 teams and organizations. As will be seen, such a representational framework must deal with different levels of abstraction that range from the objective to the subjective. At the lowest level of abstraction, objective representation is appropriate for describing objects and properties in the physical world—e.g., weapon systems, sensors, regional infrastructure. At the highest level of abstraction, military goals, values, and strategies are decidedly subjective in nature since they exist only in the cognitive realm of experts and decisionmakers. In between, one can define any number of

intermediate levels of abstraction that functionally link the physical battlespace with the conceptual world of the military strategist, planner, or operator. Herein, however, exists the challenge for the modeling of sensemaking. While the lowest (physical) level of abstraction is governed by strict laws of nature, every higher level of abstraction depends upon mental construction and human conventions for system representation. (Rasmussen, 1986) For an ontology to be useful in the three senses outlined above, it must be based on conventions that are (a) grounded in relevant theory regarding cognitive work analysis, (b) articulated in ways that computationally practicable, and (c) oriented around objects and concepts that are military relevant.

Distinguishing Information from Knowledge

In addressing an ontology for military sensemaking, one must necessarily deal with the concepts of data, information, and knowledge—the presumed "stuff" of sensemaking. In this regard, knowledge differs from data and information in significant ways. On the one hand, data and information are external representations of facts and beliefs that can be codified and exchanged among individuals, teams, and organizations. By contrast, knowledge is often better described as a state of understanding—a characteristic of the individual that measures one's ability to apply experience and expertise to the current situation, and to derive meaningful decisions that translate into action. Thus, accepting this definition, knowledge is a measure of internal mental state and sensemaking ability, and not—as in the case of data and information—a commodity that can be easily stored in computers or documents and shared across a network. Moving to the team or organizational level, defining knowledge as an internal mental state presents an epistemological and representation problem since this definition does not fit well with the popular concept of "shared knowledge"—that is, what exactly is meant by shared knowledge? As will be discussed later, any attempt to model knowledge creation within a team or organization must present a workable definition of "shared knowledge."

Operationally Bounded Knowledge

Finally, the goal of the present research is to develop an ontology that can be applied in the specific context of military operations. Hence, it is possible to bind the general problem of representing universal knowledge in ways that suffice for modeling military C2 teams and

organizations. For example, in a recent article on battle command, Major General Russel Honoré describes four elements of knowledge creation essential to the military commander. (Honoré, 2002) These elements include

- Visualize each operation from the current state along a line of operations to the end state;
- See the thinking adversary in terms of centers of gravity (primary sources of moral or physical strength, power, and resistance), capabilities, requirements, and vulnerabilities in order to determine decisive points that can be connected to form a line of operations;
- See one's own force elements in terms of a similar set of resources or centers of gravity that can be employed to impose one's will on the adversary; and
- See the battlespace environment in terms of key factors (e.g., obstacles, terrain, concealment, avenues of approach, weather) that can potentially enhance or degrade the ability to impose one's will on the adversary.

It is true that future military operations must necessarily consider a broader range of knowledge factors, as compared with traditional force-on-force combat operations against another nation-state. Increasing important for both ground operations and air operations (e.g., time-sensitive target attack) are often a host of diplomatic, political, legal, economic, and humanitarian issues that must be considered in the planning and execution of military operations. (QDR, 2001) Likewise, a commander must often consider the expertise and experience of other stakeholders in a theater of operation (e.g., governmental agencies, coalition partners, private/voluntary and non-governmental organizations). Each of these perspectives, if relevant to the ultimate decision process, will play a role in the shaping of actionable knowledge. Finally, it is becoming increasingly recognized within the military Services that future operations will involve the imposition of both lethal and non-lethal (e.g., psychological, informational) effects against an asymmetric adversary. Defined as Effects Based Operations (EBO), such operations will significantly alter the types of information considered and the types of knowledge created by a military C2 team or organization. (Deptula, 2001) However, by limiting modeling consideration to those types of information and knowledge most commonly associated with future military operations, the research avoids what might otherwise be an endless quest to accommodate an exponentially explosive knowledge set.

PIECES OF THE PUZZLE: REVIEW AND SYNTHESIS OF THEORETICAL LITERATURE

The cognitive research literature provides a number of candidate frameworks for constructing a suitable knowledge ontology for military C2 teams and organizations. A review of these frameworks reveals certain commonalities and suggests the possibility that they could be synthesized into an appropriate framework for the modeling toolkit. This section of the report reviews each of these frameworks and presents a proposed synthesis.

Jens Rasmussen—Means-Ends Abstraction Hierarchy

Sensemaking and knowledge management within a C2 team or organization are all about generating an awareness and understanding of the operational environment; identifying the emergent threats and opportunities that are defined relevant to the operational goals, resources, and constraints; framing the problem spaces that allow development of an appropriate response to each threat or opportunity; and formulating the decisions that articulate these responses in terms of coordinated action. In short, this is the cognitive work environment of decisionmakers in a C2 team or organization. Thus, it is useful to look at ontologies that have been developed specifically for conducting cognitive work analysis. In this regard, a seminal body of research is reflected in the work of Jens Rasmussen *et al.* (Rasmussen, Pejtersen & Schmidt, 1990) Here, Rasmussen and his research cohorts define a cognitive work space in terms of several dimensions, one of which is *means-ends relations*. These relations—expressed in terms of several levels of abstraction—are considered important when dealing with discretionary decisionmaking–the type that typifies most C2 teams and organizations. The different levels of abstraction are based on Rasmussen's earlier development of his *abstraction hierarchy* for man-machine interface. (Rasmussen, 1986) These levels, shown in Figure 1-1, correspond to different levels of thinking or sensemaking regarding an operational battlespace.

At the lowest level of abstraction, sensemaking deals with developing an awareness of *physical objects and their configurations* within the operational battlespace. Relevant information corresponding to this level of abstraction typically consists of sensor reports, unit status reports, reconnaissance reports, and so forth that each posits a set of beliefs about the existence and location of friendly units and assets, adversary units and assets, and other key objects within the

battlespace—e.g., civilian populations, regional infrastructure, political/territorial boundaries. In general, information at this level of abstraction is defined objectively. That is, the definition of each object is grounded in the laws of physics and this definition is largely invariant with respect to the objects relationship to other objects, mission goals, courses of action, etc. Such information can be stored in a fragmented/dispersed manner across a C2 team or organization, or—given appropriate information systems—it can be integrated and shared across a network in the form of a Common Operating Picture (COP).

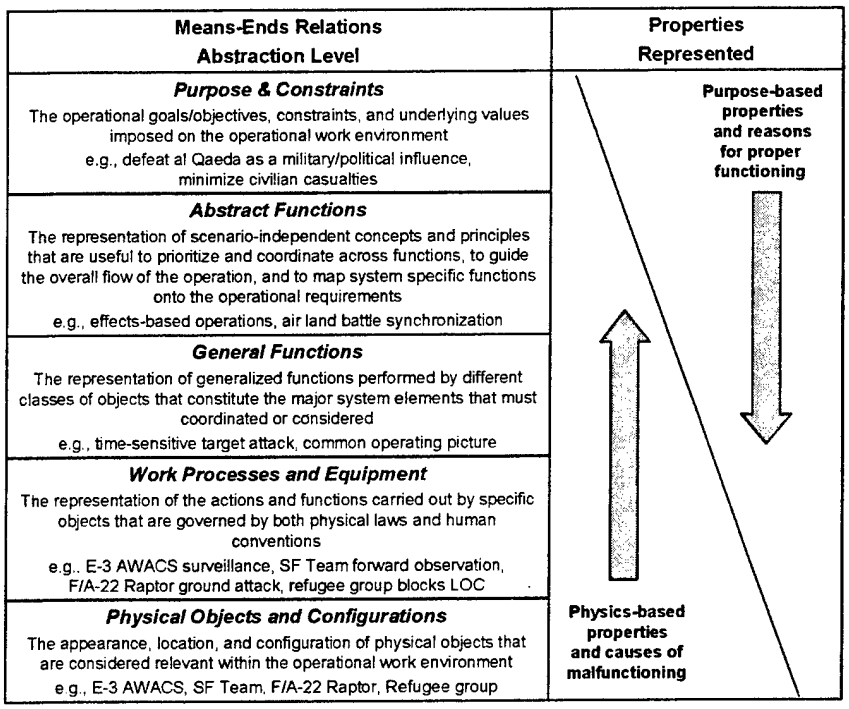

Figure 1-1. Rasmussen—Abstraction Hierarchy of Means-Ends Relations

Moving to the next higher level of abstraction, sensemaking deals with the understanding of *work processes* that are associated with each relevant object within the battlespace. For example, an E-3A AWACS platform might be understood to provide a surveillance function, a Special Forces team might be understood to provide forward area reconnaissance and targeting information or, conversely, a refugee column might represent a potential obstacle that blocks a key line of communication route. In contrast to the physical level of abstraction, work process definitions associated with each object can vary according to the overall focus and interests of the C2 team or organization. For example, in some circumstances, and E-3A AWACS platform or SF team might simply represent a communications relay function. Similarly, a refugee column

might also represent a consumer function for humanitarian supplies or an intelligence function for providing information about local terrorist networks. The point here is that each object within a complex and evolving battlespace potentially represents multiple functions, with the relative importance of each function depending upon the top-down goal framework imposed by the overall sensemaking process. Finally, it is noted that much of this functional knowledge is stored tacitly as experience and expertise in the minds of the personnel comprising the C2 team or organization. While some functions can be implied through the use of standardized map symbology or graphics, it is generally impossible for the COP to portray a complete representation of all of the potential functions associated with each battlespace object.

General functions within the abstraction hierarchy reflect the major work elements that are needed to conduct military operations within the battlespace—e.g., time-sensitive target attack, COP, logistics, ground force maneuver. Whereas work processes are carried out by individual objects, general functions are defined as the coordinated activities carried out by sets of objects to accomplish specific purposes. The taxonomy of general functions relevant to a given work environment depends on human convention and is typically structured around organizational lines of responsibility and/or areas of expertise—e.g., "intelligence, operations, logistics…", "air operations, ground operations, special forces, space operations…", or "military, political, diplomatic, humanitarian, legal…". Conversely, general functions might combine several organizational elements to perform a specific type of combat, combat support, or combat service support function. For example, "time-sensitive target attack" involves the timely orchestration of several work processes—those performed by sensors and/or other intelligence collection assets together with the real-time work process of an attack execution control system. Production and maintenance of the COP might be thought of as a general function since it involves the orchestration of many different information systems and work processes. In each case, the definition of a general function is guided more by how the C2 team or organization conceptualizes its work processes, rather than by laws of physics.

Abstract functions reflect broad, doctrinal conceptualizations of military strategy and effectiveness, although they might be closely associated with certain types of general functions. Consider Effects-Based Operations (EBO), for example. At one level of abstraction, EBO might be represented as a general function that is performed by an intelligence team or organization.

That is, EBO involves orchestrating a number of work processes that (a) identify an adversary's centers of gravity, (b) define the desired lethal or non-lethal effects to be achieved against each center of gravity and (c) associate specific physical targets with each desired effect. However, it is also possible to view EBO as an abstract function. At this level, EBO is seen as a conceptual strategy for accomplishing the defeat of an adversary—i.e., defeat the adversary's will to fight by a variety of kinetic and psychological means instead of merely through force attrition. Similarly, air land battle synchronization can be viewed as an abstract function that reflects a doctrinal principle of joint military operations.

Purpose and constraints represent the highest level of means-ends abstraction. In military terms, this level is closely associated with command intent—a reflection of the ultimate goals, objectives, and end-state sought through a military operation. For example, a goal of Operation Enduring Freedom was to defeat the al Qaeda terrorist forces as terrorist or political influence within the region. However, this level of abstraction also considers relevant constraints placed on the operation and the underlying values imposed on the operational framework. For example, the minimization of civilian casualties not only reflects traditional Western military values, but also serves as a relevant constraint on targeting operations—which, if violated, could lead to undesirable press coverage and the potential loss of support from coalition partners.

Summarizing the work of Rasmussen, it is seen that the abstraction hierarchy of means-ends relationships provides a useful set of building blocks for constructing an ontology of the external work space—or battlespace, as in the case of a military C2 team or organization. The different levels within the abstraction hierarchy are envisioned to map nicely onto the conceptual language employed by military decisionmakers, C2 teams, and C2 organizations. However, a bit more specification is required in order to express this ontology in terms of (a) how the functions are linked together to form specific plans and (b) how plans and goals are compared against perceptions of reality in order to make adjustments to the overall operation. It is in this regard that the discussion turns to the next body of research.

Lee Roy Beach & Terrence Mitchell—Image Theory

Sensemaking within a military C2 team or organization focuses on understanding a dynamic battlespace in terms of (a) the overall mission objectives, (b) the emergent events and adversary

actions that reflect specific opportunities and threats, and (c) the identification of response actions that lead to the achievement of those objectives. The dynamic nature of the battlespace implies that military plans rarely survive contact with an adversary and that a series of adjustments are often necessary to successfully move the operation forward. Indeed, the speed and precision with which a C2 team or organization can formulate and execute these adjustments is considered to be a key factor in defeating an adversary over time and space. The need to characterize this process from a cognitive perspective leads to the consideration of image theory, a body of work developed by Lee Roy Beach and Terrence Mitchell. Image theory presents a model of how decisionmaking in real life is based on a continuous adjustment of goals, plans, and expectations. As developed in the literature, image theory can be used to describe decisionmaking at both an individual level (Beach & Mitchell, 1987) and at a team or organizational level (Beach & Mitchell, 1998).

Image theory proposes both a knowledge ontology used by decisionmakers and a specific set of cognitive activities for employing and refining this ontology in an operational work setting. As such, image theory provides a framework for linking knowledge with action. The knowledge ontology proposed by Beach and Mitchell consists of four perceptual levels, as shown in Figure 1-2. These levels are defined here in terms of teams and organization; however, their definitions apply equally to the individual level.

Beginning at the top of this diagram, the *self-image* consists of those beliefs, morals, ethics, values, norms, and common experience that reflect the principles and perceived role of the individual, team, or organization. These principles and perceived role, in turn, guide the development and evaluation of goals in the operational work space. In terms of a military C2 team or organization, the decisionmakers might perceive themselves as being part of a combat force employed within a region to defeat an adversary. Conversely, they might see their military unit as a peace keeping force employed to separate warring parties and to restore stability to a region. Depending upon which of these images dominate, decisionmakers are likely to attend to different aspects of the battlespace, attach significance to different types of events, notice different types of cues, and so forth.

The *trajectory image* depicts the actual goals and goal markers adopted for a specific operational mission. Such goals might be expressed in terms of desired endstate, specific events, or specific milestones on the path to achieving a desired goal. As defined in image theory, trajectory images focus on outcomes rather than on the specific means used to achieve those outcomes. In military terms, the trajectory image corresponds closely to the command intent expressed at each level of command—i.e., tactical, operational, strategic. For example, at the operational level, a trajectory image might contain three sequential goals: initial entry into a region, decisive defeat of an adversary's military force and political control mechanisms, and restoration of civil order.

Image Level	Description
Self-Image	The beliefs, morals, ethics, values, norms, and common experience that are generally accepted across the team or organization. Together, these elements reflect the principles and perceived role of the team or organization that guide the development and evaluation of goals. e.g., a military unit sees itself as a combat force employed to defeat an adversary, a military unit sees itself as a peace keeping force employed to separate warring parties
Trajectory Image	The goals and goal markers that comprise the team or organization's agenda for the future. These goals can be concrete events, abstract states, or interim non-goal states that are milestones on the path to a goal. e.g., a military operation is envisioned to consist of an initial entry into the region, followed by decisive defeat of an adversary, followed by a restoration of civil order
Action Image	The set of plans (action sequences) associated with achieving each of the goals held in the trajectory image. Each plan consists of the resources, tactics, and timing required to implement a specific sequence of actions. e.g., initial entry is supported by long-range precision attack of air defenses and command and control facilities, defeat of adversary involves envelopment of capital region by two divisional-size ground units
Projected Image	A forecast of anticipated events and states that are expected to occur as a result of implementing the team or organization's action image. e.g., defeat of air defenses will require 3 days, civilian populations will remain neutrally aligned, ground combat objectives will be achieved in 2 weeks with minimal casualties

Figure 1-2. Beach & Mitchell—Levels of Perceptual Images

The *action image* represents the actual plans (action sequences) designed to achieve the goals and goal markers contained in the trajectory image. Such plans are expressed in terms of the resources, tactics, and timing thought to be required for achieving the goals and goal markers. At higher levels of command, such plans will be typically expressed in broad terms, with development of details left to subordinate commanders. For example, at the operational level, the initial entry of forces into a region might be envisioned to require the support of long-range precision attacks against adversary air defenses and command and control facilities. Ultimate

defeat of an adversary might be envisioned by planners to require an envelopment attack of the capital city by two divisional-size ground units.

Finally, the *projected image* reflects a set of beliefs regarding future events and states that are forecasted to occur as a result of implementing the action plans. The set of forecasted events and states are developed by projecting current situation awareness and understanding into the future—thus, they framed by the action image but are influenced by the perception of what is happening in the real world. Such beliefs are a natural part of sensemaking and serve to provide a set of markers for assessing operational progress. That is, an individual decisionmaker, team, or organization will assume that satisfactory progress is being achieved as long as actual events/states within the battlespace correspond to forecasted events/states. If expectations are violated in some way, such occurrences give rise to an adjustment or modification of one or more elements of the action image, trajectory image or, ultimately, the self-image of the individual, team, or organization. For example, defeat of an adversary's air defenses might be expected to require 3 days of attack operations. If, by the end of 3 days, this goal is not achieved, then this might trigger a change in the timing of other aspects of the operation. Another expectation might be that the civilian population within the region will remain neutrally aligned. If significant resistance develops and threatens lines of communication, then it is possible that force deployments will be modified to assign additional protection to logistics routes.

Before discussing the decision model of Beach and Mitchell, it is useful to make two points regarding the application of image theory to military operations. First, the notion of cognitive images should not be confused with the actual publication and dissemination of military plans and orders. Image theory deals primarily with the cognitive beliefs and perceptions held within the minds of decisionmakers and their supporting staff elements—beliefs and perceptions that guiding their sensemaking process. There might exist an external representation of these beliefs and perceptions in the form of written plans and orders; however, such manifestations are more properly considered to be an aspect of social communication, and not part of internal sensemaking process. Second, the hierarchical nature of military command implies that each level of decisionmaking will hold cognitive images specific to its level of sensemaking and decisionmaking responsibility. Vertical cohesion, therefore, is represented by a consistent nesting (or framing) of images at one level of command with the images held at a higher level of

command. Horizontal cohesion is represented by the consistency of image detail held by the various stakeholders and force elements at a given level of command.

Figure 1-3 depicts how this knowledge ontology interacts with decisionmaking and action. According to image theory, adoption and progress decisions reflect the fundamental mental activity of decisionmakers. Adoption decisions focus on whether to modify current goals and strategies or to continue using them as they are. Adoption decisions take the knowledge represented within the self-image, trajectory image, and action image and compare it against the decisionmaker's awareness and understanding of the operational environment. The two criteria used for judging the adequacy and appropriateness of these images are *compatibility* (Will the strategy achieve the goals within the current operational environment?) and *profitability* (Which strategy best achieves these goals?) An important aspect of image theory is its focus on a "do nothing" response—an option that corresponds to the choice of leaving existing plans in place as long as they are progressing satisfactorily toward the desired goal.

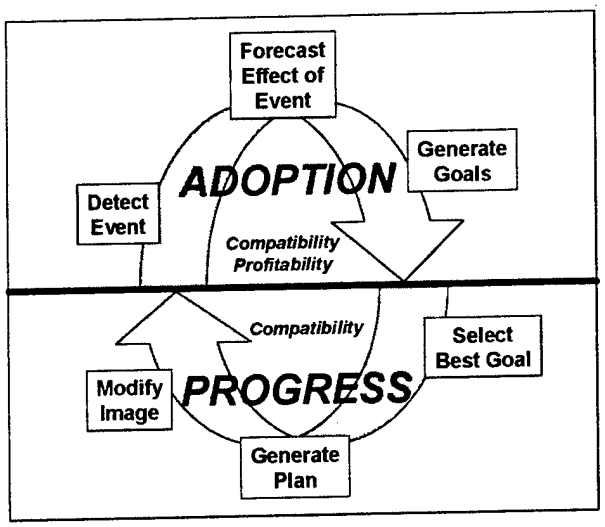

Figure 1-3. Beach & Mitchell – Adoption and Progress Decisions

Progress decisions reflect the other half of the cognitive process that operates on this knowledge ontology. Process decisions emerge from a comparison of the trajectory image with the action image. Here, the criterion for testing is simply compatibility. Forecasted events and states deemed incompatible with desired plans are taken as an indication that the current goals are inappropriate, that the plan is not sufficient for achieving the desired goals, or both. Image theory does not prescribe an exact method for adapting the various images to an unexpected or

undesired forecast. However, in a discussion of how image theory might be enacted through adaptive agent models, David Schwartz and Dov Te'eni argue that this adaptive process involves mental reflection characterized by systematic transition between levels of abstraction (levels of the images), between activities of examining the current images and testing new ones, and between different parts of the problem. (Schwart & Te'eni, 2001)

Summarizing the work of Beach and Mitchell, it is seen that image theory offers a valuable contribution to developing a useful knowledge ontology for sensemaking. Specifically, the elements of image theory can be used to relate Rasmussen's functions (either abstract or general) to the formulation of specific goals and plans. Additionally, image theory posits the manner in which goals and plans are continuously refined in light of current situation awareness and forecasted events and states. However, both of these bodies of research suffer from their singular attention only to what is known and understood, rather than considering what is not known and not understood in a specific operational situation. To address this component of the knowledge ontology, the discussion turns to yet another body of research.

Michael Zack—Types of Ignorance (Deficient Knowledge States)

While much research and modeling focus is placed on what individuals, teams, and organizations know, it is equally—if not more importantly—relevant to consider what they do not know. As noted by Karl Weick and Kathleen Sutcliffe, sensemaking can suddenly and catastrophically break down when individual decisionmakers, leadership teams, and organizations face novel and unexpected conditions in the operational work environment. (Weick & Sutcliffe, 2001) In their analysis of various case studies, Weick and Sutcliffe not only focused on the availability of information to decisionmakers, but also addressed the ability of decisionmakers to appropriately interpret available information based on their experience and expertise. Thus, it is important to identify the various ways in which a knowledge base might be inadequate for supporting effective decisionmaking. Here, it is not simply a matter of measuring the absence or lack of information. Rather, it is important to consider also the organization of the information, its interpretation, and its availability for framing response decisions and actions. In this regard, the work of Michael Zack is particularly relevant to the task of constructing a knowledge ontology for modeling sensemaking. (Zack, 1999)

Zack articulates his ideas in terms of various forms of ignorance (deficient knowledge states) that an organization can face. As shown in Figure 1-4, the various forms of ignorance represent different types of challenge to the sensemaking process of C2 teams and organizations. In each case, different steps are required to resolve or accommodate the specific form of ignorance in the sensemaking process.

Form of Ignorance	Definition	Corrective Response
Uncertainty	Uncertainty is defined as not having sufficient information to describe a current state or to forecast future states, preferred outcomes, or the actions needed to achieve them. Uncertainty can be defined in degrees (i.e., in terms of probability); however, the context of uncertainty is well-defined and meaningful to decision makers.	Uncertainty can be reduced by acquiring additional information relevant to the problem context. Uncertainty can be tolerated by using assumptions to fill in missing information, or by developing agile responses that can accommodate critical areas of uncertainty.
Complexity	Complexity is defined as being faced with a situation made up of an interrelated set of variables, solutions, and stakeholders –each individually understood, but together which exceed the processing capacity of the individual, the team, or organization to synthesize. Complexity is defined relative to available experience and expertise: what is complex for one individual might be easily understood by another.	Complexity can be accommodated by breaking problems down into manageable pieces (division of labor). However, this requires the addition of management overhead and the means to bring together the appropriate experts to synthesize the various pieces back into an integrated whole.
Ambiguity	Ambiguity is defined as the inability to make sense out of a situation, regardless of available information. Ambiguity arises when faced with novelty or situations that do not correspond to past experience. Here, what is lacking is not information but the experience and expertise to correctly frame and interpret the information.	Ambiguity can be resolved by acquiring new sources of expertise and/or allowing iterative cycles of collaboration among experts and stakeholders to create new interpretations of the situation. Such collaboration requires well-established social networks for success
Equivocality	Equivocality is defined as having multiple –equally plausible— interpretations of the same information. Here, interpretations may differ along one or more dimensions: descriptive criteria, problem boundary, relevance of specific underlying factors, means-ends models, etc. Equivocality frequently involves multiple stakeholders who each have a vested interest in characterizing the current situation, forecasting its implications, and developing response actions.	As with ambiguity, equivocality can be resolved through iterative cycles of interpretation, discussion, and negotiation among experts and stakeholders. This process can occur either democratically or in authoritative fashion, depending upon the relative influence of each stakeholder and the presence/absence of an overall decision authority

Figure 1-4. Zack—Forms of Knowledge Ignorance

Uncertainty is defined as a knowledge state wherein the problem context is well-defined and meaningful to the decisionmakers, but that sufficient information is not available to describe the current state or to forecast future states, preferred outcomes, or the actions needed to achieve them. Uncertainty can be expressed in terms of a calculable probability—e.g.., a future event is likely to occur with some known probability—or in terms of an unknown probability (the traditional definition of uncertainty). For the decisionmaker, uncertainty can be reduced through the acquisition of additional information that is relevant to the defined problem context.

Alternatively, uncertainty can be tolerated by one of several strategies: (a) using existing knowledge to fill in missing information with assumptions or (b) developing agile response actions that can accommodate critical areas of uncertainty. Military C2 teams and organizations often acquire additional information through tasking of specific sensor systems, deploying reconnaissance teams, and/or submitting information requests to other organizations. The need to tolerate uncertainty can shape the formulation of contingency plans and influence the deployment of reserve forces.

Complexity is defined as the relative inability of an individual, team, or organization to adequately process and understand all of the interrelationships that exist among a set of relevant problem variables, solutions, and stakeholders. The term "relative" is used because complexity is defined with respect to the level of experience and expertise held by the individual, team, or organization. What is difficult for one individual to mentally grasp and understand might be quite easily understood by another individual with appropriate experience and expertise. Stated alternatively, situation complexity implies that awareness of the relevant pieces of the problem exceeds the experiential knowledge of the individual, team, or organization. In response, complexity is typically dealt with by breaking down the problem space into manageable pieces—that is, a division of labor among relevant experts and stakeholders. At issue, however, is the need for the solution pieces to be brought back together to form a cohesive whole. This requirement typically implies the need for the addition of management overhead (to coordinate the synthesis of the various pieces) and/or the means to bring the relevant experts and stakeholders together in effective collaboration—i.e., a community of interest.

Ambiguity is defined as the inability to make sense out of a specific situation, regardless of the amount of information available. Because situation understanding is based on past experience, ambiguity is said to arise when the individual, team, or organization lacks appropriate or relevant experience to frame and interpret the available information. As such, ambiguity characterizes the state of knowledge when a military C2 team or organization is faced with a novel or unexpected operational situation—e.g., an adversary's employment of asymmetric strategy or tactics. For example, Iraq's employment of the Fidayeen Saddam to stiffen the resistance of the Republican Guard might be said to have created ambiguity—at least for a short period of time—in the minds of military planners. This example, however, brings up an additional point: ambiguity is defined

relative to available experience and expertise. Hence, C2 teams and organizations that employ effective learning practices can rapidly adapt their sensemaking process to novel events, strategies, and tactics as they are encountered. Ambiguity can be resolved in several different ways. In one case, the acquisition of new expertise can provide the experiential knowledge needed to bring understanding to an operational situation. This strategy, however, depends upon the openness and agility of the team or organization to adapt its lines of information flow, social networks, and authority structures to rapidly accommodate the new expertise into the sensemaking process. (Weick & Sutcliffe, 2001). A second method of resolving ambiguity is through effective collaboration—that is, through providing available experts and stakeholders with the means to mentally interact, discuss, debate, and formulate new interpretations of the situation. Such collaboration typically requires well-established social networks for successful resolution of ambiguity.

Equivocality is defined as having multiple, equally plausible interpretations of the same available information. These interpretations might differ along one or more dimensions: the criteria used to describe relevant objects, events, and states within the operational problem space, the logical problem boundary to be considered in formulating an understanding of the situation, the operational significance of different underlying factors, the relevance of different means-ends models for identifying solution paths, and so forth. Equivocality most often arises at the team or organizational level of sensemaking when multiple stakeholders each have a vested interest in characterizing the current situation, forecasting its implications, and developing appropriate response actions. As a result, effective collaboration is required to allow experts and stakeholders to engage in an iterative cycle of interpretation, discussion, and negotiation. The degree to which this process unfolds in either democratic or authoritative fashion depends upon (a) the relative strength of influence of each stakeholder and (b) the presence/absence of an overall decision authority. While it is cautioned that teams and organizations should not prematurely foreclose debate and adopt an erroneous interpretation of the situation, military operational tempo will often demand that a commander commit to a specific interpretation after hearing each perspective on a specific situation.

With the work of Zack, a method for assessing the adequacy of knowledge state begins to emerge. Specifically, Zack's definition of uncertainty, complexity, ambiguity, and equivocality

offers a framework for determining if the level of situation understanding is adequate for transforming knowledge into action. These same terms can be applied at different points within either Beach and Mitchell's image theory or Rasmussen's abstraction hierarchy to define the quality of sensemaking at different levels of thinking. With these three bodies of theory, it is possible to begin approaching the task of constructing a knowledge ontology for modeling sensemaking and knowledge management within military C2 teams and organizations. However, an additional step is required for unequivocally relating information to knowledge and actionable knowledge to operational decisions. For this, the discussion turns to a fourth area of research.

Joint Directors of Laboratories, Ralph Giffin, and the Air Force Scientific Advisory Board—Knowledge Creation Is Both a Bottom-Up and a Top-Down Process

In 1983, the Joint Directors of Laboratories (JDL) Command, Control, and Communications (C3) Research and Technology Program was established to perform broad-based multi-Service research and technology demonstrations in C3. The JDL Data Fusion Subgroup—subsequently reorganized under the Office of the Secretary of Defense—was established to provide guidance for conducting research and development in the area of data fusion. Out of this body grew a framework for comparing and diverse problems and technologies for fusing data into useful information and knowledge—particularly data automatically collected by various types of sensor platforms. This framework, known as the *JDL Levels of Information Fusion*, is illustrated in Figure 1-5.

Level of Fusion	Definition
Level 4 **Process Refinement**	Level 4 fusion is defined as a meta-process that serves to monitor, assess, and refine the quality of the other three levels of fusion. This meta-process is envisioned to regulate the acquisition of data in order to achieve optimal results
Level 3 **Threat Refinement**	Level 3 fusion is defined as an iterative process of analyzing and integrating the combined activity and capabilities of an adversary's force to infer operational intentions and the threat that these operations pose to friendly forces. The product of this level of analysis is called the *threat assessment*.
Level 2 **Situation Refinement**	Level 2 fusion is defined as an iterative process of analyzing and integrating the spatial-temporal relationships among objects (e.g., combat platforms) to group them together and form an abstracted interpretation of the patterns. These patterns are used to infer military force order of battle. The product of this level of analysis is called the *situation assessment*.
Level 1 **Object Refinement**	Level 1 fusion is defined as an iterative process of analyzing and integrating data (e.g., sensor reports) to determine the identity and other attributes of objects (e.g., combat platforms) within the battlespace, and to construct spatial-temporal tracks to represent their position and velocity within the battlespace. The product of this level of analysis is called the *situation picture*.

Figure 1-5. Joint Director of Laboratories - Levels of Information Fusion

Despite the popularity and informal acceptance of this framework within the defense technology community, the JDL definitions leave considerable room for interpretation and debate as to (a) what is actually represented at each level and (b) what is required to produce this representation. (Wald, 2001; FTIAC, 2002) For example, the JDL levels claim to address process and functionality as well as content; thus, it is difficult to generalize their application beyond sensor data to other domains and other types of information. Nevertheless, the JDL framework suggests ways in which information at different levels of abstraction and semantic content relate to the specific needs of the military decisionmaker. Hence, this framework has potential utility for analyses that focus on operational sensemaking in a military context.

Another point of confusion with regard to the JDL definitions is whether the process levels are linked in an ascending mode, are linked in a descending mode, or are linked in a mode that is contextually dependent. A common interpretation of this framework by many technologists is that the process flows primarily upward from data, to fusion, to knowledge. That is, it is assumed by many technologists that suitable algorithms can be found and generalized to provide for the automatic assemblage of data into meaningful objects, objects into meaningful orders of battle, and orders of battle into meaningful threats. By contrast, Ralph Giffin argues that this normal assumption of ascending linkage—based on naïve inductivism—is logically flawed and unworkable in most instances. (Giffin & Reid, 2003) He argues that the assumption of ascending linkage leads to a futile quest for discovering "universal truth." Instead, Giffin argues that a more efficient approach to information fusion is one that employs a descending linkage—i.e., command intent and tentative selection of course of action are used to formulate a specific set of working hypotheses regarding an adversary and the threats and opportunities posed to a military operation. Information fusion is then organized as a process referred to as *critical rationalism* to empirically test and refine each of these working hypotheses from data and information collected from the battlespace. Once these hypotheses are sufficiently validated (to some acceptable level of empirical support), they then can serve as the basis for decisionmaking.

Arguments can be made that information fusion involves a combination of both ascending and descending linkages—that is, a combination of both inductivism and critical rationalism—and that the overall process is contextually dependent. This is essentially the argument posited in a recent Air Force Scientific Advisory Board study on predictive battlespace awareness. (AFSAB,

2002) In this study, it is argued that the management of battlespace data collection focuses too much on sensor capabilities and not enough on problem formulation. Such a strategy results in the accumulation of too much data that is often irrelevant to the sensemaking and decisionmaking needs of the commander. In contrast, the study recommends several profound changes to the Air Force's information management process: (a) more tightly couple data collection and sensor management to the operational problem space and decision requirements of the commander and (b) make greater use of non-sensor information from other sources to provide a meaningful context for interpreting sensor data.

Taken together, the work of the Joint Directors of Laboratories and the insights provided by Ralph Giffin and the Air Force Scientific Advisory Board point make several useful points that can serve to guide the development of a knowledge ontology for military sensemaking. First, these studies remind us that knowledge must serve a useful purpose—one that is tightly coupled with the decisionmaking responsibilities of C2 teams and organizations. This implies that a knowledge ontology for military sensemaking should be tailored to the relevant work domain while still reflecting the abstraction characteristics of a general knowledge ontology. Second, these studies suggest that what is represented within a knowledge ontology should often be expressed in the form of working hypotheses—hypotheses that are conceptually derived in a top-down manner of thinking, but which are empirically tested, refined, and supported in a bottom-up manner and analysis and integration.

While each of these bodies of research offer valuable insight, there are other issues that must be addressed before assembling these ideas into a tentative knowledge ontology for military sensemaking. This next issue addresses the need for operational definitions that can be used for distinguishing and relating the three concepts of data, information, and knowledge. Without acceptable definitions, it is difficult—if not impossible—to use these terms for analytically representing the primary commodities that are created, transformed, communicated, and used within a military C2 team or organization.

Dick Stenmark and Keith Devlin—Distinguishing Knowledge from Data and Information

A familiar story from India recalls a situation in which a group of blind men were each asked to describe an elephant. One man, grasping a leg concluded that the elephant was much like a tree.

Another man groping the elephant's trunk announced that an elephant was like a snake. The man touching the elephant's ear stated the belief that the animal was like a fan, while the man grasping the elephant's tail argued that the elephant was like a rope. While each argued different viewpoints, none of the men had ever actually seen the elephant in its entirety. This story serves as a reminder that the research community reflects little agreement over what is meant by data, what is meant by information, what is meant by knowledge, or how these three terms relate to one another. To illustrate the problem of language and definition, Figure 1-6 extracts a comparison of these terms from a recent paper by Dick Stenmark. (Stenmark, 2002). In this paper, the author traces the movement of these terms from philosophy to information technology and compares the definitions of "data," "information," and "knowledge" across a number of leading researchers in the field of knowledge management.

Author(s)	Definition of Data	Definition of Information	Definition of Knowledge
Wiig		Facts organized to describe a situation or condition	Truths and beliefs, perspectives and concepts, judgments and expectations, methodologies and know-how
Nonaka & Takeuchi		A flow of meaningful messages	Commitments and beliefs created from these messages
Spek & Spijkervet	Not yet interpreted symbols	Data with meaning	The ability to assign meaning
Davenport	Simple observations	Data with relevance and purpose	Valuable information from the human mind
Davenport & Prusak	A set of discreet facts	A message meant to change the receiver's perception	Experiences, values, insights, and contextual information
Quigley & Debons	Text that does not answer questions to a particular problem	Test that answers the questions who, when, what, or where	Text that answers the questions why and how
Choo *et al*	Facts and messages	Data vested with meaning	Justified, true beliefs

Wiig, K.M. (1993). *Knowledge Management Foundations: Thinking About Thinking – How People and Organizations Create, Represent, and Use Knowledge*. Arlington, TX: Schema Press.
Nonaka, I. & Takeuchi, H. (1995). *The Knowledge-Creating Company*. New York: Oxford University Press.
Spek, R. & Spijkervet, A. (1997). *Knowledge Management: Dealing Intelligently with Knowledge*. Utrecht, Holland: CIBIT.
Davenport, T.H. (1997). *Information Ecology*. New York: Oxford University Press.
Davenport, T.H. & Prusak, L. (1998). *Working Knowledge*. Boston: Harvard University Press.
Quigley, E.J. & Debons, A. (1999). Interrogative theory of information and knowledge. *Proceedings of SIGCPR '99*, ACM Press, New Orleans, LA. Pp. 4-10.
Choo, C.W.; Detlor, B.; & Turnbull, D. (2000). *Web Work: Information Seeking and Knowledge Work on the World Wide Web*. Dordrecht, Holland: Kluwer Academic Publishers.

Figure 1-6. Stenmark—Comparison of Definitions for Data, Information, and Knowledge

As suggested by Figure 1-6, researchers have evolved a variety of meanings for the terms data, information, and knowledge—and these differences exist just within a single academic field. When comparing these definitions across other academic disciplines, one encounters an even greater disparate range of definitions, with these terms often used as synonyms for one another. What is particularly troubling—at least for those attempting to analytically represent data,

information, and knowledge in an appropriate manner—is the apparent tendency to treat knowledge as if it is just a higher (more processed or interpreted) form of information and data.

In an attempt to clarify the use of these terms, Stenmark notes that two philosophical traditions shape current definitions on knowledge: the positivist view and the constructivist view. The positivist view of knowledge (rooted in the positivism philosophy that dominates much of the natural sciences) assumes that knowledge corresponds to some absolute and universal truth. Hence, this view considers knowledge as an artifact or commodity that can be possessed and communicated in discrete units. By contrast, the constructivist view (rooted in the philosophy of Locke and Hume that dominates much of the social sciences) assumes knowledge to be something that has definition and value only in a specific social context. Hence, this view considers knowledge to be socially constructed for specific situations, to be dynamic in nature, and to be something that is impossible to define in a universal manner. From a review of these two philosophical positions and their manifestation by other researchers in information science, Stenmark summarizes several useful points about data, information, and knowledge:

- Data and information are two end points on a continuum of representation. At one end, data represents facts, propositions, and beliefs that are completely decontextualized—separated from the knowledge required to provide meaning and place in a functional or social world. As more and more semantic context is attached to data, such data can be said to evolve into information. To speak of the level of information—i.e., the level of semantic context—is a relative matter since what is viewed as information for one task domain might be considered merely data for a higher level task domain.
- While few would question the fact that data and information can be represented as objects outside of the human mind, it has been much harder for philosophers and researchers to characterize knowledge in like fashion. Knowledge seems to exist only in the mind of the individual (or collectively in the minds of individuals that comprise a team or organization).

- Received data and information require internal knowledge in order to be interpretable; however, data and information are useful building blocks for constructing new knowledge in the mind of the individual. Such data and information does not become knowledge, per se; rather, the data and information alter the knowledge state of the individual.
- One cannot transmit knowledge, per se, to another individual. What becomes transmitted is merely information generated from knowledge. This information, in turn, can serve to increase the knowledge state of another individual. While some might view this distinction as "splitting hairs," such definition is required in order to preserve the fundamentally different nature of knowledge, as compared to information.
- A number of prominent researchers frame their arguments in terms of two different types of knowledge—tacit and explicit. In these arguments, tacit knowledge is generally defined as internally stored experience that is difficult to articulate through language. Explicit knowledge is defined by these researchers as that part of knowledge that can be externally codified in the form of rules, propositions, stories, procedures, etc. However, such a classification blurs the distinct nature of knowledge versus information and provides little workable basis for useful analysis and modeling. In contrast to these arguments, redefining "explicit knowledge" as merely being information allows one to retain the notion that knowledge speaks more to an internal state of mind rather than a commodity that can be externally dealt with. Thus, it is more proper to use the terms "tacit knowledge" and "explicit information."

In a second body of work, Keith Devlin addresses much the same issue in his attempt to mathematically articulate the differences that exist among data, information, and knowledge. (Devlin, 2001) In parsimonious fashion, Devlin posits a number of definitions in equation form:

Information = Data + Meaning

Knowledge = Internalized information + Ability to utilize the information

Like Stenmark, Devlin concludes that data is transformed into information by attaching meaning to it. Likewise, Devlin concludes that knowledge is something that exists within the mind of an individual and supports action-taking by that individual in the real world. However, Devlin goes

beyond these definitions to discuss the process by which information can be successfully passed from one individual, team, or organization to another. Here, he introduces the notion of *constraint*—defined as "the regularities that make intelligent action possible."

Information = Representation + Constraint

Constraints are embodied in language, rules, stories, and other forms that convey the basic notion of *types*, and *types* are essential to understanding the nature of information. As outlined by Devlin, information always takes the form of a statement that some represented object is of some defined type:

***a* : T** **where *a* is any object and T is a type**

In conversations between two individuals, the meaning of information is successfully transmitted only if the two individuals share a common understanding of the types or constraints being employed. That is, conversations—whether they are verbal or electronic—typically convey only a representation of an object, whereas the two parties provide the types or constraints needed to interpret that representation in terms of intelligent action. If each party holds different constraints, then it is highly likely that the conversation will result in misunderstanding. This is why it is often necessary for two individuals to engage in a preliminary discussion in order to establish a common context of meaning before conveying the actual information. Alternatively, common meaning can be established through common training and experience, standardized rules and procedures, and other forms of institutional convention. This process can be seen graphically in Figure 1-7, which shows that meaningful conversation is possible between two individuals only in the region where their knowledge areas overlap—i.e., they share a common ground of understanding about some situation. The implication of this relationship is seen when more than two parties attempt to engage in collaboration: the greater the number of involved parties, the smaller the area of overlapping knowledge. This diagram illustrates mathematically why collaboration becomes more difficult as the number of participants increase.

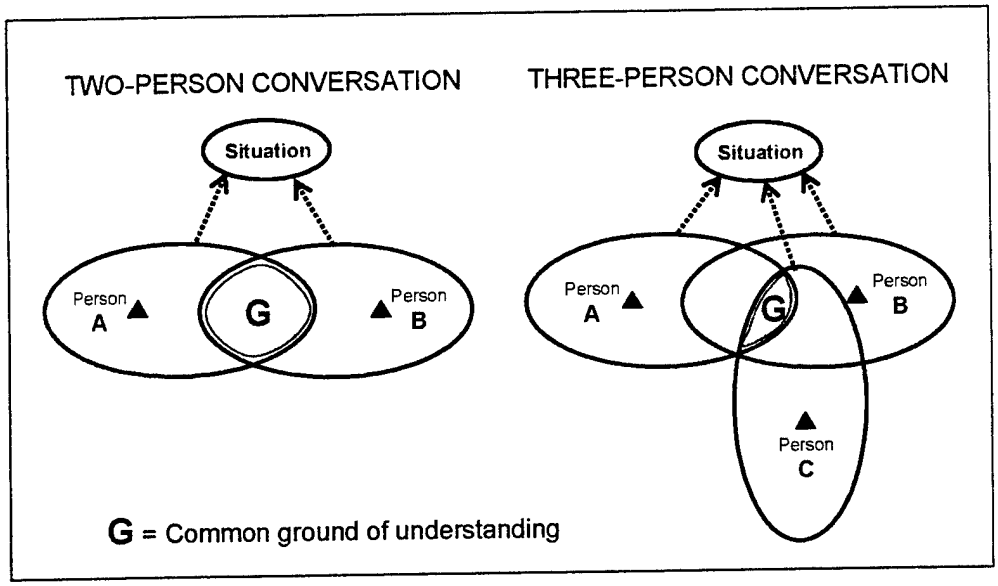

Figure 1-7. Devlin—Common Ground of Understanding in Conversations

Summarizing the work of Stenmark and Devlin, a picture begins to emerge that knowledge can be best thought of as a state of understanding within an individual (or, collectively, as the state of understanding within a team or organization). Knowledge has several aspects. In one sense, knowledge reflects the past experience and expertise of an individual—a set of beliefs that are presumed to be relevant for interpreting real world situations and guiding action. In another sense, knowledge—when combined with current situation awareness—can be "actionable" when certain beliefs are held to be true about the current situation. What is passed between individuals, teams, and organizations is represented by either data or information at various levels of abstraction. Referring to something as either data or information depends upon the relative amount of semantic context associated with the representations that are communicated. Such information is generated by the knowledge state of the sender and can be used to modify or enhance the knowledge state of the receiver. In order for conversations to correctly pass information, the sender and receiver must share a common ground of understanding—a commonly understood contextual framework that can be established in the short-term through preliminary discussions or over the long-term through language, training, common experience, culture, standardized rules/procedures, and so forth. If a common ground of understanding is not sufficiently established, then it is likely that conversations between individuals will either fail or result in miscommunication of beliefs.

Having established a basic definition of knowledge, the discussion turns to a final area of research that illustrates the dynamic nature of knowledge within a team or organization. The dynamic nature of knowledge, in turn, is influenced by the class of problems being addressed by the team or organization.

Alison Kidd and Horst Rittel—Wicked Problems and Dynamic Knowledge Creation

Teams and organizations must often deal with multiple perspectives that arise within a social network of various experts and stakeholders. This requirement adds an additional dimension to the process of creating actionable knowledge—one influenced heavily by the nature of the class of problems being addressed. To better understand this aspect of knowledge creation, this final discussion turns to the work of Alison Kidd and her studies of knowledge workers. (Kidd, 1994) In this work, Alison Kidd makes an important distinction between *knowledge work* and *procedural work*—although she acknowledges that all work is generally a mixture of both. Procedural workers—e.g., an equipment operator, secretary, or assembly line worker—will use information to carry out specific assigned work tasks. Quite often, procedural workers employ very detailed and fixed taxonomic structures for filing and organizing information—structures that are determined by the nature of their task assignments and work procedures. However, their view of their problem space remains unaffected by new information that they acquire in the course of their task work. By contrast, knowledge workers—e.g., a design engineer, military analyst, or operational planner—will use information in an entirely different manner. With these workers, information is consumed in order to increase or refine one's knowledge state about the task or problem space. Hence, information, once mentally digested, is often of little further value to the individual. Information which might have future value is usually left uncategorized in untidy piles—e.g., informal notes, whiteboards, e-mails—rather than being carefully integrated into a fixed taxonomic structure. Important, however, is the notion that the knowledge states of these workers are in a constant state of flux as new information is acquired and absorbed.

As discussed in more detail in a later chapter of this report, two additional distinctions can be made between procedural workers and knowledge workers. With regard to behavioral patterns, procedural workers generally engage in a fixed set of work activities—more specifically, fixed patterns of information acquisition, information processing, and information management. By contrast, knowledge workers will seek out, utilize, and pass on information in very opportunistic

ways, dependent upon their evolving understanding of the problem space and their role within the team or organization. The resulting patterns of work activity will often reflect little consistency from one moment to the next as they adjust and adopt their task work to accommodate new issues and hypotheses, new priorities, and new relevant problem variables. In a related area of comparison, procedural workers generally engage in a fixed set of social interactions and communication networks. Since their task work remains invariant, they are likely to establish and maintain specific channels of communication for acquiring needed information and passing their task products to others. By contrast, knowledge workers will exhibit highly variable patterns of communication with others, and even reply upon different means of communication—e.g., e-mail, face-to-face, chat rooms, briefings—that vary according to the perceived needs of each situation. As a result, formal job titles and organizational charts will provide less understanding of individual roles than, say, what people actually do or who they communicate with from moment to moment.

The notion of information exchanges constantly changing the knowledge state of knowledge workers introduces another facet of this process: the class of problems being addressed by the team or organization. Here, the discussion turns to the classic work of Horst Rittel who first introduced the notion of *wicked problems*. (Rittel & Webber, 1973; Rittel & Webber, 1984) Wicked problems are distinguished from other (simple) problems inasmuch as they are not commonly understood and, hence, they cannot be analyzed in a traditional linear manner using accepted methods. Wicked problems arise in the social context of multiple experts and stakeholders where participants must simultaneously (a) negotiate and agree on an acceptable definition of the problem space—e.g., goals, constraints, relevant variables—and (b) collectively agree on a solution path—e.g., means-ends hypotheses, milestones, success criteria For military C2 teams and organizations, wicked problems tend to dominate at the operational and strategic levels of decisionmaking–particularly where joint, coalition, or multi-agency interests and operations must be reconciled and synchronized.

In contrast to simple problems that primarily correspond to procedural work, wicked problems display a number of characteristics that uniquely associate them with knowledge work:

- *Problem Understanding Evolves with Solution.* The problem space consists of an evolving set of interlocking issues and constraints. Each attempt at formulating a solution potentially shifts goal priorities and the relevance of specific constraints, variables, and means-ends models. Hence, the problem space is never collectively understood by the team or organization until specific solutions have been developed and assessed against an evolving definition of the requirement.
- *Solutions Evolve in a Satisficing Manner.* Since there exists no definitive problem space, there cannot be a definitive solution. The problem solving process terminates when the team or organization runs out of available resources. Resulting solutions tend to be "good enough" or "satisficing" in nature, rather than being optimal. Goals and constraints might not be fully satisfied as the team or organization attempts to accommodate multiple perspectives on the operational situation.
- *Solutions Tend to be Unique, Rather than Selected from Available Alternatives.* Each developed solution path has expenses and potential consequences for the future. In some cases, these consequences will spawn new wicked problems. Solutions evolve through discovery, rather than being pulled off the shelf. There might exist multiple possible solutions, no possible solution, or a set of solutions that are never thought of.

Taken together, the concepts of *knowledge work* and *wicked problems* imply that knowledge creation often involves negotiation and argumentation. That is, much of the information exchanged among collaborating experts and stakeholders serves to support specific arguments or positions regarding the relevance or priority of different goals, constraints, variables, and means-ends models. The goal of each participant is to influence or redefine the knowledge state of other participants so that the team or organization can come to collective agreement on both the problem space and the proposed solution path. Of course, in the case of military C2 teams and organizations, there will often be an individual—e.g., commander or senior military officer—who exerts formal authority over this process. However, there are likely to be cases where the senior authority defers to the perspective of a technical or operational expert. In still other cases—e.g., coalition or multi-agency task forces—the process of negotiation and argumentation might occur among true equals and, hence, involve a real compromise of goals and constraints.

In collaboration with Werner Kuntz, Rittel developed an expressive language for representing knowledge as argumentation—as system known as Issue Based Information System (IBIS). (Kuntz & Rittel, 1972) As illustrated in Figure 1-8, IBIS represents knowledge in the form of questions (or issues), positions (or ideas) that respond to each question, and arguments that either support or detract from each position. Using these basic building blocks, one is able to construct a network that depicts how various positions might relate to a given issue, and how each of the positions are supported by various arguments.

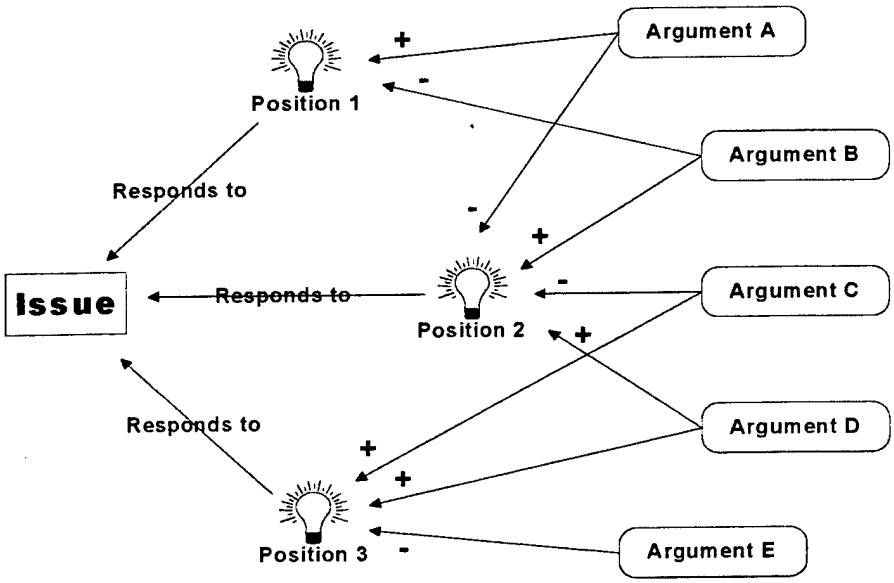

Figure 1-8. Kuntz & Rittel—Issue Based Information System (IBIS)

Extensions of the IBIS notational framework have been used by numerous researchers as a foundation for developing various issue-oriented collaboration systems. (cf. Conklin & Begeman, 1988; Lee & Lai, 1991; MacLean et al, 1991) More specifically, Gilles Falquet and Claire-Lise Mottaz have employed the IBIS framework together with a cyclical conflict resolution process to develop a conceptual model of a multi-perspective knowledge base. (Falquet & Mottaz, 1999) A critical part of this work addresses the fact that different perspectives can either (a) employ different terms to mean the same concept (*correspondence*) or (b) employ the same term to mean different concepts (*conflict*). Using a terminological method based on term comparison, manipulative derivation of terms, and the inheritance of argument properties, Falquet and Mottaz's conceptual model allows for the identification of convergence and divergence among competing perspectives.

Summarizing the work of Kidd and Rittel, knowledge creation is seen as a dynamic process of negotiation and argumentation among relevant experts and stakeholders. Here, information is acquired and exchanged not merely to validate working hypotheses, but also to influence the thinking of other participants. Knowledge is also seen as being valued relative to each situation. That is, actionable knowledge consists of a set of interlocking issues and constraints that form a tentative definition of the problem space and potential solution paths. The process is also satisficing in nature and will terminate when the senior authority figure within the team or organization judges that (a) each of the relevant goals, constraints, variables, and means-ends models have been appropriately considered and (b) a workable solution path has been found.

A critical contribution of this work to the present project is the notion of representing actionable knowledge as (a) a network of interlinked issues, (b) the competing positions that reflect different perspectives on each issue, and (c) a set of linked arguments that support of detract from each position. Representing knowledge in this manner provides a useful foundation for considering multiple perspectives—e.g., different technical or operational experts, different stakeholders—and the degree to which their interpretations of the problem space converge or diverge.

PUTTING THE PUZZLE TOGETHER: A SYNTHESIS OF KNOWLEDGE REPRESENTATION FEATURES

Having reviewed several bodies of relevant literature, it is now possible to begin putting together an ontology for military C2 teams and organizations. As will be seen, this framework draws upon ideas and concepts from each of the researchers addressed earlier in this chapter The discussion begins with the representation of tacit knowledge—experience and expertise stored internally in the minds of individuals. Considered next is a discussion of how the notion of images can be expanded to provide a structure for actionable knowledge within a military C2 team or organization—actionable knowledge that permits intelligent decisionmaking. This is then followed by a discussion of how tacit knowledge and current awareness come together to produce actionable knowledge for each individual. Here, actionable knowledge can be described as an actionable set of positions and supporting arguments that are organized around a set of interlinked issues relevant to the operation. Discussed next is the interactive nature of this framework in which actionable knowledge, in turn, generates (a) requirements for new,

modified, or decomposed hypotheses and (b) requirements for new information elements. These requirements are seen to be driven by the different types of ignorance (deficient knowledge states) that can arise. Finally, the discussion concludes with a look at how different experts and stakeholders collaborate to develop a representation of shared actionable knowledge. The common ground supporting this type of mental collaboration is represented by the degree to which each participant understands the set of interlinked issues, alternative positions, and supporting arguments.

Tacit Knowledge—The Building Blocks of Actionable Knowledge

In his analysis of how organizations manage what they know, Chun Wei Choo identifies three forms of knowledge that are employed to guide decisionmaking. (Choo, 2000) *Tacit knowledge* is defined as the personal (internalized) knowledge used by members to perform their work and make sense of their operational environment. *Explicit knowledge* is knowledge codified either in the form of objects (e.g., software, databases, plans, drawings) or rule sets (e.g., routines, business rules, operating procedures). *Cultural knowledge* is represented in the shared assumptions, beliefs, and values that guide team or organizational thinking and behavior. Of these three forms, however, tacit knowledge is generally emphasized as the most important form of knowledge for knowledge creation. (Nonaka & Takeuchi, 1995) For this reason, the present chapter focuses on the form or structure of tacit knowledge as it might exist within a military C2 team or organization. Explicit knowledge will be discussed in a later chapter and, at least for the present discussion, cultural knowledge will be assumed to be that part of the tacit knowledge of an individual.

Depending upon the level of expertise, tacit knowledge can take different forms. For example, in a classic paper that challenges the notion that all knowledge can eventually be captured in software form, Hubert and Stuart Dreyfus define five levels of expertise—and, hence, five levels of tacit knowledge ability (Dreyfus & Dreyfus, 2002):

- *Novice*—The person approaches tasks by following rules in an unquestioning, context-free fashion. Action is simply guided by rote application of rules, rather than by an awareness of what needs to be accomplished. Performance appears awkward with no account taken of contextual factors.

- *Advanced Beginner*—While still acting in a rule-based fashion, the person can modify some of the rules according to context. The person has started to recognize certain situation types and is able to modify the rules according to those types. Action is still guided by rules, but with some sensitivity to the operational context. Performance is still marked by conscious decisions at each stage of the process.
- *Competence*—The person still following rules, but does so in a fairly fluid fashion—at least when things proceed normally. Instead of stepping from one rule to another, the person has a more holistic understanding of all the rules. The person has an overall sense of the activity and chooses freely among the rules for the appropriate one. Action is guided by an automatic blending or integration of rules for familiar situations; however, the person is unlikely to be able to respond well to novel events of factors.
- *Proficiency*—For much of the time, the person does not select and follow rules. Rather, the person's experience allows them to recognize situations as being very similar to ones already encountered many times before, and to react accordingly, by what has, in effect, become a trained reflex. Appropriate plans spring to mind and certain aspects of the operational situation stand out as important. Action becomes easier as the individual simply sees what needs to be achieved, rather than deliberately deciding among possible alternatives.
- *Expert*—The person does not follow rules and indeed is not generally consciously aware of any rules governing the activity. The person performs smoothly, effortlessly, and subconsciously. The ability to make subtle discriminations and to link situation understanding with action is what distinguishes the expert from the proficient performer. The proficient performer sees what needs to be done, but must consciously decide how to do it. By contrast, the expert performer both sees what needs to be done and—possessing a vast repertoire of situational discriminations—sees how to do it. As a result, the expert performer is apt to arrive at decisions much more quickly than the proficient performer.

According to some researchers, tacit knowledge can be regularly transferred or shared with others—that is, primarily learned through observation and imitation—by means of apprenticeships and on-the-job training. Although not completely expressible in words or symbols, tacit knowledge can be passed along through the storytelling and the use of analogies, metaphors, and models. (Choo, 1995) In terms of modeling, however, there are limits to the

degree to which tacit knowledge can be explicitly represented. As argued by Dreyfus & Dreyfus, when experts are asked to justify a decision or articulate a position, these individuals are forced to unnaturally structure their thinking in terms of rules that correspond more to a novice or beginner level. (Dreyfus & Dreyfus, 2002) In the process or articulating their knowledge to others, they essentially lose the very expertise—i.e., the ability to rapidly make subtle distinctions in a situation and subconsciously link these distinctions to action—that defined them as experts. The writings and arguments of Choo and the Dreyfus brothers raise two implications for the present project. First, it is important to denote the level of expertise—and, hence, the level of problem-solving ability—of each individual being represented or modeled in a C2 team or organization. Ultimately, the level of problem-solving ability demonstrated by the team or organization—at least in the short-term time frame—will be limited to the highest level of expertise that can be brought into the sensemaking and decisionmaking process. Second, it is doubtful that the structure and contents of individual tacit knowledge can be explicitly modeled in rule-form at the higher levels of expertise—say, above *Advanced Beginner*. That is, the representation of higher levels of expertise will likely follow more the form of case-based reasoning in which the expert has acquired the ability to abstract the essential features of various situations and to discriminate among thousands of special cases. (Dreyfus & Dreyfus, 2002)

To further describe the tacit information possessed by a member of a military C2 team or organization, it is useful to apply an adaptation of Rasmussen's means-ends abstraction hierarchy. That is, the means-ends abstraction hierarchy can be used in a modeling sense (a) to define what categories and levels of tacit information the individual possesses, (b) to assess whether or not the individual's tacit knowledge is relevant to a given problem or decision task, and (c) to compare whether an individual's tacit knowledge is consistent (or shared) with another individual with whom they might be communicating or collaborating. As show in Figure 1-9, it is possible to apply Rasmussen's abstraction hierarchy in terms of both knowledge of self and knowledge of an adversary.

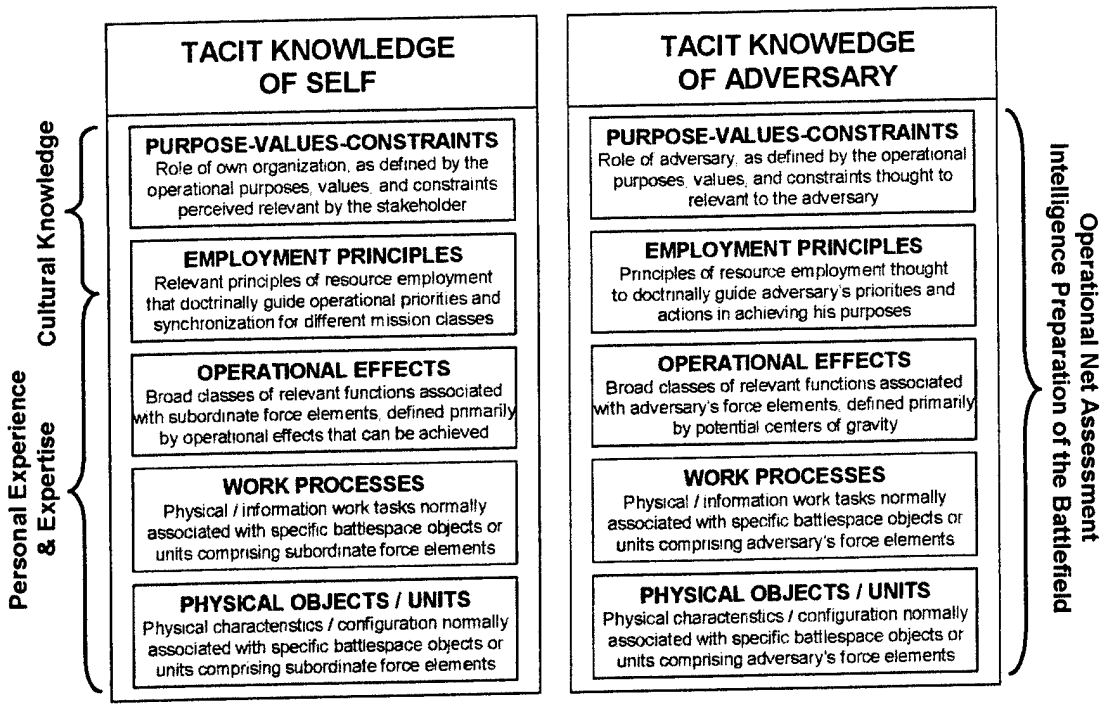

Figure 1-9. Tacit Knowledge as a Means-Ends Abstraction Hierarchy

In terms of knowledge of self, tacit knowledge begins with an understanding of the types of force elements (objects and units) that can populate the battlespace. Moving upward in level of abstraction, tacit knowledge would also include an understanding of the types of work processes typically performed by each force element and an understanding of the general types of effects that could be achieved with each force element. The specific force elements represented in a given individual's tacit knowledge would generally be a function of experience and expertise common to their military Service or branch of military specialization. Moving further upward, an individual might be expected to possess tacit knowledge of certain employment principles that doctrinally guide operational priorities and synchronization for different classes of missions. Finally, an individual's tacit knowledge might be expected to reflect an understanding of the team's or organization's role, as defined by the operational purposes, values, and constraints considered relevant by the individual. As noted on the left side of this figure, there does not likely exist a sharp dividing line between which levels of knowledge are considered "cultural"

versus "person" in nature. Thus, for the present project, such labels are not considered useful or relevant for modeling purposes.[1]

A similar hierarchy can be considered with respect to knowledge of an adversary. Tacit knowledge at the most concrete level begins with knowledge of the force elements that an adversary is likely to employ. Similarly, higher levels of abstraction address knowledge of the operational tasks performed by each force element and an adversary's potential centers of gravity that can be targeted with specific effects. At the highest levels of abstraction would be knowledge of an adversary's doctrinal employment principles and the overall operational roles and goals of the adversary. Unlike knowledge of self, however, various levels of tacit knowledge of an adversary is likely to be possessed by few individuals—primarily those serving in an intelligence role responsible for preparing operational net assessments or conducting intelligence preparation of the battlefield.

As discussed later, it is important to represent relevant differences in the tacit knowledge held by specific individuals within a C2 team or organization. Such differences will give rise to different perspectives on the scope and definition of an operational problem and the formulation of solution paths. These same differences will also be an important element in modeling the requirement for effective collaboration and the development of shared actionable knowledge.

Actionable Knowledge Structure—The Decomposition of Images into Key Operational Questions

Equally important to representing individual tacit knowledge in a C2 team or organization is the representation of actionable knowledge. Here, however, one must consider a different structure altogether. Whereas tacit knowledge is organized around different levels of abstraction,

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[1] This is not to say that important "cultural" differences might not exist within a coalition force headquarters occupied by staff officers from different nations. However, there might also exist important individual differences within a team or organization with regard to Service or military occupational specialization. Hence, the present framework merely defines these differences in terms of the various abstraction levels, rather than referring to them as "cultural" or "personal."

actionable knowledge takes on a more action-oriented structure. A good starting point for this structure is Beach & Mitchell's various images (Beach & Mitchell, 1998); however, these images must be further decomposed to be relevant for military operations. Proposed in Figure 1-10 is one such method of decomposition—one organized around the basic operational questions that would be asked by a commander. As seen in Figure 1-10, the key operational questions can be further decomposed into a set of interlinked issues that comprise a C2 team's or organization's structure for actionable knowledge.

As with the means-ends abstraction hierarchy used to organize tacit knowledge, the issues reflected in actionable knowledge link the operational goals to be achieved with the operational strategy and means that can achieve them. In the present case, each of the issues shown on the right side of Figure 1-10 represents a critical operational question that must be answered before a course of action can be meaningfully developed. However, the organization of actionable knowledge into a set of issues allows for the representation of two other critical components of actionable knowledge: positions and arguments.

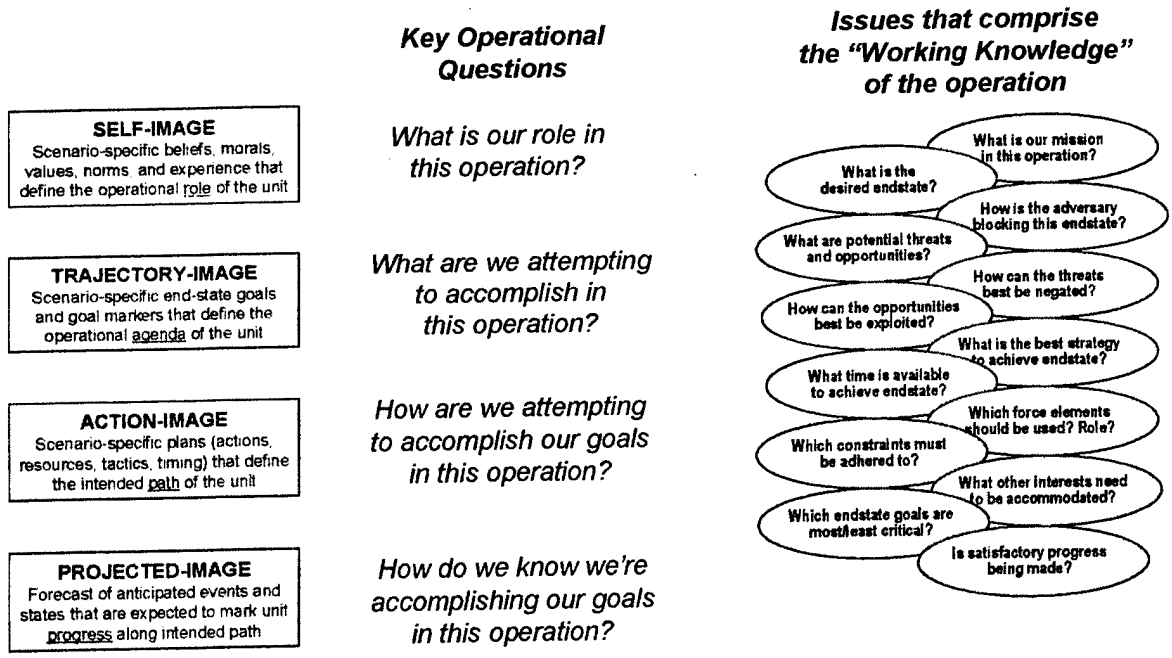

Figure 1-10. Decomposition of Images into Actionable Knowledge Issues

Actionable Knowledge Development—The Integration of Awareness with Tacit Knowledge

The representation of actionable knowledge as a set of interlinked issues is motivated by the earlier work of Kuntz & Rittel that led to the development of the argumentation language known as IBIS. (Kuntz & Rittel, 1972) Recalling the structure presented in Figure 1-8, it is noted that a set of hypothesized positions and supporting empirical arguments can be mentally associated with each issue. This would seem to reflect the type of structure suitable for actionable knowledge. Such a structure is supported by the work of Nonaka & Takeuchi that posits that effective teams and organizations operate on the basis of "*chishiki keiei*"—the continuous creation of new knowledge. (Nonaka & Takeuchi, 1995) However, in contrast to the western epistemology that emphasizes the absolute, static, and objective nature of knowledge, Nonaka & Takeuchi argue the eastern view of knowledge as "justified true belief." That is, action is taken on the basis of what one believes or accepts as working truth, rather than simply on the basis of empirically established facts. Such a view seems entirely consistent with Carl Von Clausewitz's concept of the "fog and friction of warfare" and the notion that military C2 decisionmaking will—despite advances in information technology and networking—always involve a certain degree of uncertainty and the unknown. In this regard, it is useful to recall the specific words of Clausewitz regarding the peculiarities of war (Von Clausewitz, 1873):

> *"Lastly, the great uncertainty of all data in war is a peculiar difficulty, because all action must, to a certain extent, be planned in a mere twilight, which in addition not unfrequently—like the effect of a fog or moonshine—gives to things exaggerated dimensions and an unnatural appearance. What this feeble light leaves indistinct to the sight, talent must discover, or must be left to chance. It is therefore again talent, or the favour of fortune, on which reliance must be placed, for want of objective knowledge."*

The representation of actionable knowledge as a set of interlinked issues, associated positions, and supporting arguments is also consistent with Giffin's information fusion concept of critical rationalism. (Giffin & Reid, 2003) That is, information concerning the operational battlespace is organized around a set of relevant hypotheses developed from experience and expertise (tacit knowledge). The information is used to test and refine each of these working hypotheses to some acceptable level of empirical support. Once the hypotheses have been sufficiently validated, they

then can serve as the basis for decisionmaking and intelligent action taking. The same notion is seen to provide the basis for the Air Force Scientific Advisory Board's recommendation that the Air Force's information management process should more tightly couple data collection and sensor management around the operational problem space and decision requirements of the commander. (AFSAB, 2002)

The concepts and language of Nonaka & Takeuchi, Von Clausewitz, Giffin, and the Air Force Scientific Advisory Board are amazingly consistent in their view of the development and structure of actionable knowledge. This process and structure are summarized in Figure 1-11 that illustrates how awareness of the current situation (empirical evidence interpreted as supporting arguments) is organized around a set of relevant operational issues to validate and refine a set of working hypotheses (positions) that can lead to intelligent action taking.

As seen in Figure 1-11, tacit knowledge of self and tacit knowledge of an adversary are combined to develop a working set of positions regarding each of the issues comprising actionable knowledge. These issues and hypotheses serve to provide the structure for organizing empirical evidence that is used to test and refine the positions into a "justified true belief" regarding the current and projected state of the battlespace. Which issues and positions receive emphasis is a function of the experience-based perspective of the individual. Together, however, the issues and associated positions reflect the individual's definition of the problem space to be addressed by the decisionmaking process. Of course, as discussed later, this perspective might vary across different experts or stakeholders—thus, leading to the requirement for collaboration and the development of a common ground of understanding.

The empirical evidence used to test and refine each position (hypothesis) is obtained from the current awareness of the individual. Current awareness of self includes awareness of assigned mission(s), awareness of force elements either organic or attached to the command, supporting force elements from other Services, and the status of the units and assets of these various force elements. In the era of network-centric operations, much of this current awareness is likely to come from the common operating picture available to the C2 team or organization. However, it is possible that specific aspects of awareness of self might be generated by direct queries from

the decisionmakers to subordinate force elements—e.g., "directed telescopes," as described by Martin Van Creveld. (Van Creveld, 1985)

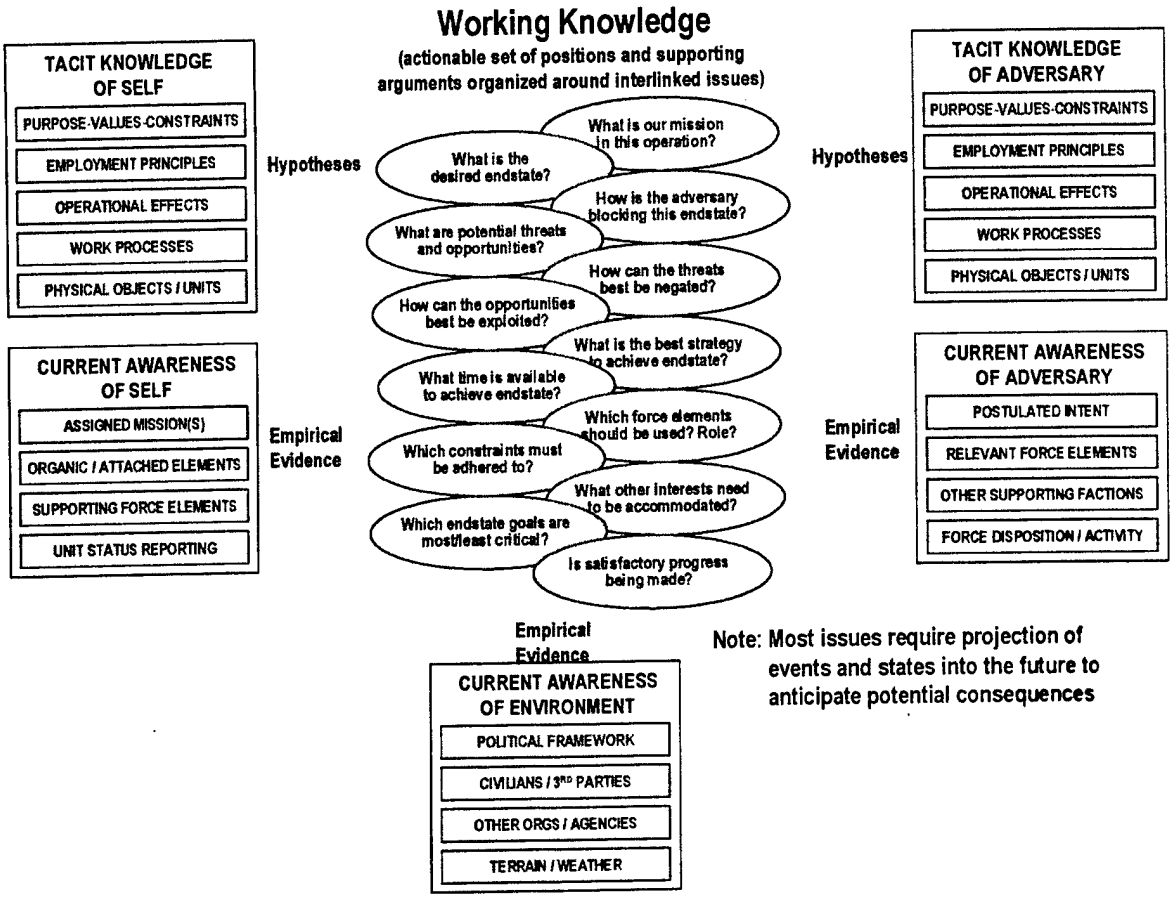

Figure 1-11. Current Awareness Combines with Tacit Knowledge to Produce Actionable Knowledge

In a similar fashion, current awareness of the adversary includes awareness of postulated intent, awareness of relevant force elements available to the adversary, awareness of other supporting factions that must be taken into consideration in the operation, and awareness of the disposition and activities of these elements and factions. The primary source of this awareness will be the Intelligence, Surveillance, and Reconnaissance (ISR) systems reporting to the command and intelligence organizations sharing information with the command.

Current awareness of the environment includes awareness of the specific political framework that focuses and constrains the military operation, relevant civilian populations and third-party players within the battlespace, relevant private/voluntary and non-governmental organizations and other government agencies with which the operation must be politically or legally

coordinated, and the various terrain and weather factors that influence the operation. While awareness of self and awareness of the adversary is traditionally supported by well-defined reporting channels, awareness of the environment—with the exception of terrain and weather—is likely to be more situationally defined by the specific liaison channels set up between the military command and other non-military agencies and organizations. As discussed later, much of this information might develop through collaborative work sessions with representatives from these other agencies and organizations.

Finally, it is noted that the organization and integration of current awareness with tacit knowledge will necessarily involve a certain degree of future projection. That is, most issues reflected in actionable knowledge will require not only an awareness of the battlespace as it currently is, but also a projected awareness of the battlespace as it is anticipated to become. Of particular concern will be (a) a projection of adversary events and states into potential threats and opportunities and (b) a projection of alternative strategies and force capabilities into future effects against these threats and opportunities. Although not explicitly depicted in Figure 1-11, these projections will be based on either (a) means-ends models derived from the individual's tacit knowledge—as in the case of recognition-primed decisionmaking[2]—or (b) formal analysis using external models and planning methods.

Interaction—The Impact of Actionable Knowledge on Tacit Knowledge and Awareness

Looking inside of the actionable knowledge portion of Figure 1-11, a structure begins to emerge that is similar to the IBIS language developed by Kuntz & Rittel. (Kuntz & Rittel, 1972). This structure, depicted in Figure 1-12, consists of the set of interlinked operational issues, the alternative positions hypothesized by the individual, and the supporting arguments organized from the current awareness of self, the adversary, and the environment. The alternative positions provide the building blocks of what the individual considers to be "justified true belief"

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[2] Recognition-primed decisionmaking, as defined by Gary Klein, includes the internal mentally ability of decisionmakers to rapidly project current events and their consequences forward in time, based on recognized or familiar operational patterns. (Klein, 1999)

regarding each operational issue. The relevance and strength of each alternative position is governed by the weight and veracity of supporting arguments developed from current awareness. As will be discussed in the next section, the relevance and strength of these alternative positions might or might not support effective decisionmaking. That is, decisions are likely to be formulated and committed to only when the individual has arrived at what is considered to be an acceptable level of comfort regarding the state of understanding.

The structure presented in Figure 1-12 suggests that actionable knowledge involves an on-going process of organizing current awareness to test and refine alternative hypothesized positions associated with a set of interlinked operational issues. Major General Russel Honoré refers to this process and structure as the "running estimate" (Honoré, 2002):

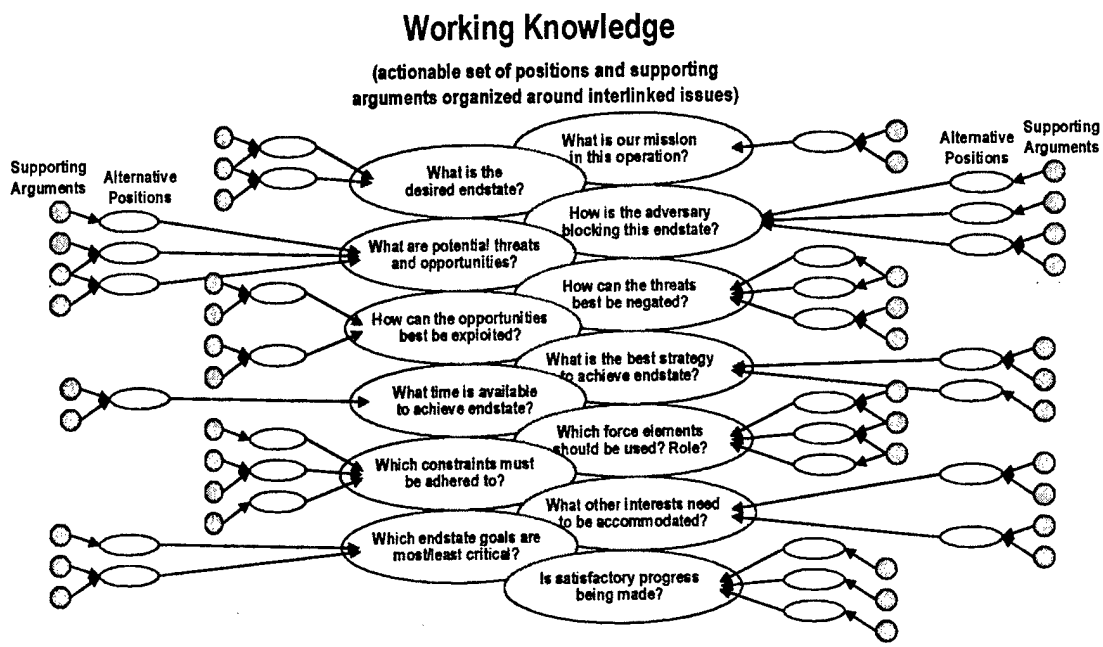

Figure 1-12. Internal Structure of Actionable Knowledge

"The concept of the operation establishes common understanding up to execution time. Since the anticipated conditions of METT-TC [mission, enemy, terrain and weather, troops and support, time, and civil considerations] never survive first contact, the running estimate provides the medium for continual situation understanding. The running estimate begins with mere situational awareness,

becomes knowledge with confirmation, and finally becomes understanding when the commander realizes the effects of changing conditions and adapts."

The proposed model of actionable knowledge fits very well with Honoré's concept of the running estimate. The set of operational issues provide the central organizing structure for this estimate, while the associated positions and supporting arguments reflect the primary contributions of expertise and current awareness that continually refine and update the estimate. Referring back to the arguments of Dreyfus & Dreyfus, it is likely that the alternative positions hypothesized for each issue will be based on the fine discrimination among thousands of special cases available from the individual's experience and expertise—at least for individuals operating above an *Advanced Beginner* level. Supporting arguments, then, will take the form of empirical evidence gleaned from current awareness. Such evidence will either add to or subtract from the likelihood that a hypothesized case acceptably describes a specific aspect of the current or projected situation.

Comparing the work of Giffin & Reid, Beach & Mitchell, Rasmussen, and others, it can be concluded that knowledge creation works as both a bottom-up and top-down process of synthesizing hypothesized positions with available empirical evidence. The top-down aspect of this process is suggested in Figures 1-11 and 1-12 wherein empirical evidence is gleaned and organized from current awareness to validate and refine a set of hypothesized positions to some level of "justified true belief." The bottom-up aspect of this process is illustrated in Figure 1-13 that depicts how the state of actionable knowledge can serve as motivation to either (a) develop new, modified, or decomposed hypotheses to account for unexplained information or (b) seek new information elements to further justify acceptance of a particular position.

As shown in Figure 1-13, several factors govern the requirement for new hypotheses or new information elements. These factors are best represented in terms of Zack's forms of knowledge ignorance. That is, the basic goal of the individual is to develop an acceptable level of "justified true belief" regarding the projected state of the battlespace and the actions (effects) that can be taken to move the battlespace toward the desired end-state. This means that (a) the individual's experience should adequately explain or account for what is known from current awareness and (b) current awareness should adequately justify acceptance of the positions (cases) hypothesized

from experience. Maintaining this balance of understanding is an on-going process and can be upset in several ways:

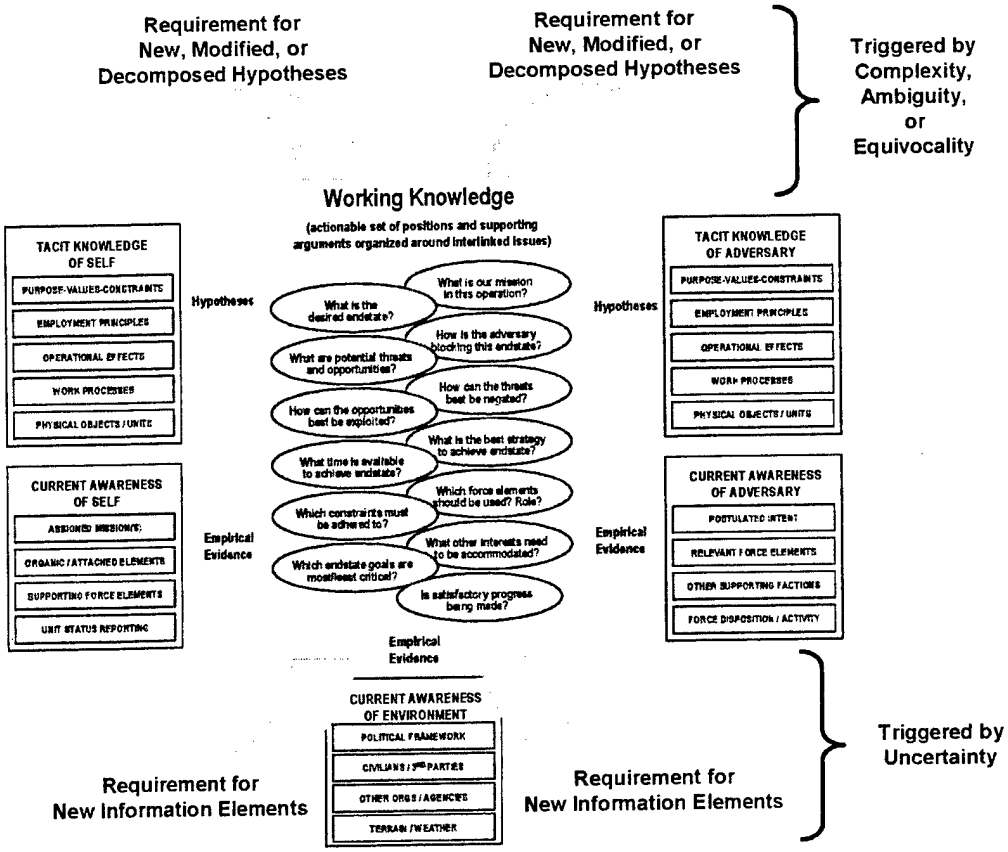

Figure 1-13. Actionable Knowledge Generates the Requirement for New Hypotheses and New Information

- *Complexity* If the individual possesses more information from current awareness than can be reasonably processed, the likely response will be to decompose the structure of actionable knowledge into a finer set of operational issues. In this fashion, some of this processing can be offloaded to others who are then given the task of developing hypothesized positions that explain part of the available information. Hence, complexity will likely lead to a further decomposition or elaboration of the operational issue structure. If these issues can be successfully resolved, they might be recombined into the original structure used for actionable knowledge.

- *Ambiguity*. If the individual possesses information that exceeds their levels of expertise, the likely response will be to consult with others who are thought to have more extensive experience with that specific aspect of the operation. As with complexity, some of the processing is offloaded to others who are then given the task of developing hypothesized positions that explain part of the available information. In the case of ambiguity, however, the individuals will likely retain the original set of operational issues as the basic structure for actionable knowledge.
- *Equivocality*. Equivocality exists when the available evidence from current awareness supports more than one position for each issue. At the level of the individual, one possible response will be to seek additional information that can discriminate the relative likelihood of the alternative positions. This process continues until one of the positions emerges as the best "justified true belief" for the specific operational situation. However, a different response might be to seek new hypotheses (or to modify existing hypotheses) based on bringing some additional area of experience to bear on the problem. This ability to look at existing information from different perspectives corresponds to both the "problem framing" skills and "strategic reasoning" skills identified by Susan Fischer in a recent Army workshop on critical thinking. (Fischer, 2000)
- *Uncertainty*. Uncertainty reflects a lack of confidence in the level of information supporting a given position. The likely response in this case will be to collect additional elements of information relevant to the hypothesized position being examined. As in some cases of equivocality, the individual is led to seek additional information—a process that will continue until the individual believes that a "justified true belief" has been obtained, or that the circumstances of the situation demand a decision. Unlike equivocality, however, only a single hypothesized position is being tested and refined.

Consideration of these various dimensions of ignorance suggests that the actionable knowledge process also involves a type of meta-knowledge. That is, the individual will rely upon experience and expertise to indicate just how much complexity, ambiguity, equivocality, or uncertainty can be tolerated in a given decisionmaking situation. When the nature and amount of actionable knowledge ignorance in a specific operational situation exceeds the individual's level of tolerance, this will trigger the individual to initiate one of the responses described above.

Threshold values for each of these conditions will be a matter of individual preference, thus reflecting the degree of decisionmaking risk the individual is willing to tolerate.

Shared Actionable Knowledge—Building a Common Ground of Understanding

Moving to the level of C2 teams and organizations, one now must consider the concept of *shared* actionable knowledge—that is, the common ground of understanding that allows individual members of C2 teams and organizations to coordinate and synchronize their decisionmaking processes. However, approaching the concept of shared knowledge in any form raises certain epistemological questions regarding (a) the internal versus external nature of knowledge and (b) whether knowledge can actually be communicated externally—like information—among different individuals. The present project recognizes that research positions have been taken both ways with regards to these two questions. Authors such as Keith Devlin take the position that knowledge reflects an internal state of understanding within the individual, and that what is exchanged during collaboration is merely information derived from the knowledge of one individual that is passed to alter the knowledge state of another. The same idea seems to be consistent with the notion of knowledge workers presented by Alison Kidd. By contrast, however, the development IBIS-based collaboration systems and multi-perspective knowledge bases by Falquet & Mottaz, Lee & Lai, and Conklin & Begeman seem to reflect the assumption that external representation and sharing of knowledge is possible.

The present project takes both viewpoints into consideration by arguing that (a) tacit knowledge and actionable knowledge are both primarily internal states of understanding of the individual but that (b) it is possible to externally codify limited aspects of tacit knowledge and actionable knowledge. In terms of modeling C2 teams and organizations, the present project takes the view that shared actionable knowledge can be represented as a set of interlinked issues, alternative positions, and supporting arguments that are commonly shared among members of a team or organization that are collaborating in a specific community of interest.[3] However, the degree to

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[3] Community of interest is defined here as a group of different functional experts and/or stakeholders that have come together to collaboratively frame and solve an operational problem

which the members commonly share all elements of this actionable knowledge structure is thought to be a function of the teamwork exhibited within the community of interest. The general structure for shared actionable knowledge is presented in Figure 1-14.

Reflected around the periphery of this structure are the multiple perspectives held by the different members of the community of interest. Similarly, participants in the community of interest hold multiple states of awareness regarding self, different aspects of the adversary, and different aspects of the environment. Functionally, the community of interest provides a forum in which the participants can engage in what Karl Weick defines as *collaborative debate*. (Weick, 1995) Collaborative debate involves a process in which participants (a) post their respective positions and supporting arguments within the forum, (b) debate the relevance and strength of conflicting positions, (c) reconcile and accommodate different positions into a mutually acceptable group position, and (d) expand or alter the individual knowledge states of other participants.

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of mutual interest and relevance. Most likely, the operational problem exhibits "wicked" characteristics, as defined by Horst Rittel.

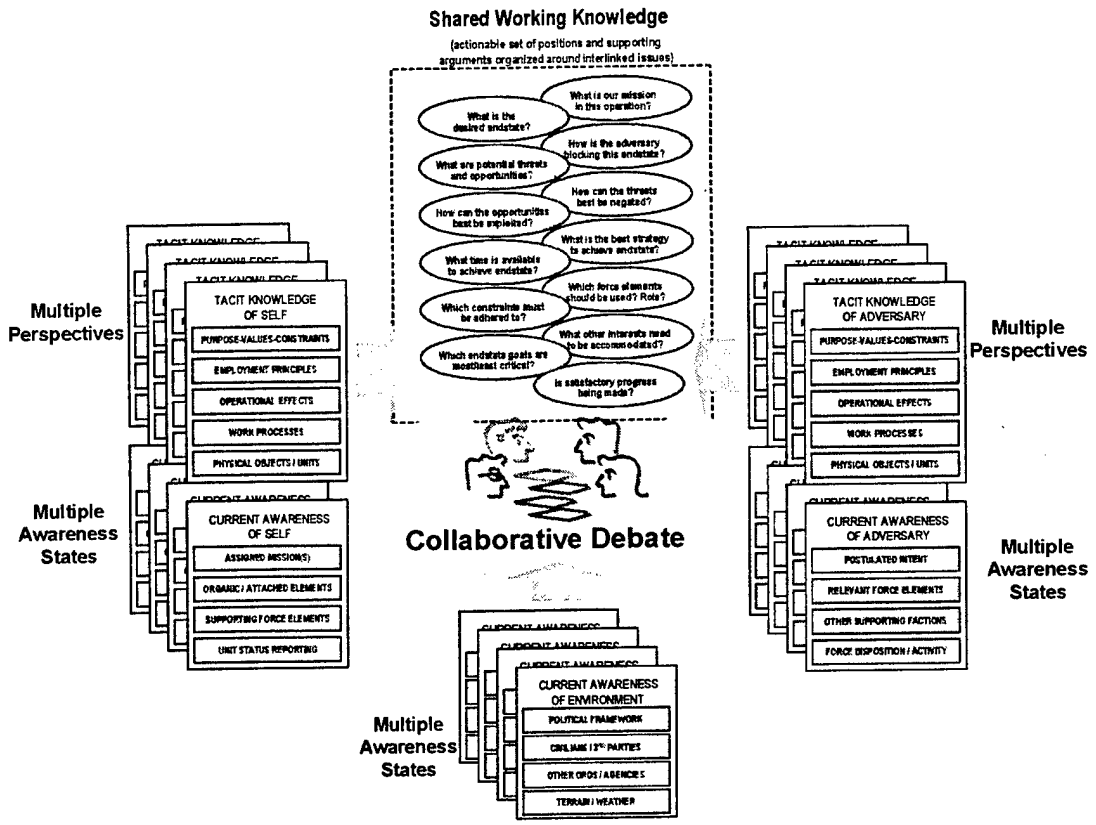

Figure 1-14. Shared Actionable Knowledge

The goal of collaborative debate is for the group of participants to arrive at a mutually acceptable "justified true belief" that addresses the goals, constraints, and means-ends considerations relevant to each expert and/or stakeholder. If one of the participants—e.g., commander, recognized best expert—possesses greater formal or informal authority than the others, then the process of collaborative debate will likely be brought to a close when the ranking leader of the group determines that all perspectives have been considered and decides which positions have greatest relevance and importance. If the collaborative debate occurs among co-equals,—say, representatives from different organizations or agencies—then final resolution of the competing positions will likely depend upon their relative level of empirical support. Of course, a myriad of variations to this process are possible.

While the structure presented in Figure 1-14 provides a basic model of shared actionable knowledge for a C2 team or organization, the actual process is considerably complex and influenced by not only cognitive factors but by social factors as well. In short, the quality or robustness of the shared actionable knowledge produced within a community of interest will be

influenced by a number of elements, including those identified by David Noble and John Kirzl in recent research on team effectiveness (Noble & Kirzl, 2003): team setup and adjustment, methods of group problem-solving, and methods of group task synchronization. These elements, in turn, will be influenced by a number of factors, including interpersonal trust, the social currency of each participant, and whether or not the group members possess the requisite variety of experience needed for framing and solving the operational problem.

SUMMARY

In summary, this chapter has identified a number of concepts and ontologies from current bodies of relevant research on knowledge representation. The resulting synthesis of these concepts and ontologies has produced an integrated model of shared actionable knowledge that can form the basis for operational decisionmaking within a military C2 team or organization. The model begins with the representation of tacit knowledge (experience and expertise) of the individual and how this serves to organize the individual's hypothesized positions regarding a set of interlinked operational issues. Information elements available from the individual's current situation awareness are then used to test and refine these hypothesized positions to an acceptable level of "justified true belief." In turn, the state of actionable knowledge can be assessed in terms of several meta-knowledge dimensions—complexity, ambiguity, equivocality, uncertainty—that trigger different types of response, including the decomposition of issues, the development or refinement of positions, and/or the collection of new information elements. Moving to the team or organization level, the model addresses the need for collaborative debate among a group of experts and stakeholders to debate and reconcile alternative positions regarding each issue, and to develop a common ground of understanding that serves as the basis for coordinated decisionmaking. In the process of collaborating, each individual is considered a knowledge worker in the sense that their individual knowledge state is altered by the collaborative debate process.

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CHAPTER 2: SENSEMAKING AND KNOWLEDGE MANAGEMENT PROCESS MODEL

INTRODUCTION

Sensemaking and knowledge management are concepts frequently discussed in the management science and organizational psychology literature. From a review and synthesis of this literature, it is possible for one to gain a general sense of what issues these concepts address and how they potentially relate to the decisionmaking performance of a military C2 team or organization. Yet, a great deal of confusion still exists as to how each process might best be operationally defined, analytically modeled, empirically tested, and critically assessed in terms of key constructs and variables, process interactions and obstacles, performance dimensions and metrics, and objective criteria for assessing the adequacy or sufficiency of outcome. In terms of usefully applying these terms to understand the workings and effectiveness of military C2 teams and organizations, it could be said that we are still at what Thomas Kuhn would describe as a preparadigmatic stage of science. (Kuhn, 1975)

The OODA Loop Paradigm

In terms of Kuhn's model of scientific progression, the advancement of research and analysis in a particular area of study—say, the representation of human decisionmaking in military combat—requires the common acceptance of a specific, organizing paradigm. Here, Kuhn defines a paradigm as being "a collection of beliefs shared by scientists, a set of agreements about how theories and problems should be understood." While such a definition sounds impressive and simple, its actual meaning is elusive and has generated no end of debate within the scientific community. For the purpose of the present study, the term "paradigm" is illustrated by the "*Observe—Orient—Decide—Act*" (OODA) loop example shown in Figure 2-1.

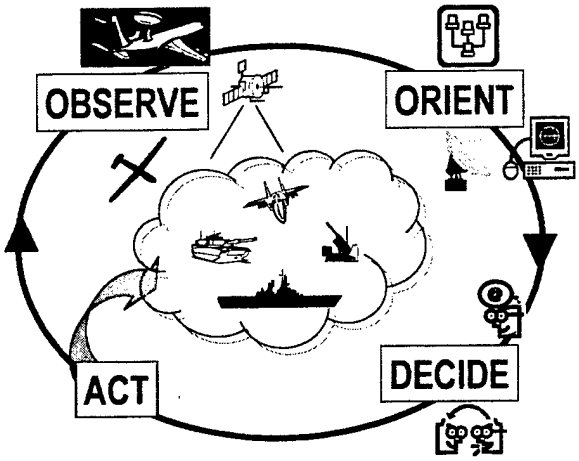

Figure 2-1. OODA Loop Paradigm

As developed by John Boyd over a period extending from the 1970s until his death in 1997, the concept of the OODA loop has had a profound impact on the study of decisionmaking within both the military and the corporate world. (Boyd, 1987) In terms of an organizing paradigm for the scientific study of military C2, the OODA loop provided several important elements of guidance:

- It decomposed decisionmaking into a number of specific process elements that would be the focus of attention in much of the C2 research that would follow;
- For each of these processes, Boyd's general description dictated the types of variables of primary interest;
- Overall, the model's linkage of these elements in a loop suggested that military C2 should be viewed as a cyclical process; and
- The basic measure of decisionmaking performance is speed (success in combat is based on acting inside of the adversary's decisionmaking cycle).

As useful as this model was for helping analysts to think about military C2, the OODA loop paradigm also led some researchers to distort or oversimplify decisionmaking process. For

example, consider Boyd's original model[4] of the OODA loop shown in Figure 2-2. In this original conception, Boyd placed considerable emphasis on the *Orient* stage of C2, showing it to be a complex interaction of genetic heritage, cultural tradition, previous experience, new information, and analysis and synthesis. Decisionmaking was seen to involve both hypothesis formulation followed by action that served to test each hypothesis. At the same time, the original model contained multiple, cross-referencing feedback paths that served to reshape *Observation* in terms of guidance provided by the other three stages.

Unfortunately, most attempts to apply the OODA loop paradigm in subsequent studies have ignored the complexity of the *Orient* stage, and have assumed the process to be only forward directed without any backward feedback loops. In extreme cases, the OODA loop paradigm has been reduced to simply observation, followed by minimal or rote information processing, which then leads to simple, rule-based tactical actions. Understandably, such distortions lead some researchers and analysts to conclude that (1) simply collecting more information (observations) will lead to better C2 decisionmaking; (2) decisionmaking performance is based solely on the amount of information collected (often stated in terms of the degree to which "ground truth" is accurately portrayed in the observations); and (3) the process of formulating data into information, information into knowledge, and knowledge into action is a one-way, bottom-up cognitive or computational process. The complexity of the *Orient* stage alluded to by John Boyd provides a focal point for the discussion that follows in this chapter. Specifically, if one intends to model military C2 processes at the team or organizational level, then one must necessarily focus on those elements that make up the complexity of the *Orient* stage in Boyd's model

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[4] This slide is actually based on John Boyd's last briefing, entitled "The Essence of Winning and Losing," developed in 1996, and contained in a collection of writings loosely referred to as the "Green Book."

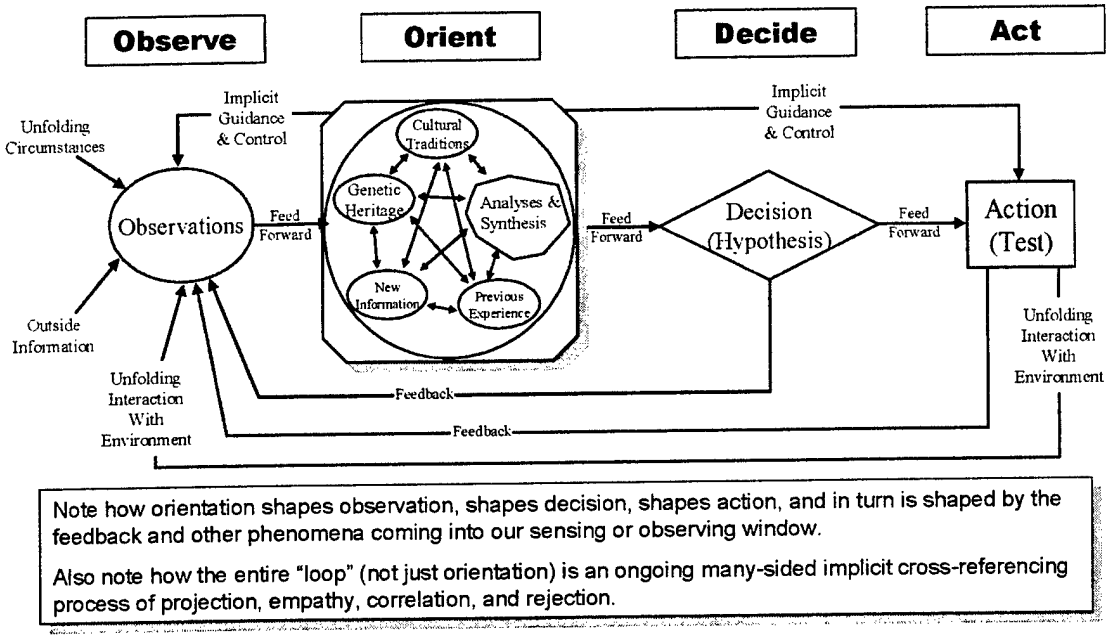

Figure 2-2. Boyd's Original Conceptualization of the OODA Loop

As noted by Kuhn, research paradigms represent an important aspect of any field of science inasmuch as they provide the organizing framework around which to build, test, and refine theories or models of a given process or phenomenon. (Kuhn, 1975) If researchers find that a specific paradigm is no longer effectively supporting the advancement of understanding in a given field, they will begin to look for competing paradigms that provide greater theoretic potential. The transition from one paradigm to another is referred to by Kuhn as a "paradigm shift"—a period of time in which researchers cease to practice normal science around the former paradigm and move backwards to explore other paradigms on a first principles basis. Several competing paradigms might emerge during this period—with either one of the new paradigms eventually proving to offer greater explanatory utility or with several of the paradigms merging into yet a newer and more powerful framework. Such appears to be the case with the OODA loop paradigm—perhaps, not so much as John Boyd originally intended it, but as this model has been applied in simplistic fashion to represent military C2 as a linear, industrial-age, decisionmaking process.

The Search for a New Paradigm

Recent studies and writings within the military community have suggested the emergence of a new paradigm—network-centric operations—that suggests the need for a more comprehensive

approach to the modeling and analysis of military C2 systems. The network-centric paradigm has been useful in three respects. First, the paradigm has identified four domains relevant to the functioning of military C2 systems: (1) the physical domain of the battlespace with its various combat platforms and physical environment; (2) the information domain that involves various sensors, information processing, and communication systems; (3) the cognitive domain of human decisionmaking; and (4) the social domain of various actors and stakeholders within the C2 process. (*cf.*, Alberts, Garstka & Stein, 1999; Alberts, et al, 2001) Second, the paradigm has suggested that these four domains interact with one another in important ways to influence the overall functioning and effectiveness of C2 systems. Third, the paradigm has underscored the importance of addressing all three domains in the analysis and assessment of military C2 systems.

As part of the network-centric literature, the concept of *sensemaking* receives prominent mention as a sociocognitive process that must be better understood if one is to assess the contributions and limitations of various components of force development—e.g., technology, training, personnel, organization, and procedures. (*cf.*, Leedom, 2002a; Leedom, 2002b) It should be noted here that the concept of sensemaking is not unique to the military. Rather, it reflects a line of research that began nearly a decade ago within the corporate sector. (*cf.* Weick, 1995; Weick & Sutcliffe, 2001) As will be discussed later, the current literature on sensemaking suggests important components to consider in the development of a new research paradigm for C2 modeling and analysis.

Useful Perspectives from the Management and Social Sciences

To guide our understanding of what must be represented in this model, the discussion examines military C2 from three different perspectives in the research literature. The first perspective is taken from current literature on organizational sensemaking. As useful as the sensemaking literature is for helping one to understand the essential process by which a C2 team or organization transforms information into actionable knowledge, several additional perspectives must be considered. In this regard, the present study turns to research that has emerged from the knowledge management literature.

The second perspective can be loosely defined as the paradigms that have emerged out of the western and eastern research literatures on knowledge management. The western literature reflects an analytic way of thinking about knowledge management and uses the paradigm of a marketplace to identify important aspects of knowledge management. The eastern literature places its emphasis on knowledge creation and uses the paradigm of organizations as the amplifier of individual knowledge. While these perspectives overlap in some areas, each of these paradigms tend to focus on different aspects or dimensions of the military C2 process, and each elevates different variables and factors in importance within the overall process. Taken together, these two paradigms complement the sensemaking perspective in useful ways and offer (1) additional insights for the C2 modeler and (2) specific performance metrics for the C2 analyst.

Finally, it is useful to examine C2 organizations from a roles and actors perspective. That is, each layer within an organization is represented by different classes of actors who each fulfill specific types of roles. Understanding the nature of these actors and their roles is useful for (1) specifically modeling both linear and emergent processes within an overall C2 model and (2) developing additional types of performance metrics. Together, these various perspectives complement one another and provide the modeler with a comprehensive framework for representing the essential ingredients of sensemaking and knowledge management within a military C2 team or organization.

SENSEMAKING: THE CONSTRUCTION OF UNDERSTANDING

What does it mean for a military C2 team or headquarters organization to "make sense" of an operational situation? Implicit in much of the past modeling work on C2 systems has been the assumption that there exists a one-way, upward transformation of data into information, information into knowledge or understanding, and knowledge into action. As noted in a previous chapter, it is assumed by many technologists that suitable algorithms can be found and generalized to provide for the automatic assemblage of data into meaningful objects, objects into meaningful orders of battle, orders of battle into meaningful threats, and so forth. In response, Ralph Giffin argues that this normal assumption of ascending linkage—based on naïve inductivism—is logically flawed and unworkable in most instances. (Giffin & Reid, 2003) So, if sensemaking is not an automatic, bottom-up, fixed process of perception, then what does it involve? To address this question in a modeling context, the current research considers four ideas

that have emerged from the sensemaking literature: (1) the occasions for sensemaking, (2) the basic knowledge structures of sensemaking, (3) the basic cognitive and social process elements of sensemaking, and (4) the basic mechanisms of sensemaking failure.

Occasions for Sensemaking

A similar thread of reasoning is reflected in the literature on sensemaking. Specifically, it is argued by Karl Weick that problems frequently arise with the processing, organization, interpretation, and transformation of available data and information into actionable knowledge—and that it is precisely these occasions that give rise to the need for sensemaking: (Weick, 1995)

- *Information Overload.* As available information increases in volume and variety beyond the processing capacity of the team or organization, members must find expedient ways of dealing with the resulting ambiguity, equivocality, and overload.
- *Complexity.* As the number of diverse elements and interactions increase within the operational problem space, team and organizational members must find ways of simplifying and focusing their mental workload.
- *Turbulence.* As operational situations evolve over time, team and organizational members must responsively identify important changes in the operational problem space so that their resulting decisions and actions remain relevant to emerging mission goals and constraints.

The failure of a military team or organization to effectively deal with each of these problems can (and often does) lead to a collapse in decisionmaking reliability as members become overwhelmed by information overload and situational complexity, or as they fail to adapt their decisionmaking process to a new or novel operational situation. (Weick & Sutcliffe, 2001). The collapse of decisionmaking reliability can be sudden—as in the case of the terrorist attack against the World Trade Center—or can evolve over a period of time—as in the case of transitioning from major combat to peace and stability operations in Operation Iraqi Freedom. In each case, the team or organization suddenly finds that its previous decision rules, premises and assumptions, and problem framework no longer support intelligent action. Thus, the team or organization is forced to search its experience and expertise for ways of reframing the operational problem, for redefining critical variables and issues, and for identifying new types of

relevant information. In reality, while certain situations such as the World Trade Center dramatically attack highlight the need for sensemaking, sensemaking is more often performed on a continuous basis as decisionmakers constantly test the validity of their assumed problem frameworks, variables, rules, and information needs against the evolving nature of the operational battlespace. To illustrate the many ways in which ambiguity or equivocality can arise in the course of decisionmaking, Weick summarizes a number of areas previous identified by McCaskey. (1982) These areas are paraphrased as follows:

- The nature of the problem has shifted from the known (e.g., simple problem) to the unknown (e.g., wicked problem);
- The ability to effectively collect, interpret, and organize information becomes problematic because of the volume of available information or the reliability of this information;
- There exist multiple, conflicting interpretations of the available information as different experts or stake holders each apply their unique perspectives and expertise;
- Functional experts and stakeholders differ in terms of the underlying values, political goals, or emotional reactions;
- Overall guidance and direction received from above does not set forth a clear and consistent set of goals that address the present operational situation;
- Time and other resource constraints necessitate tradeoffs among competing goals and operational requirements;
- The operational situation appears to present decisionmakers with a seemingly inconsistent pattern of features, relationships, or demands;
- Various relevant players lack a clear and consistent assignment of roles and responsibilities;
- Decisionmakers lack a clear and consistent set of success measures for judging operational progress and adjusting future decisions and actions;
- Decisionmakers lack a clear understanding of cause-effect relationships;
- Functional experts and stakeholders employ symbols and metaphors to articulate their perspective, but these symbols and metaphors are not consistently understood by others; and

- Key decisionmakers, functional experts, and stakeholders change as a function of the evolving operational situation.

In order to cope with information overload, complexity, and turbulence, humans rely upon their past experience and expertise to mentally construct and impose meaning on their operational environment. This tendency to construct reality—as opposed to merely searching in an exhaustive manner for "ground truth"—lies at the heart of sensemaking, whether it is at the individual, team, or organizational level. However, the degree to which *constructed* reality corresponds to the *physical* reality of the battlespace varies generally as a function of the level of abstraction being dealt with. At the level of physical objects—say, Rasmussen's lowest level of abstraction—constructed reality is likely to show a high degree of correspondence to physical reality. For example, a pilot encountering a surface-to-air missile must deal with this physical reality or risk being destroyed by that missile. Sensemaking at this lowest level of abstraction is also likely to be highly structured by the laws of physics and rote procedures. Hence, sensemaking at the lowest levels of abstraction can often be characterized as a simple process of mental interpretation, rather than mental construction. At a moderate level of functional abstraction—say, Rasmussen's general function level—constructed reality might bear only some resemblance to physical reality. Certain elements of thinking will be grounded in the physical objects and events of the battlespace. However, each individual will adopt some type of abstraction that helps him envision critical linkages between states, actions, and goals that are unique to his decisionmaking responsibilities. For example, in the case of time-sensitive targeting operations, military planners might agree on a specific sensor-shooter kill chain for engaging such targets, but hold different interpretations as to what qualifies as a time-sensitive target.[5] At the highest levels of abstract reasoning and decisionmaking, constructed reality is likely to be uniquely defined by the individual perspectives of functional experts and

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[5] In a draft (in publication) report on time-sensitive targeting operations in Operation Enduring Freedom, it was reported that in-theater planners focused more on targets that posed an immediate tactical threat to friendly troops, whereas planners at higher echelons of national command authority focused more on targets that reflected an immediate political value.

stakeholders. As noted by Donald Schön, this ability to abstractly conceptualize a problem space is a characteristic of sensemaking at the professional—versus rote task—level of decisionmaking. (Schön, 1983) For example, a maneuver brigade commander, a corps civil affairs officer, a HUMINT intelligence analysts, and a humanitarian relief worker might each look at a given village or other area of the battlespace from different functional perspectives—each highlighting different mission goals, constraints, means-ends models, and so forth that are unique to their experience and role responsibilities.

The fact that human decisionmakers routinely develop and operate out of a constructed reality rather than physical—or "ground truth''—reality provides great explanatory power for understanding why/how some military C2 systems produce "good" operational decisions while others produce "bad" operational decisions. A decision might flow in a very logical fashion from a constructed understanding of a given situation; however, if that constructed understanding does not capture the essential features of the situation, then it is likely that the decision will be flawed in some qualitative manner. Interestingly, in many cases, the decisionmaking team or organization has access to all or most of the relevant information needed to make a sound decision—yet, because the information was misinterpreted or disorganized by an inappropriate problem framework, the decision process failed to produce intelligent action. One only needs to look at incidents like the Columbia Shuttle disaster, the shoot down of the Iranian Airbus by the USS Vincennes, or the Air Force's shoot down of two Army Blackhawk helicopters over Northern Iraq to illustrate this phenomenon. In each case, logical decisions were deduced from a particular understanding of the situation: the problem was that the understanding was flawed, not the logical deduction process.

Basic Knowledge Structures Employed in Sensemaking

The fact that decisions can be "good" or "bad" rather than merely "timely" or "untimely" represents a radical departure from past C2 modeling efforts that have assumed that each C2 system node operates according to a fixed (and correct) set of decision rules. Rule-based modeling approaches generally work well for representing decision behavior at a low level of abstraction where the problem space is well-grounded in the physical reality of the battlespace—e.g., simple target engagement decisions, tactical maneuver decisions. It is not surprising that many modelers have elected to interpret Boyd's OODA loop in this fashion since Boyd's

original thinking was based on his experience with air-to-air combat. However, the applicability of rote, rule-based decision models for representing higher level operational decisionmaking is problematic—simply because real-world decision behavior at this level is more highly abstracted and influenced by the ways in which individual experts frame the problem space.

In order to represent higher levels of abstract thinking in the modeling of decision behavior, it is important to consider what types of experience are brought to bear by military C2 teams and organizations. In this regard, Karl Weick provides a useful discussion of what he calls "minimal sensible structures" for sensemaking. (Weick, 1995) Several of these sensible structures are summarized in Figure 2-3 and illustrated in terms of military C2.

As seen in Figure 2-3, Weick defines ideology as those sets of beliefs and values commonly shared at the level of a society that serve to shape and bound decision behavior. While these beliefs and values can be codified or written down, they are more frequently held as tacit knowledge acquired over time. In terms of military operations, ideology is best reflected in service and joint military doctrine—e.g., "parallel warfare," "effects-based operations," network-centric warfare. As opposed to other, more specific forms of experiential or socially-constructed knowledge, ideology is usually stated in broad conceptual terms that apply across many different situations. At the same time, ideology often reflects beliefs that have strong emotional attachments and are defended by intuition rather than rigorous logic or empirical evidence. Finally, ideology is frequently expressed in abstract—rather than concrete or physical—terms; hence, it is not uncommon for two individuals to interpret or apply ideology to specific instances in different ways. Nevertheless, ideology can serve to keep the sensemaking process of a team or organization bounded or constrained in specific ways.

Third-order controls derive their name from the work of Charles Perrow whose critical analysis of organizations identified three forms of control: (1) first-order controls operate by direct supervision, (2) second-order controls operate by programs and routines, and (3) third-order controls operate by means of assumptions and definitions that are taken for granted within an organization. (Perrow, 1986) Weick defines third-order controls as "premise controls" because they reflect the premises that influence how team or organizational members diagnose situations and make decisions. Significantly, unspoken premises tend to exert more influence in

professional teams and organizations that deal with higher levels of abstraction, nonroutine operations, and situations where decisionmaking depends more on expert judgment and problem framing rather than rote computation. Premises are the stuff of professional development within an organization and are reflected as general principles of expertise rather than as a specific set of rules for one to follow in specific situations. In terms of military operations, this form of tacit knowledge is acquired through years of military training and the individual's development of expertise in operational art. However, one aspect of premise control is seen to operate more explicitly in the form of command intent and mission type orders. As these concepts have developed over recent years, command intent and mission type orders reflect a set of guiding principles and operational criteria—rather than a specific set of commanded actions—that subordinates are expected to internalize and consistently apply in planning and executing operations over an evolving military situation.

Paradigms are self-contained systems of belief that are commonly held by members of a community of practice. Paradigms represent the functional perspective of each community of expertise and, hence, are unique to that community. Weick considers paradigms the "vocabulary of work" primarily because they represent the specialty language and mental constructs employed by a community of practice to structure their work environment. Quoting Richard Harvey Brown, "By paradigm, we refer to those sets of assumptions, usually implicit, about what sorts of things make up the world, how they act, how they hang together, and how they may be known." (Brown, 1978) In terms of military operations, paradigms represent the specialized knowledge and expertise acquired within specific service branches and military occupational specialties—e.g., intelligence, logistics, tactical air-to-ground combat, civil affairs, mechanized infantry, special operations, and so forth. When speaking of the need for collaboration among different functional experts within a military C2 organization, the focus of collaborative problem-solving and planning will often be on the synthesis or reconciliation of relevant paradigms brought forth by different communities of practice.

Theories of action, unlike the previous structures already discussed, are more dynamic in nature and are called forth from moment to moment to bring understanding to the current operational situation. Theories of action correspond to the situational "patterns" that are dynamically recognized by experts when they engage in naturalistic—or "recognition-primed"—

decisionmaking. (Klein, 1998) Theories of action reflect a coping mechanism employed by experts within teams and organizations to fit salient cues from the operational environment into a sensible framework. They are considered a coping mechanism precisely because they provide experts with a mental shortcut for simplifying complex situations, reducing the number of situation elements that must be attended to, filling in "missing" pieces of relevant evidence, and providing an immediate linkage between sensemaking and action-taking. Pattern recognition works in both a top-down and bottom-up manner, and reflects a continuous trial-and-error method of sensemaking. In a top-down fashion, experts will rely upon their repertoire of experience to suggest possible explanatory frameworks for a given situation. At the same time, incoming cues from the operational environment will either be matched against these candidate frameworks or serve to trigger other possible frameworks. As described by Gary Klein, this dynamic sensemaking process can be characterized as a "data-frame" matching process. (Klein et al, 2003) In terms of military operations, theories of action are reflected in the operational experience acquired by individual staff officers and decisionmakers. In essence, the depth and breadth of an individual's repertoire of available theories of action reflect a key dimension of that individual's level of expertise. (Dreyfus & Dreyfus, 2002)

Type of Experiential or Socially-Constructed Knowledge	Description	Illustrations from Military C2
IDEOLOGY: Vocabularies of Society	• Shared, relatively coherent and interrelated set of emotionally charged beliefs, values, and norms that bind people together and structure their sensemaking • Beliefs about cause-effect relations, preferences for certain outcomes, and expectations of appropriate behavior that make social situations predictable and meaningful	Service and Joint Military Doctrine
THIRD-ORDER CONTROLS: Vocabularies of Organizations	• The often unspoken premises that professionals uniquely use within a team or organization to help them diagnose situations and structure decisions • Tacit guidelines and principles employed to guide sensemaking at higher levels of abstraction, with nonroutine operations, and where decision making depends more on expert judgment and framing rather than computation	General Military Training, Command Intent, Operational Art
PARADIGMS: Vocabularies of Work	• Self-contained systems of beliefs that are commonly held within communities of practice to structure reality and guide problem-solving • Unique to individuals, paradigms reflect a person's perspective on the world –what things are important, how these things act and interact, and how they may be known	Expertise Acquired within Specific Military Occupation Specialties
THEORIES OF ACTION: Vocabularies of Coping	• Cue-based stimulus-response frameworks adopted by teams or organizations that are believed to abstract the essential features of the current situation (held until available and salient cues disrupt this belief, triggering a search for a new explanatory framework) • As long as a specific framework is held, it serves to automatically guide (1) what cues and other information are attended to and (2) how available information is organized and interpreted	Experience-Based Situation Recognition, Rehearsed Battle Drills or Staff Drills
STORIES: Vocabularies of Sequence and Experience	• Narrative—rather than argumentative—generalizations that are used to explain a sequence of unfolding events that begin with a specific problem, continue with certain actions and events, and lead to a specific type of resolution or outcome • While sequence is the important sensemaking feature of a story, it is often an abstracted reordering of events rather than a literal retelling of actual experience	Familiar Tactics Operational Strategy Derived from Military History
TRADITION: Vocabularies of Predecessors	• Images of action and beliefs recommending these actions be reenacted that are passed down from one generation of team or organizational members to the next • These images can embody recommended know-how, scripts, rules-of-thumb, and heuristics that reflect the practical experience of the predecessors and that are offered as a "better way" to accomplish the decision making responsibilities of the team or organization	Military Lessons Learned "Battle Books" Guidance Passed Down from One Staff Generation to the Next

Figure 2-3. Minimal Sensible Structures

In terms of modeling decision behavior, current research on naturalistic pattern matching suggests consideration of two important properties of theories of action. First, the adoption of a specific theory of action can have a powerful influence on situation monitoring and the search for additional cues. That is, individuals general exhibit a strong tendency to cling to a given theory of action until they are presented with significant evidence that is no longer reasonably explained by that theory. Hence, they will tend to search the environment only for cues and evidence that are consistent with the currently held theory of action. In terms of linking thought to action in military operations, theories of action are reflected in rehearsed battle drills and staff drills that automatically focus the attention and decision behavior of teams and organizations to the accomplishment of specific responses that are deemed appropriate for a "recognized" situation. The upside of this tendency is that it exploits the experience of experts to efficiently reduce the complexity of the situation to a workable level. The downside of this tendency is that it can mentally trap individuals, teams, and organizations into a particular problem mindset—

thus causing them to improperly weigh different types of evidence and, perhaps, creating blind spots to the emergence of novelty and important changes in the nature of the operational situation. Second, theories of action are typically "triggered" by the awareness of specific cues. Citing the earlier work of Paul Feltovich (Feltovich et al, 1984), Klein emphasizes the importance of "anchors"—usually two or three salient cues that are uniquely associated with a specific theory of action and that serve as powerful triggers for a specific framework. (Klein et al, 2003) Given this role of anchors, they are seen in the present study to represent a significant feature to be modeled. That is, the performance of a military C2 team or organization for correctly recognizing and framing a given operational situation can be seen to be strongly influenced by their ability to detect and recognize salient anchors from the environment.

Along with theories of action, stories reflect another form of experiential knowledge that is dynamically applied to develop an understanding of the current situation. Unlike frames or theories of action which are paradigmatic in nature, stories organize experience in narrative form. Research on sensemaking suggests that stories reflect a natural way of thinking about events and situations—of reshaping the unpredictable into the predictable, hence something that is manageable. (*cf.* Robinson, 1981; Orr, 1990) Storytelling in organizations is seen as a critical ingredient to transferring knowledge and expertise in the information age. (Denning, 2001) Stories also serve as an expedient method of communicating knowledge under time stress because they (1) chronologically link what is understood about the present situation to projected future events and states, (2) serve as mnemonics that enable others to quickly reconstruct earlier complex events and apply standard representations to the current situation, and (3) allow individuals to rapidly visualize a complete sequence of actions leading from the current situation to some desired future state. In terms of military operations, story elements are reflected in familiar tactics, courses of action, and operational strategies derived from either past military history or current operational experience. Hence, the employment of familiar tactics, courses of action, and operational strategy provide a team or organization with all of the mental efficiencies associated with storytelling. Conversely, it is not surprising that military staffs experience considerable difficulty in articulating or projecting the sequence and details of operations for which they have no previous narrative experience—e.g., effects-based operations. Only with the accumulation of experience and "tellable" stories in a given operational area comes expertise in visualizing and articulating similar operations for the future.

The last area of experiential or socially-constructed knowledge identified by Weick is referred to as tradition. Tradition embodies recommended action images, know-how, procedures, scripts, rules-of-thumb, and other heuristics that as passed down from one generation in a team or organization to the next. They are passed down for the purpose of informing new members about "better ways" of performing their decisionmaking tasks. Typically, tradition deals with aspects of roles and tasks that are not articulated in formal procedural manuals or other documents. Like theories of action, tradition can have an upside and a downside. The upside of passing along tradition is that (presumably) new members of a team or organization can benefit vicariously from the experience of predecessors—thus, making their learning curve more steep as they acclimate into their new role assignments. Within a military context, the effective passing along of tradition can be important when the personnel assignment system results in a rapid turnover of staff members. Methods of handing down such knowledge from one generation of staff officers to the next include (1) the formal documentation of "lessons learned" from after action reviews, (2) the development of unit "battle books" that provide a collection of local knowledge and procedures, and (3) the overlap of assignments that afford the opportunity for one-on-one mentoring. Without the passing of tradition, units and headquarters potentially face a period of degraded staff performance as new members require time and experience to move up their individual learning curves. On the other hand, the downside of passing along tradition is that team and organizational decision responsibilities, problem spaces, and mission requirements can change over time—perhaps to the point of making previous shortcuts and heuristics irrelevant or inappropriate.

Basic Cognitive and Social Process Elements of Sensemaking

In addition to introducing the notion of minimal sensible structures for sensemaking, Weick also summarizes four basic processes that comprise the act of sensemaking by a team or organization. In contrast to the simple "data-frame" matching process that Klein hypothesizes for individuals, Weick's four processes correspond more to the case where sensemaking is carried out by a team or organization of many individuals that each bring different perspectives and areas of expertise to bear. Since military C2 is rarely an individual activity, the present research focuses more on Weick's model. The four processes are summarized in Figure 2-4.

As seen in Figure 2-4, sensemaking involves both belief-based and action-based processes. Belief-based processes reflect the basic notion that sensemaking involves the creation and shaping of situation understanding in the minds of the decisionmakers and their supporting personnel. However, certain action-based processes are involved in this creation and shaping process. That is, rather than being a diffuse mental activity, sensemaking tends to involve both mental and social activity that is focused around the actions that people, teams, and organizations take within the real world.

Beginning with *positional arguing*, sensemaking within a team or organization typically involves various functional experts and/or stakeholders coming together within a community of interest to (1) develop a shared understanding of the problem space and (2) produce decisions that will lead to taking intelligent action within that problem space. These various experts and stakeholders each hold different abstracted perspectives or positions regarding the problem space, based on their individual experience and role responsibilities. Research on wicked—or undefined—problems suggests that a major activity of the team or organization will be for the parties to collaboratively engage in what Allison Kidd (Kidd, 1994) calls "knowledge work"—the presentation of different operational views with the purpose of achieving a shared awareness and appreciation of the specific goals, constraints, threats, and opportunities developed within each perspective. Achieving this common ground of understanding involves the exchange of both information and positions among the collaborating parties—a process referred to by Kjeld Schmidt as "debative cooperation." (Schmidt, 1991) Information is exchanged primarily to increase the situation awareness of others in a bottom-up fashion, whereas positions are exchanged primarily to expand or modify the hypotheses held by others in a top-down fashion.

Next, *plausible expectation* reflects an aspect of sensemaking wherein the key leaders of a team or organization express there vision of an unfolding operational situation in the concrete form of projected events or outcomes. The notion of plausible expectation embodies several key ideas. First, expectations—like arguments—involve both bottom-up thinking (they reflect references to concrete events or outcomes) and top-down thinking (they are shaped by the leader's abstracted vision of the operation). By articulating their abstracted vision of the operation in terms of

concrete events and outcomes, leaders are able to communicate their understanding of the situation to others in more meaningful and emotionally significant ways. In turn, such expressions are a powerful motivational mechanism for shaping and focusing the decisionmaking behaviors of others within the team or organization. In a military C2 context, this phenomenon can be easily observed in the shaping effect that a commander's feedback comments and questions can have on what the staff focuses its attention on during the next battle rhythm cycle. Second, the word "plausible" suggests that real-world decisionmaking always implies a degree of uncertainty about the current operational situation and the many possible directions it can take in the future. The plausible nature of sensemaking outlined by Weick also reflects the notion—discussed in more detail later in this chapter—that knowledge reflects "justified true belief" rather than an understanding that is based on perfect awareness or ground truth. (Nonaka & Takeuchi, 1995)

Moving to action-based elements of sensemaking, *behavioral commitment* reinforces plausible expectation as a mechanism that leaders use to further shape and focus the attention and thinking of their supporting team and organizational members. Individuals, teams, and organizations tend to build meaning and understanding around those actions to which they are committed to. Prior to commitment being expressed, all types of perceptions, experiences, and positions within the team or organization are only loosely coupled to an evolving situation. Once a leader expresses commitment to a course of action—usually in an explicit, public, and irrevocable manner—this action serves to transform these various unorganized perceptions, experiences, and positions into a more orderly and purposeful pattern. In a military C2 context, commitment is often formally expressed in terms of "commander's assessment," "commander's course of action approval," "command intent," or the publication of official operational plans and orders. In each case, the commander is saying, "This is what I want to achieve, this is what I expect to happen, this is what I have committed our organization to, and these are the aspects of the situation I want the staff's attention focused on."

Finally, *environmental manipulation* reflects the fact that sensemaking is about more than just passive perception of the world. Not only do people construct and hold abstract visions of their world, they will also take action to conform the world to these constructed visions—i.e., a self-fulfilling prophecy. Individuals, teams, and organizations construct or adopt abstract visions in

order to simplify and clarify what they consider important in an operation. If they can take preemptive actions to shape the world in conformity with those visions, such actions contribute to their process of understanding. Preemptive shaping actions also demonstrate the close linkage between belief and action: "If I can force the world to react or behave in a certain manner, this will confirm that I have correctly understood what is relevant and important to my existence." In a military C2 context, environmental manipulation also serves to reduce uncertainty and risk. For example, if a commander takes preemptive actions to foreclose certain options available to an adversary, then the commander no longer has to expend sensemaking resources to monitor and assess those areas of the battlespace. Similarly, if a commander directs certain overwhelming actions be taken against an adversary, then it is more likely that he can impose his vision on the battlespace and force the adversary to responds in predictable ways. In both cases, situation understanding is increased by causing the adversary to behave in more predictable ways.

Sensemaking Process	What This Process Entails	Why This Is an Essential Component of Sensemaking
POSITIONAL ARGUING Belief-based	• Various functional experts and/or stakeholders within the team or organization present their perspectives or positions in an attempt to shape the constructed problem framework • As part of this collaborative process, each individual attempts to change or expand the knowledge state of others until there exists a commonly shared understanding of how each of the relevant problem elements and potential solution paths fit together in a cohesive whole • Sometimes referred to as "debative cooperation"	• Whenever teams or organizations face wicked problems, the major challenge is constructing an appropriate problem framework within which to shape the resulting decisions • Wicked problems—including their relevant threats and opportunities—will often be viewed differently by each expert or stakeholder, dependent upon their roles and tacit knowledge • Joint problem-solving and planning requires experts and stakeholders to first achieve a common ground of understanding
PLAUSIBLE EXPECTATION Belief-based	• Key leaders express their expectation of certain outcomes, events, or future states in order to focus the attention and thinking of their supporting team or organizational members • Expectations link belief to action inasmuch as constructed futures implicitly require certain actions or accomplishments that must be planned and executed by the team or organization • Expectations reflect constructed futures that evolve over time to conform with unfolding events and states	• The efficiency of sensemaking within a team or organization depends upon its leaders focusing the attention and thinking of its members • Part of the responsibilities of a leader are to construct a vision for the team or organization out of many possible futures • Linking thought to action and accomplishment is a powerful motivational mechanism for shaping the decision behaviors of others
BEHAVIORAL COMMITMENT Action-based	• Key leaders demonstrate explicit, public, irrevocable commitment to specific plans and actions in order to further shape and focus the attention and thinking of their supporting team and organizational members • Commitment is expressed in the form of approved plans and orders issued to subordinate elements • Commitment serves to provide a team or organization with purpose, order, and value	• Individuals, teams, and organizations try hardest to build meaning and understanding around those actions to which they are committed to • Prior to leaders expressing commitment, all types of perceptions, experiences, and positions within the team or organization are loosely coupled to an evolving situation • Commitment transforms unorganized perceptions, experience, and positions into a more orderly and purposeful pattern
ENVIRONMENTAL MANIPULATION Action-based	• Teams and organizations selectively act within their operational environment to conform that environment to their constructed reality • Manipulation reflects the role of the team or organization in actively shaping the future • Manipulation can take the form of preemptive actions taken to shape the problem space, even before that problem space is completely understood	•Sensemaking is more than merely the passive interpretation of the operational environment as given: it involves the active construction of a workable reality within which a team or organization can operate •Sensemaking links beliefs and action together within an understandable framework; hence, the construction of reality can involve both hypothesis building and action taking

Figure 2-4. Sensemaking Process

The Basic Mechanisms of Sensemaking Failure

While Weick's earlier book on sensemaking provides an overview of how knowledge is possessed and communicated within a team (minimal sensible structures) and tells us something about the belief-driven and action-driven processes that facilitate sensemaking (positional arguing, behavioral commitment, etc.), it is his more recent book—coauthored with Kathleen Sutcliffe—that speaks more directly to the manner in which sensemaking can catastrophically collapse within a team or organization when faced with novel or emergent situations. (Weick & Sutcliffe, 2001) Thus, it is appropriate to conclude this review by briefly looking at ways in which military C2 systems can fail.

The paradigm introduced by Weick and Sutcliffe is that of a "high-reliability" teams and organizations—those that can maintain effective sensemaking (and, hence, decisionmaking) in the face of stressful and emergent situations, and those that face grave or costly consequences as the result of bad decisions. Examples of such teams and organizations studied in this research include aircraft carrier flight deck teams, hospital emergency rooms, and nuclear power plant control rooms. However, the principles derived from these studies apply to a variety of other organizations, including military C2 teams and organizations—hence, their relevance to the present modeling research.

The basic principle derived from high-reliability teams and organizations is their ability to maintain what Weick and Sutcliffe call "mindfulness"—the ability to monitor and know when/how the sensemaking process needs to be adjusted in some critical way. By organizing and operating in ways that promote mindfulness, teams and organizations are able to maintain the reliability of their sensemaking process. Mindfulness is broken down into the five elements shown in Figure 2-5.

Preoccupation with failure simply reflects the assumption that teams and organizations commit decisionmaking errors on a continuous basis. Rather than striving to eliminate error (unrealistic), high-reliability teams and organizations organize themselves to detect such errors and to use them as symptoms or clues that their sensemaking process is producing a faulty understanding of the operational situation. Such monitoring, however, requires that reporting systems be particularly adept at reporting such errors upward to key decisionmakers in a timely manner.

Reluctance to simplify interpretations addresses the basic mental tendency of people—particularly experts—to automatically abstract operational situations in familiar sorts of ways. While such abstraction can serve to simplify mental workload and focus attention on what is believed to be relevant and important in a situation, it can also blind individuals when their expertise no longer adequate to interpret emergent elements of the situation. Thus, high-reliability teams and organizations remain continuously open to multiple interpretations and perspectives. In particular, key decisionmakers remain vigilant and open to environmental cues and information that "doesn't fit" their current mental framework or estimate of the situation. At the same time, they engage in constant testing of such information to determine if it suggests a

different set of hypotheses—a notion similar to Feltovich's anchors introduced earlier in this chapter. (Feltovich et al, 1984)

Sensitivity to operations suggests that high-reliability teams and organizations recognize the need to decentralize decisionmaking in operations where front-line subordinates might have a more appropriate and timely understanding of the situation. At the same time, senior decisionmakers do not exclusively rely upon standard reporting systems to keep them appraised of operational developments. Recognizing that early warning signals often present at the tactical level of operations, they will often employ what Martin Van Creveld calls "directed telescopes" to probe critical areas of interest in a more proactive and focused manner. (Van Creveld, 1985) Thus, they maintain a balance between "information push" and information pull" to identify subtle shifts in the nature of the problem space and the need to focus attention in new areas.

PREOCCUPATION WITH FAILURE MODES	• High-reliability teams and organizations operate under the principle that small failures and errors occur all of the time. Rather than striving to eliminate error (unrealistic), they organize themselves to keep small errors from concatenating into catastrophic error chain. • In particular, they are sensitive to detecting small errors that provide a symptom or clue that something within their sensemaking process is causing them to misunderstand the operational situation. • This requires reporting systems to be particularly adept at reporting errors upward to key decision makers.
RELUCTANCE TO SIMPLIFY INTERPRETATIONS	• High-reliability teams and organizations understand that abstracted visions of an operation—while allowing simplification and focus—reflect only one possible view of reality. Rather than naively operating within a single vision, they remain open to multiple interpretations and perspectives. • In particular, they remain vigilant and open to information that "doesn't fit" their current estimate of the situation, constantly testing such information to determine if it suggests a different set of hypotheses.
SENSITIVITY TO OPERATIONS	• High-reliability teams and organizations understand that, in complex and emergent situations, front-line subordinates often have a more appropriate and timely understanding of the operational situation. • Rather than relying totally on standard reporting systems that might be constrained by existing mindsets, they expect that front-line subordinates will—if empowered and enabled—provide them early warning signals that their current vision and understanding is faulty in some significant way.
COMMITMENT TO RESILIENCE	• High-reliability teams and organizations understand that error management will often require a bending of rules or an adaptation of procedures as their knowledge and understanding of an operational situation changes. • Rather than being wedded to a single course, they constantly engage in mental simulation and take steps to keep open multiple course of action options that can be combined or adapted to meet the demands of an evolving situation.
DEFERENCE TO EXPERTISE	•High-reliability teams and organizations operate under the principle that problem spaces and decision spaces are best shaped by functional experts with the most current situation awareness, not necessarily by the highest ranking individual in the authority chain. •In particular, they constantly seek out and defer to the best available expertise and best available awareness, regardless of where it resides within the team or organizational structure.

Figure 2-5. Mindfulness—The Elements of Reliable Sensemaking

Commitment to resilience implies that high-reliability teams and organizations are not rigidly bound by business rules and procedures when critical changes in the operation situation demand adaptation. This aspect of mindfulness, like the others identified by Weick, implies that effective teams and organizations cannot be modeled as fixed, industrial-age decision processes. At the same time, these teams and organizations are constantly mindful of the potential need to shift to alternative courses of action whenever environmental cues suggest that the current course of action is no longer effective. As a result, they are constantly engaging in mental simulation to explore potential branches, sequels, and alternatives to the current plan.

Finally, high-reliability teams and organizations reflect a willingness to *defer to expertise*. That is, they recognize that effective sensemaking and effective decisionmaking depends as much on involving the right expertise as it does on the timely flow of information. Involving the right functional experts and stakeholders in the shaping of the problem space increases the likelihood that the team or organization will correctly identify the relevant threats and opportunities in a complex, emergent situation. Implicit in this concept is the willingness and ability of the team or organization to reach out and engage such expertise no matter where it resides within the formal hierarchy or structure of the command and control system.

KNOWLEDGE MANAGEMENT—THE FLOW OF KNOWLEDGE WITHIN A TEAM OR ORGANIZATION

Complementing the sensemaking view are two areas of research on knowledge management that have been frequently cited in the social science literature. The first area of research, illustrated by the writings of Thomas Davenport and Laurence Prusak, reflects a western epistemological tradition—one that views teams and organizations in mechanistic ways and sees them as a mechanism for sharing information and knowledge. (Davenport & Prusak, 1998) By contrast, the second area of research, illustrated by the writings of Ikujiro Nonaka and Hirotaka Takeuchi, reflects an eastern epistemological tradition—one that views teams and organizations in organic ways and emphasizes the subtle processes by which teams and organizations create knowledge. (Nonaka & Takeuchi, 1995) Taken together, these two views add to our understanding of what is important to capture or reflect in future models of command and control.

The Marketplace of Information and Knowledge

The basic paradigm employed by Davenport and Prusak is that a team or organization operates as a marketplace of information and knowledge. For the team or organization to make appropriate and timely decisions, the marketplace must support the appropriate and timely sharing and distribution of knowledge. As shown in Figure 2-6, a marketplace consists of four types of knowledge actors: Managers, sellers, buyers, and brokers. *Managers* decide on the goals to be pursued by the organization, identify the issues to be addressed and resolved in order to attain those goals, and evaluate the relevance and utility of knowledge generated within the marketplace. *Knowledge sellers* represent the functional experts within (or available to) a team or organization. They each possess some type and degree of tacit experience or expertise that is deemed valuable for interpreting and understanding specific aspects of the operational situation. Unless this tacit knowledge is identified and appropriately utilized within the planning and decisionmaking process, its value remains only potential and not actualized. *Knowledge buyers* are defined by Davenport and Prusak as those individuals responsible for problem-solving. However, the term "problem-solving" is interpreted here in a broad sense to imply (1) the existence of wicked or undefined operational problems, (2) the synthesis and reconciliation of multiple perspectives in order to appropriately construct a problem space, and (3) the need for teams and organizations to develop a common ground of understanding upon which to develop cohesive plans and synchronized action. As they engage in problem-solving, knowledge buyers are the key to linking tacit experience and expertise to action. *Knowledge brokers* are those actors within a team or organization that either (1) control access to specific experts and information) or (2) act as boundary spanners between different communities of practices in order to facilitate the integration of different areas of expertise.

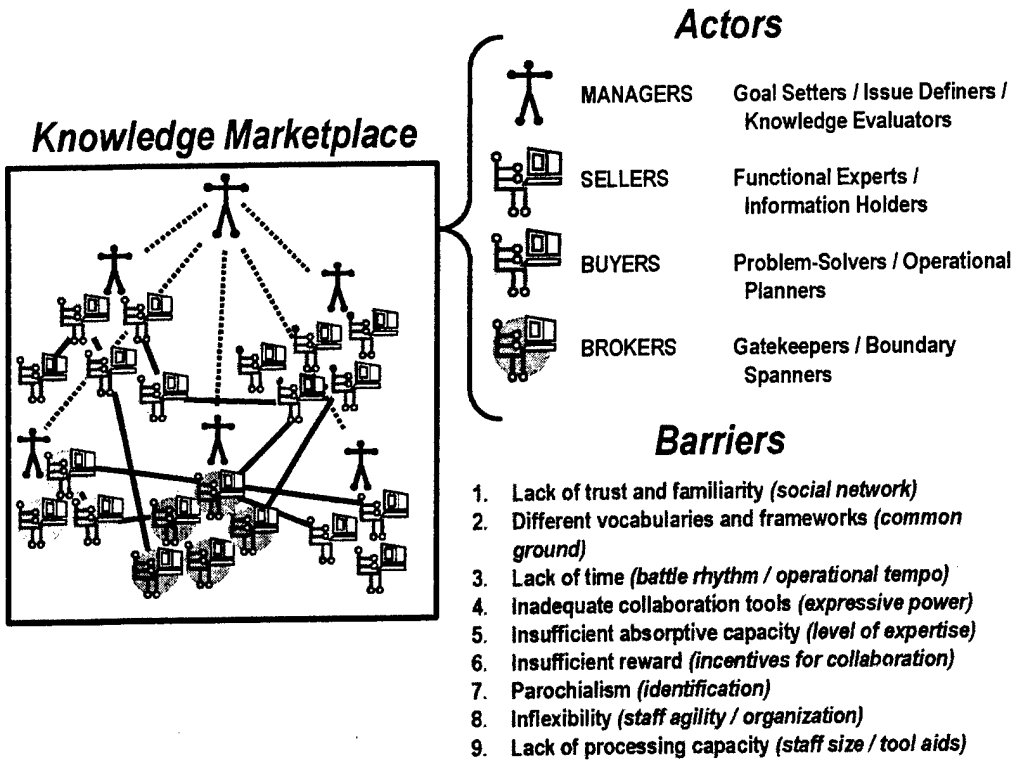

Figure 2-6. Knowledge Marketplace Paradigm

For any marketplace to operate, it must have in place certain mechanisms that either initiate or facilitate the transfer or exchange of commodities (in this case, knowledge). Exchanges are initiated as a result of actions taken by the leaders of a team or organization. Specifically, leaders (1) develop the overall mission goals that focus and guide the knowledge exchanges, (2) identify what areas (and forms) of knowledge are relevant to achieving these goals, and (3) assess the relative and dynamic utility of specific knowledge products. Such roles reflect to some degree Weick's notion of plausible expectations and behavioral commitment—actions taken by key leaders within a team or organization to focus and guide the mental and social taskwork of the supporting staff. Davenport and Prusak's paradigm also speaks about the need for a pricing mechanism to exist within the marketplace. A pricing mechanism provides the reward structure often needed in a commercial enterprise setting to encourage individuals to share their expertise with others. For military C2 systems, this would seem to be less of a critical variable since the military has a built-in expectation that everyone will contribute as required. However, for coalition C2 operations in which is important to share knowledge and information among coalition partners, international government agencies, private/voluntary organizations, and

others, modeling efforts might need to consider whether or not adequate reward mechanisms existed.

For knowledge marketplaces to continue in operation there must be spontaneous, unstructured transfer of knowledge among the various parts of the team or organization. Davenport and Prusak argue that this is most effectively carried out through personal conversations and face-to-face meetings—a practice that is increasingly being threatened by electronic networking and virtual meetings. In addition, they identify several obstacles or "frictions" within a team or organization that can inhibit the transfer of knowledge:

- *Lack of trust* (immature relationships or inadequate face-to-face contact);
- Different cultures, vocabularies, and frames of reference (lack of common ground);
- *Lack of time and meeting places* (inadequate opportunity for collaboration);
- Status and rewards go only to knowledge owners (lack of incentive for sharing);
- *Lack of absorptive capacity in recipients* (inadequate training, narrow-mindedness);
- Belief that knowledge is prerogative of specific groups (parochialism, not-invented-here); and
- *Intolerance for mistakes or need for help* (failure to recognize that errors and learning are a normal part of the organizational process).

Although not addressed by Davenport and Prusak, the advent of networked teams and organizations present an additional set of obstacles or "frictions" that must be considered for virtual collaboration. These would include

- *Inadequate expressive power provided by collaboration tools* (constrained message formats or lack of expressive tools) and
- *Inadequate or unreliable connectivity* (inadequate bandwidth or access to intranet).

For the analyst, the marketplace paradigm of Davenport and Prusak suggest several relevant measures of performance. In a broad sense, the effectiveness of a team or organization as a knowledge marketplace is reflected in the degree to which available tacit experience and expertise is linked to action—that is, the degree to which knowledge buyers and sellers are brought together in ways that are (1) appropriate for the evolving problem space and (2) timely

for enabling effective decisionmaking and action taking. In a narrower sense, the effectiveness of a team or organization is reflected in the degree to which it minimizes or eliminates each of the specific obstacles or "frictions" identified by Davenport and Prusak.

Organizations as Amplifiers of Individual Knowledge

In contrast to the marketplace paradigm of Davenport and Prusak, Ikujiro Nonaka and Hirotaka Takeuchi view organizations as amplifiers of individual knowledge. (Nonaka & Takeuchi, 1995) Rather than focusing on knowledge transfer, they emphasize the process by which teams and organizations continuously create new knowledge—a process referred to as "*chishiki keiei*". That is, organizations serve to amplify the knowledge created by individuals and crystallize it as part of the knowledge network of the organization. Two types of activity drive this process of amplification: (1) the conversion of tacit knowledge into explicit knowledge and (2) the movement of knowledge from the individual level to the team, organizational, and inter-organizational levels.

As shown in Figure 2-7, the knowledge amplifier paradigm is expressed through a specific set of structures and a specific set of activities. Structurally, Nonaka and Takeuchi define organizations in terms of three levels: *knowledge base*, *business system*, and *project team*. The *knowledge base* of an organization consists of both tacit and explicit knowledge. Tacit knowledge is represented in the form of the expertise, culture, and heuristic procedures possessed by the organization. Explicit knowledge is represented in the form of documents, filing systems, and databases. Within a military headquarters context, explicit knowledge includes the Common Operating Picture as well as plans, briefings, and other information available from the organization's intranet. This layer serves as a knowledge archive or corporate university for the organization. (Nonaka, Toyoma, & Byosiere, 2001) The *business system* represents the rules, hierarchies, and structured activities by which the organization carries on its normal, routine operations. The analogy of this in a military setting would be the formal reporting channels, daily battle rhythm of scheduled meetings and briefings, formal approval authorities, and the planning and briefing document templates employed within a headquarters. The topmost layer consists of ad hoc *project teams*—multiple, loosely interlinked, situationally-driven, and self-organizing patterns of collaboration within the organization that form in response to emergent issues and specific

operational planning problems. Project teams are led by middle managers within the organization who serve to translate command visions into concrete operations.

As defined by Nonaka and Takeuchi, all three levels are essential for effective knowledge creation within an organization. The knowledge base—consisting of both tacit and explicit expertise—provides the basic building blocks of individual knowledge and shared situation awareness. The business system in the middle provides the predictable and cyclical framework for focusing the sensemaking activities of the ad hoc project teams toward useful and purposeful goals, and for synchronizing their knowledge products into cohesive decisions and actions. At the topmost level, the ad hoc project teams provide the emergent and adaptive collaboration mechanism by which individual areas of knowledge or expertise are combined and synthesized to create actionable knowledge and shape the organization's decision space. The paradigm outlined by Nonaka and Takeuchi illustrates a basic tension between (1) the traditional—predictable and cyclical—military decisionmaking process defined during the industrial age and (2) a more dynamic, agile, and self-organizing decisionmaking process argued by various futurists. The spontaneous formation of ad hoc project teams provides a headquarters with the agility needed to cope with the complexities and dynamics of future military operations. On the other hand, without some type of business system—i.e., battle rhythm—in place, there exists nothing to insure proper focus and synchronization of these ad hoc knowledge creation activities into cohesive and purposeful action. Thus, a military C2 team or organization must reflect a proper balance between the predictable/cyclical and the emergent/nonlinear.

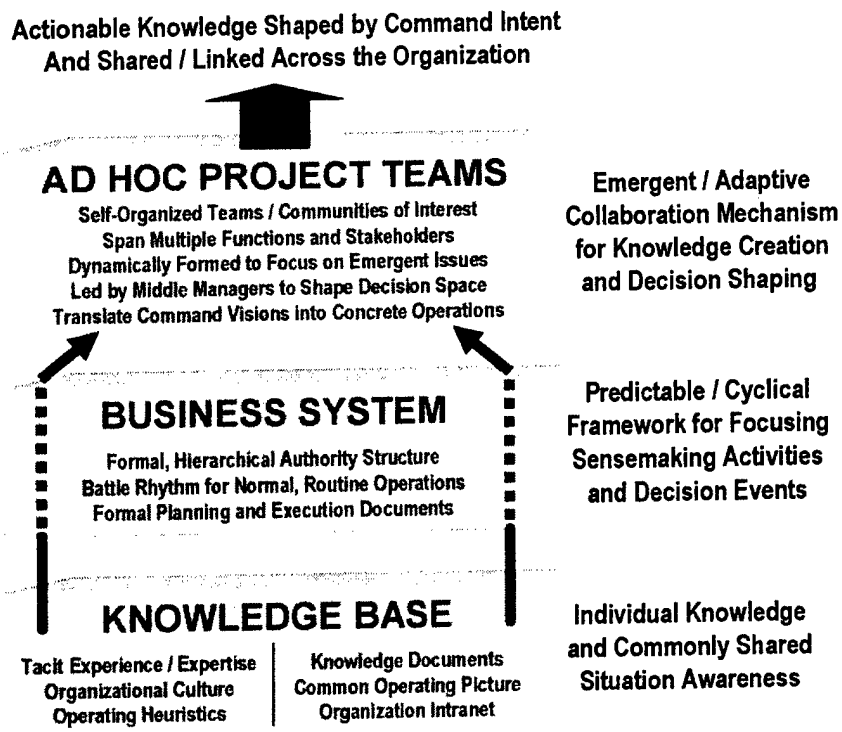

Figure 2-7. Knowledge Amplifier Paradigm

ACTORS AND ROLES AT EACH LEVEL WITHIN A C2 ORGANIZATION

Past studies of military headquarters operations and organizations suggest that participants at different levels within the command and staff hierarchy play different roles in the sensemaking process. (Leedom, 2001) Hence, at each level, participants value and use data, information, and knowledge in different ways. While exceptions to this general hierarchy can be found in many organizations, the sharing, reconciling and use of information and knowledge increases in complexity as one moves upward in the organization from rote task performers, to problem-solvers and coordinators, to visionaries and decisionmakers. As illustrated in Figure 2-8, these various roles differ in their specific contributions to the sensemaking process and in their specific use of information and knowledge. At the top of the organization, the commander—e.g., key decisionmaker—provides the overall vision and sets the decisionmaking framework for the remainder of the staff. Such guidance and commitment of direction is necessary to (1) deal with the "wicked problem" nature of the operational environment and (2) to focus the organization's sensemaking resources on the mission goals assigned by higher headquarters. The middle level of the organization is characterized by problem solvers and coordinators—the principal staff advisors to the commander that represent the leaders of the different functional staff sections.

Their role is to assist the commander in shaping the decision framework of the organization as they highlight emerging threats and opportunities from their different operational perspectives. At the same time, they serve to translate the commander's intent and vision into workable plans and operations consistent with the capabilities and resources limitations of the military units supporting the operation. At the bottom level of the organization are the supporting staff sections that carry out the information management, analysis, and detailed planning activities within each functional section of the headquarters staff. Whereas the top and middle level roles correspond to knowledge workers, the bottom level of the staff correspond to procedural workers—i.e., they utilize information in their performance of specific analytic and planning tasks, but their perspectives and task performance are not changed by the information.

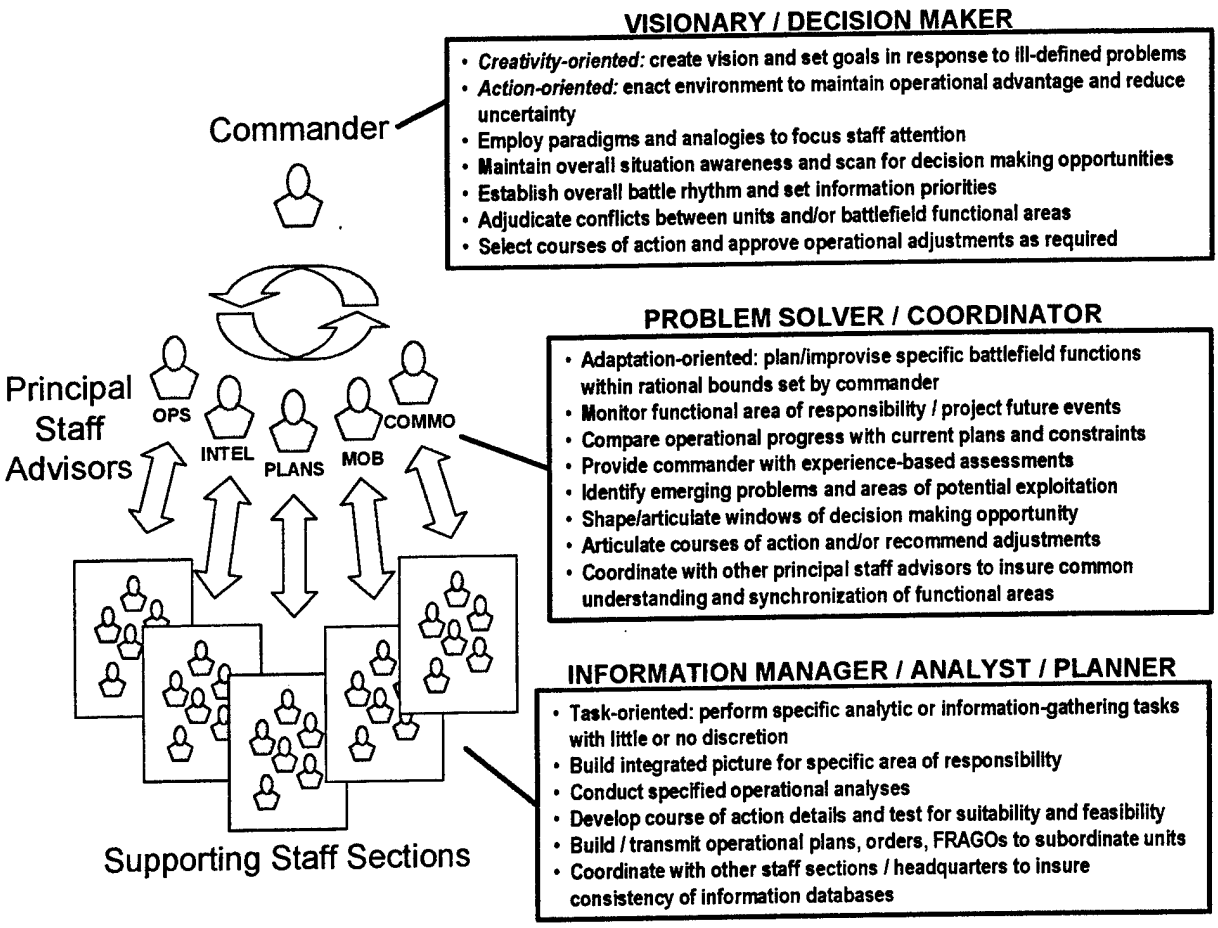

Figure 2-8. Levels of Role Responsibility Within a Military C2 Organization

To better understand the important aspects of these different levels, it is useful to examine several areas of research that potentially provide guidance for how these actors and roles should be represented in future modeling efforts.

Top Level—Visionary and Decisionmaker

In a classic study of the work activities of general managers, John Kotter identified several unifying threads to explain what otherwise appeared to others as their seemingly hit-or-miss, random set of interactions with other members of the organization. (Kotter, 1999) As a context for their work activities, Kotter found that most leaders and managers at the top of an organization face two general challenges:

- Figuring out what to do despite uncertainty and an enormous amount of potentially relevant information, and
- Getting things done through a large and diverse group of people despite having little direct control over most of them.

In response, these leaders and managers generally engage in two primary work tasks: agenda setting and network building. In the first area, effective leaders and top managers develop agendas that are made up of loosely connected goals and plans that address a range of immediate, intermediate, and long-term mission objectives. While most organizations have formal planning processes that produce written plans, leaders and managers maintain agendas that differ from formal plans in several ways. Whereas formal plans are more detailed and focus on resource allocations and specific actions, agendas generally express intent and expectations of outcome. Second, formal plans tend to be explicit, rigorous, and logically linked whereas agendas tend to reflect only a loosely connected set of issues that must be resolved in order to achieve the leader or manager's vision. Finally, formal plans are normally produced by a linear, sequential planning process whereas agendas often emerge over time through a dynamic, interactive process within the organization. This is not unlike the "running estimate" described by Major General Russell Honoré in a previous chapter. (Honoré, 2002)

Linear, sequential planning processes nominally rely on an "information push" strategy wherein various elements of the staff develop and integrate different parts of the operational plan. By contrast, leaders and top managers generally employ an "information pull" strategy by posing

issues for the staff to address, and by reaching down into the organization for answers to specific questions. In a military context, Martin Van Creveld describes such a process of cutting through normal reporting channels as the commander's "directed telescopes." (Van Creveld, 1985)

Agenda setting also impacts the manner of decisionmaking exhibited by a leader or top manager. A common perception within the military modeling community is that decisionmaking always revolves around specific combat events—e.g., selection of a course of action for the next engagement, selection of a list of time-sensitive targets to be attacked during the next air operations cycle. By contrast, Kotter found that the agenda setting decisions of leaders and top managers are often not observable. Since they often desire to accomplish multiple—and often competing—goals and objectives, leaders and top managers constantly look for ways to compromise, satisfice, and combine. They do this by encouraging their staffs to pursue options and activities that appear to accomplish multiple goals, are consistent with all other goals and plans, and are within their power to execute. Options and activities that do not meet these criteria tend to be either discarded or resisted.

Network building constitutes the other major work activity of leaders and top managers. That is, they seek out individuals both vertically and horizontally that appear to be able to contribute to implementing and achieving their agenda. Just as agendas are different from formal plans, so too are networks different from—but consistent with—the formal organizational structure. Although Kotter does not use the term "social network," it is clear from his writing that this is what is meant—an effective, informal network of experts and problem solvers who can collaborate to address and resolve specific issues identified by the leader or top manager.

Building networks in order to accomplish agendas involves a specific set of interventions on the part of the leader or top manager. First, effective leaders more often influence team and staff members by asking questions or posing issues rather than by giving direct commands. They understand that questions and issues provided to an appropriately formed social network will generally motivate and focus the sensemaking and knowledge creation activities of the participants. Second, they encourage and guide specific patterns of collaboration within the team or organization. That is, they understand which types of functional experts and stakeholders need to be brought together to address specific types of issues. Finally, they engage proactively with

these networks by suggesting specific positions or hypotheses that can be tested by the participants. Taken together, these questions, issues, positions, and hypotheses shape the work threads for problem solvers and coordinators at the middle level.

Middle Level—Problem Solver and Coordinator

An operative term for middle level actors is that of improvisation. As defined by Karl Weick, improvisation can be defined as "adaptive organizing." (Weick, 2001) The concept of adaptive organizing brings together several ideas:

- If organizations—like military C2 headquarters—gains competitive advantage through speed of decisionmaking, then an essential competence is the ability to do more things spontaneously without lengthy prior planning.
- Thinking spontaneously requires specific training and skills. Specifically, improvisation requires the mental competence and experience needed to bend and reshape mental models, adapt procedures and resources, and to look for unorthodox ways of solving problems within existing means.
- It is unlikely that junior personnel possess the level of expertise required to move beyond rule-based techniques and thinking. Hence, improvisation tends to be practiced only by middle and higher level actors within a team or organization.

In this regard, Weick brings together a number of actor characteristics required for effective improvisation. These characteristics, paraphrased below, include

- Willingness to forego planning and rehearsing in favor of acting in real time;
- Well-developed understanding of internal resources and materials at hand;
- Proficient in sensemaking and decisionmaking without blueprints and diagnosis;
- Able to identify and agree on minimal mental structures for embellishment;
- Open to reassembly of and departures from routine task structures;
- Ability to shape actions and work threads according to a rich and meaningful set of themes or hypotheses;
- Predisposed to recognize partial relevance of prior experience to present novelty;
- Skill and confidence to deal with nonroutine events;

- Availability and linkage to other team or organizational members who are similarly committed to and competent at improvisation;
- Skill at identifying and employing potential contributions of others by maintaining continuous interaction (foundation for knowledge creation);
- Able to maintain an operational tempo that enables everyone to contribute;
- Focused on real-time coordination without being distracted by past memories or future anticipation; and
- Preference for process over structure that enables the creation of actionable knowledge.

Another perspective on middle level managers is given by research on knowledge workers published by Allison Kidd. (Kidd, 1994) In this work, Alison Kidd makes an important distinction between knowledge work and procedural work—although she acknowledges that all work is generally a mixture of both. Procedural workers—e.g., an equipment operator, secretary, or assembly line worker—will use information to carry out specific assigned work tasks. Quite often, procedural workers employ very detailed and fixed taxonomic structures for filing and organizing information—structures that are determined by the nature of their task assignments and work procedures. However, their view of their problem space remains unaffected by new information that they acquire in the course of their task work. By contrast, knowledge workers—e.g., a design engineer, military analyst, or operational planner—will use information in an entirely different manner. With these actors, information is consumed in order to increase or refine one's knowledge state about the task or problem space. Hence, information, once mentally digested, is often of little further value to the individual. Information which might have future value is usually left uncategorized in untidy piles—e.g., informal notes, whiteboards, e-mails—rather than being carefully integrated into a fixed taxonomic structure. Important, however, is the notion that the knowledge states of these workers are in a constant state of flux as new information is acquired and absorbed.

Two additional distinctions can be made between procedural workers and knowledge workers. With regard to behavioral patterns, procedural workers generally engage in a fixed thread of work activities—more specifically, fixed patterns of information acquisition, information processing, and information management. By contrast, knowledge workers will seek out, utilize, and pass on information in very opportunistic ways, dependent upon their evolving

understanding of the problem space and their role within the team or organization. The resulting patterns of work activity will often reflect little consistency from one moment to the next as they adjust and adopt their task work to accommodate new issues and hypotheses, new priorities, and new relevant problem variables. In a related area of comparison, procedural workers generally engage in a fixed set of social interactions and communication networks. Since their task work remains invariant, they are likely to establish and maintain specific channels of communication for acquiring needed information and passing their task products to others. By contrast, knowledge workers will exhibit highly variable patterns of communication with others, and even reply upon different means of communication—e.g., e-mail, face-to-face, chat rooms, briefings—that vary according to the perceived needs of each situation. As a result, formal job titles and organizational charts will provide less understanding of individual roles than, say, what people actually do or who they communicate with from moment to moment.

The notion of information exchanges constantly changing the knowledge state of knowledge workers introduces another facet of this process: the class of problems being addressed by the team or organization. Here, our discussion again considers the classic work of Horst Rittel who first introduced the notion of wicked problems. (Rittel, 1973) Wicked problems are distinguished from other (simple) problems inasmuch as they are not commonly understood and, hence, they cannot be analyzed in a traditional linear manner using accepted methods. Wicked problems arise in the social context of multiple experts and stakeholders where participants must simultaneously (a) negotiate and agree on an acceptable definition of the problem space—e.g., goals, constraints, relevant variables—and (b) collectively agree on a solution path—e.g., means-ends hypotheses, milestones, success criteria. For C2 teams and organizations, wicked problems tend to dominate at the operational and strategic levels of decisionmaking—particularly where joint, coalition, or multi-agency interests and operations must be reconciled and synchronized.

In contrast to simple problems that primarily correspond to procedural work, wicked problems display a number of characteristics that uniquely associate them with knowledge work:

- *Problem Understanding Evolves with Solution.* The problem space consists of an evolving set of interlocking issues and constraints. Each attempt at formulating a solution potentially shifts goal priorities and the relevance of specific constraints, variables, and means-ends models. Hence, the problem space is never collectively understood by the team or organization until specific solutions have been developed and assessed against an evolving definition of the requirement.
- *Solutions Evolve in a Satisficing Manner.* Since there exists no definitive problem space, there cannot be a definitive solution. The problem solving process terminates when the team or organization runs out of available resources. Resulting solutions tend to be "good enough" or "satisficing" in nature, rather than being optimal. Goals and constraints might not be fully satisfied as the team or organization attempts to accommodate multiple perspectives on the operational situation.
- *Solutions Tend to be Unique, Rather than Selected from Available Alternatives.* Each developed solution path has expenses and potential consequences for the future. In some cases, these consequences will spawn new wicked problems. Solutions evolve through discovery, rather than being pulled off the shelf. There might exist multiple possible solutions, no possible solution, or a set of solutions that are never thought of.

Taken together, the concepts of knowledge work and wicked problems imply that knowledge creation often involves negotiation and argumentation. That is, much of the information exchanged among collaborating experts and stakeholders serves to support specific arguments or positions regarding the relevance or priority of different goals, constraints, variables, and means-ends models. The goal of each participant is to influence or redefine the knowledge state of other participants so that the team or organization can come to collective agreement on both the problem space and the proposed solution path. Of course, in the case of military C2 teams and organizations, there will often be an individual—e.g., commander or senior military officer—who exerts formal authority over this process. However, there are likely to be more cases where the senior authority relies upon trusted middle level actors to tackle such problems in response to broad guidance or issues articulated by that authority. Hence, the concept of knowledge work has a particular association with middle level actors within a C2 team or organization.

Bottom Level—Information Manager, Analyst, and Planner

The bottom level of actors within a C2 team or organization constitutes its basic capacity for information management, analysis, and planning—task work guided by the middle level actors. The ultimate effectiveness and efficiency of task work at this level therefore depends on the level of expertise possessed by actors at the bottom level of the staff. Therefore, it is useful from a modeling perspective to examine alternative theories regarding the definition of expertise. One theory argued by Hubert and Stuart Dreyfus defines expertise in terms of a movement beyond rule-based thinking to case-based thinking. (Dreyfus & Dreyfus, 2002) Here, these researchers define five levels of expertise:

- *Novice*—The person approaches tasks by following rules in an unquestioning, context-free fashion. Action is simply guided by rote application of rules, rather than by an awareness of what needs to be accomplished.
- *Advanced Beginner*—While still acting in a rule-based fashion, the person can modify some of the rules according to context. The person has started to recognize certain situation types and is able to modify the rules according to those types.
- *Competence*—The person still following rules, but does so in a fairly fluid fashion—at least when things proceed normally. Instead of stepping from one rule to another, the person has a more holistic understanding of all the rules. The person has an overall sense of the activity and chooses freely among the rules for the appropriate one.
- *Proficiency*—For much of the time, the person does not select and follow rules. Rather, the person's experience allows them to recognize situations as being very similar to ones already encountered many times before, and to react accordingly, by what has, in effect, become a trained reflex. Appropriate plans spring to mind and certain aspects of the operational situation stand out as important.
- *Expert*—The ability to make subtle discriminations and to link situation understanding with action is what distinguishes the expert from the proficient performer. The proficient performer sees what needs to be done, but must consciously decide how to do it. By contrast, the expert performer both sees what needs to be done and—possessing a vast repertoire of situational discriminations—sees how to do it. As a result, the expert performer is apt to arrive at decisions much more quickly than the proficient performer.

By distinguishing between rule-based thinking and case-based thinking, one is potentially able to better account for the effects of training instruction and experience. That is, a staff that is both well instructed (in terms of being given appropriate procedures and rules sets to apply) and given ample opportunity for gaining real-world experience (a variety of experiential cases to process) will possess a higher level of expertise. This higher level of expertise will manifest itself in terms of the competence to handle a wider variety of novel and complex problems.

A second body of work related to levels of expertise is based on the original work of Elliot Jaques (reported by VanDevender & Barker, 1999). Here, Jaques defines expertise in terms of cognitive capability and leadership. Jaques linked these two concepts by demonstrating that leadership is often implicitly accepted within an organization based on an individual's capacity to expand a problem solving task to the next higher level of processing along a series of discrete information processing levels. Thus, an individual who can think at a project level instead of a task level is considered to be more expert, an individual who can think at an enterprise level instead of a project level is considered to be more of an expert, and so on. Jaques' levels of expertise (revised and expanded by Phillips & Hunt, 1992) are paraphrased as follows:

- *Direct Judgment.* Ability to carry out clearly defined and detailed operating procedures to complete a task.
- *Diagnostic Accumulation.* Ability to assist a task leader by solving problems through diagnosis and troubleshooting.
- *Alternative Paths.* Ability to approach problems at a project level by constructing several alternative step-by-step procedures, selecting the optimal approach to accomplish the assigned task, and executing the optimal procedures through one or more assistants.
- *Parallel Processing.* Ability to adjust project work as a whole by orchestrating aspects of a theory or hypothesis to solve a problem, and by balancing units of workload among project components.
- *Unified Whole System.* Ability to define a project and interpret results in the context of an evolving system of technical/political/social constraints and opportunities, combined with the ability to leverage their expertise to attract collaborators.

- *Worldwide Diagnostic Accumulation*. Ability to synthesize information across organizational and national boundaries to stimulate informed consensus of what should be collectively accomplished.
- *Business Units in Society*. Ability to synthesize enterprises—for others to manage—by mergers or joint developments.
- *Business Synergy*. Ability to assess how systems influenced by the organization are evolving, combined with ability to create or alter component organization structures and processes to meet emerging challenges and opportunities.

In terms of Jaques' hierarchy of cognitive abilities, actors at the bottom level of a C2 team or organization would be expected to carry out work activities and work threads at the first four levels: *Direct Judgment* through *Parallel Processing*. As one moves to Jaques' level of *Unified Whole System*, we begin to see elements of the role played by middle level actors. As these middle level actors are empowered by advanced networking capabilities, it becomes possible for them to take on the broader cognitive perspectives associated with *Worldwide Diagnostic Accumulation* by collaborating with counterpart actors across organizational and national boundaries. Beyond this level, senior managers—e.g., commanders—would likely be responsible for the top two levels of responsibility in Jaques' hierarchy.

PUTTING THE PUZZLE TOGETHER: THE SENSEMAKING AND KNOWLEDGE MANAGEMENT PROCESS

Having reviewed several bodies of relevant literature, it is now possible to begin building a description of the key structures and processes that make up sensemaking and knowledge management within a military C2 team or organization. In turn, these structures and processes represent critical elements to be considered in the modeling of future headquarters and other C2 systems. The description begins with an emphasis on problem spaces and solution paths, the cognitive setting for sensemaking and knowledge management. The mental construction of an appropriate problem space through which to understand an operational situation is the essence of sensemaking. Constructing and negotiating problem spaces are central to sensemaking because they provide the frame of reference from which to develop solutions paths, take decisions, and initiate actions. Next, the discussion addresses the important actors to be represented in the sensemaking and knowledge management process. Here, the terms "knowledge manager" and

"sense maker" are compared to identify both their commonality and differences. The discussion continues with a summary description of the basic knowledge and information commodities that are produced, transferred, and used in this process. Finally, the discussion concludes with a summary review of the basic form and structure of the process. Here, the process of sensemaking and knowledge management that leads to decision outputs can be seen as a collection of emergent, non-linear creation processes embedded within an overarching linear framework. By describing sensemaking and knowledge management in terms of setting, actors, commodity flows, and process structure, a picture begins to emerge regarding the essential elements to be analytically represented in future C2 models.

Making Sense in a Complex World: The Construction of Problem Spaces and Solution Paths

From the viewpoint of modeling military command and control, the research literature on organization sensemaking and knowledge creation provides the analyst with a number of process insights. Perhaps the most basic insight is that decisionmakers generally operate within a constructed frame of reference or problem space, not the physical battlespace. These mental problem spaces will correspond in certain ways to the physical battlespace, with the degree of correspondence being highest at the tactical level of decisionmaking. However, at higher and more abstract levels of reasoning and decisionmaking, these constructed problem spaces are likely to differ in significant ways between individuals, depending upon their experience and functional responsibilities. At the team and organizational level, the process of sensemaking has both a cognitive and a social component. The cognitive component deals with matching available information from the battlespace or Global Information Grid (GIG) with specific explanatory frames that have been developed from one's experience or expertise. The social component deals with the process of accumulating and reconciling both information and explanatory frames produced by different perspectives into a single, cohesive, and shared understanding.

The implication of this basic insight for modelers is that sensemaking—not decisionmaking—is the critical element to represent in the modeling of a military C2 team or organization. In the past, military C2 systems have been often modeled as a set of decision rules, with the problem space externally defined or assumed by the analyst. While such an approach has generally sufficed at the tactical level (where decisions and actions are more tightly bounded by the

physical world), it has been more problematic at the operational level (where decisions and actions address more highly abstracted concepts such as effects-based operations, adversarial centers of gravity, stability and security operations, and so forth). By contrast, real-world military decisionmaking primarily deals with defining an appropriate problem space within which to conduct decisionmaking—not simply with making rote decisions according to some fixed set of rules. The act of decisionmaking—committing to a specific course of action—is subsumed in the larger process of sensemaking. That is, decisions are almost an automatic consequence of defining the problem space in a specific way and identifying a solution path within an agreed upon problem space. When viewed in this light, the quality of decisionmaking can be seen to depend equally upon both (1) the availability and flow of information from the battlespace (the "know what") and (2) the efficiency and effectiveness with which a C2 team or organization collaboratively frames the problem space (the "know how").

Sensemaking is what military C2 teams and organizations engage in when they (1) face ambiguous situations, (2) are presented with information overload, or (3) must resolve differences in perspectives between competing experts and stakeholders. If one wants to better understand the value of intelligence collection and sensor systems, the value of information networks, the value of collaboration systems, the value of leader and staff training, the value of effects-based thinking, or the value of a whole host of other C2 elements, then future C2 models must better illuminate how these various elements contribute to the underlying sensemaking process. Thus, the degree of fidelity required in a future C2 model depends in large part on the analytic purposes and goals motivating model development.

Finally, sensemaking always relates to action—but in ways that are more subtle and profound than have been considered in most past C2 modeling projects. Developing understanding or making sense in an operational setting is a cognitive and social activity that is certainly motivated and guided by the desire to accomplish specific mission goals and objectives. Hence, the problem space will be constructed in a way that best serves to highlight obstacles, constraints, threats, and opportunities deemed relevant to the accomplishment of those mission goals and objectives. However, sensemaking and action are liked in other important ways. A more traditional way of modeling military operations employs paradigms such as the simplified OODA loop discussed at the beginning of this chapter. Here, *observation* and *orientation* have

been viewed as a passive phases of the decision cycle, whereas *decision* and *action* are viewed as the more proactive phases. Such a dichotomy, however, is not reflective of real-world sensemaking and decisionmaking. In actual practice, a commander's vision of an operation represents a very proactive structuring of the world—a structuring that presumes (1) the need to accomplish certain goals and objectives by inflicting certain effects on an adversary, (2) the existence of an adversary that will behave or react in specific ways, and (3) a specific set of issues that must be resolved successfully in order to create each effect.

As part of this process, a commander will rely upon his C2 systems and organizations to initiate different actions. The most obvious type of actions will be those executed by supporting military units to achieve specific effects on the adversary. However, other types of actions include (1) actions to collect different or additional types of information from the battlespace or GIG, (2) actions to identify and enlist the support of specific experts, (3) actions to direct the focus and work activities of his own staff, and (4) actions to foreclose certain options for the adversary or to expand certain options for his own forces. Each of these actions will, in one way or another, influence the shaping and validation of the problem space adopted by the commander for his decisionmaking process. Thus, when the purpose of a study is to better understand how each element of a C2 system or organization supports a commander, it is essential that the supporting analytic models (1) represent sensemaking as a proactive process and (2) reflect the interactive nature of sensemaking with an entire range of actions.

Taken together, these various insights suggest that the collaborative and dynamic construction of appropriate problem spaces and solution paths represents the basic sociocognitive setting for modeling military C2 systems. While this setting will have some degree of correspondence with the physical battlespace, other, more abstract concepts such as mission objectives, command intent, trust, and experience will also exert considerable shaping influence. An important dimension of this setting is knowledge state—the quality of what is effectively understood within the C2 team or organization. This is true because C2 system performance questions ultimately reflect the ability of military personnel to transform their experience and expertise together with available information from the battlespace into actionable knowledge for the commander and other key decisionmakers.

Knowledge Managers or Sense Makers?—Describing the Important Actors

Within any dynamic system model, there are typically a set of important actors that initiate and control the flow of activities and outputs within some type of process. Here, the research literature on organizational sensemaking and knowledge management provide several different perspectives that can be combined to yield a picture of the important actors to be represented in a military C2 model. At the level of individual actors, the marketplace paradigm discussed earlier in this chapter suggests that individuals within a C2 team or organization can act as buyers, sellers, brokers, and managers of information and knowledge. Certainly, each of these roles must be reflected in a modeling representation. However, in many cases, an individual actor may take on more than one of these roles. Specifically, the research on knowledge workers tells us that some actors perform a knowledge transformation role—i.e., they receive certain forms of knowledge from others, provide a "value added" contribution to the structuring or interpretation of this knowledge, and then pass the augmented knowledge product on to others.

In addition to specifying the role (or roles) that an actor can serve, it is also important to characterize their area and level of expertise. Area of expertise will specify the relevance of the actor to specific types of operational issues, problems, or tasks. Actors possessing more than one area of expertise can potentially serve as boundary spanners between two or more communities of practice. Level of expertise, in turn, will serve determine the level or quality of the "value added" contributed by the actor in a given transaction. For lower levels of expertise, it might be possible to derive "value added" from a specific rule set associated with the tacit knowledge of a particular actor. Such actors would most likely be characterized as "task workers" responsible for carrying out rote information processing tasks. However, for higher levels of expertise, tacit knowledge becomes more "recognitional" and associated with the ability to make fine case-based discriminations or the ability to adapt experiential models to a given problem or situation. Past attempts to capture this level of expertise in rule form have led to a combinatorial explosion of rules in an effort to cover all possible contingencies and interactions—e.g., >10,000 rules. As a result, the computer science community—specifically those working in artificial intelligence—have looked to other mechanisms such as agent-based processes, genetic algorithms, and neural networks for codifying human intelligence and experience. Suffice it to say, however, the

effective and robust representation of human expertise has and will remain a research challenge for the computer science community in years to come.

A further challenge associated with the explicit codification of human intelligence and experience has been noted by Robert Hoffman, Paul Feltovich, and Kenneth Ford. In their review of current research on modeling human expertise, they conclude that expertise is more properly considered to be a socially-defined concept, rather than a static concept. (Hoffman, Feltovich & Ford, 1997) That is, an individual is considered to be an expert only when placed in a social or work context that requires application of their specific tacit knowledge and experience. Thus, the match between context and the individual's particular form of tacit knowledge is the critical variable in the equation. This notion has led various researchers to consider variations of a tetrahedron structure that links (1) individual knowledge/skills, (2) familiar solution task strategies, (3) information and tools required for the task strategies, and (4) problem solution goals. Outside forces that can act on this tetrahedron include such things as (1) social norms and expectations, (2) organizational and cultural constraints, and (3) professional training norms.

The difficulty of expressing tacit knowledge and expertise in explicit form suggests that modelers should consider alternative representational strategies when deemed appropriate for a given type of investigation. For example, it might be possible to represent tacit knowledge in a synthetic manner. Here, the modeler would conduct an external analysis and decomposition of the problem space being addressed in a specific modeling project. For each element or region within the decomposed problem space, the modeler would identify the specific types of problems to be addressed and resolved by the military C2 system. Subject matter experts could then be polled to assess and identify the types of information, areas of tacit knowledge, and levels of expertise required to successfully resolve each problem—i.e., produce actionable knowledge in the form of identified threats and opportunities, associated resources and operational constraints, and a coordinated solution path. Extensions of the tetrahedron model outlined by Hoffman, Feltovich, and Ford might even be used as the organizing paradigm for assembling these requirements. In this manner, the modeling task takes on the nature of an accounting process that tracks the emergence of specific types of operational problems and assesses whether or not the

C2 system is capable of bringing together the right information and right expertise to resolve each problem in a timely and effective manner.

While individual actors are an important entity to be represented in any military C2 model, it is also important to represent their placement and aggregation within a C2 team or organization. Placement concerns the level at which various actors operate and the types of responsibilities they carry out within the overall sensemaking and knowledge management process. Current research suggests that there exist three distinct levels of actors within a C2 team or organization. At the top level, the "commander" or "key decisionmaker" actor drives the sensemaking and knowledge management process by providing the operational vision—expressed in terms of command intent and an articulation of the issues to be resolved in achieving that intent—and by influencing the formation of specific informal networks that will support appropriate patterns of collaboration across the team or organization. Command intent and the articulated issues will, in turn, drive the information collection and analysis activities of the team or organization. These roles are as important as (or, perhaps, more important than) the role of decisionmaker who adjudicates conflicts between units and gives final approval to emerging plans and orders. At the middle level, a second set of actors—representing the commander's key advisors or heads of different staff sections—drive the emergent processes of improvisation and problem solving that respond to command intent and the articulated issues. In some instances, these actors might interact with the "commander" actor to identify or refine additional issues, based on their functional expertise and access to specific sources of current information. In a very real sense, these actors will portray knowledge workers inasmuch as their work threads, information sources, patterns of interaction with others, and operational focus will dynamically change over time in response to the ongoing flow of operational issues that must be resolved. At the bottom level, a third set of actors—representing the technical personnel supporting each principal advisor or section chief—will carry out routine task sequences in accordance with (1) direction provided by the middle level actors and (2) the standard operating procedures established for the team or organization. In essence, this third set of actors make up the participants of various ad hoc project teams formed to address specific threats, opportunities, or other issues identified by the first and second set of actors. While their activities can be generally classified as task work, the nature and sequencing of this task work will be guided by the improvisation and problem solving strategies identified by the middle level actors.

Aggregation concerns the manner in which individual actors collaborate within ad hoc project teams to address specific issues or problems. Research suggests that the knowledge product created by such aggregations will often be greater than the sum of the individual inputs. This reflects the research finding that collaboration in the form of ad hoc project teams acts as an amplifier of individual knowledge. Hence, it is conceivable that these ad hoc project teams might be best represented as an additional class of actor—one that reflects a synergistic combination of the tacit knowledge possessed by its constituent members. Additional characteristics of project team actors would be (1) that they are transient and exist only for a finite period of time, (2) form only when certain conditions of mutual familiarity and trust exist, and (3) require the establishment of a common ground of understanding among the constituent members.

Together, these various insights underscore the importance of accurately modeling the role, placement, and area/level of expertise of each actor within a C2 team or organization. At a tactical level of C2, problem spaces, tasks and work threads will tend to be more fixed and constrained by the physical battlespace. At the same time, actors within a tactical C2 team or organization will tend to perform more task work rather than knowledge work. As a consequence, it will be relatively easy and straightforward to represent actors and work flow within a military C2 model. However, as analyses begin to address C2 systems and headquarters at a more operational level, the wicked or open-ended nature of the problem space places greater importance on knowledge work. This implies that work flow will become more adaptive and emergent in nature. Correspondingly, analysts need to devote greater attention to properly accounting for how the role, placement, and area/level of expertise of each actor influence their ability to collaborate and to generate meaningful knowledge products within the overall sensemaking and knowledge management process.

Codified, Tacit, and Social Knowledge—The Flow and Use of Specific Commodities

A third component of most dynamic systems models is the representation of commodities that are produced and consumed by the various process activities and that populate various flows and transactions between these activities. In the case of military C2 systems, the basic commodities are information and knowledge. Hence, a concern of the modeler will be how to properly represent these types of commodities in their various stages of transformation. From a broad look across the research literature, five specific forms of information and knowledge emerge as the

principal input and output commodities of sensemaking and knowledge management. As shown in Figure 2-9, these commodities fall across several domains and reflect different elements of an effective military C2 process.

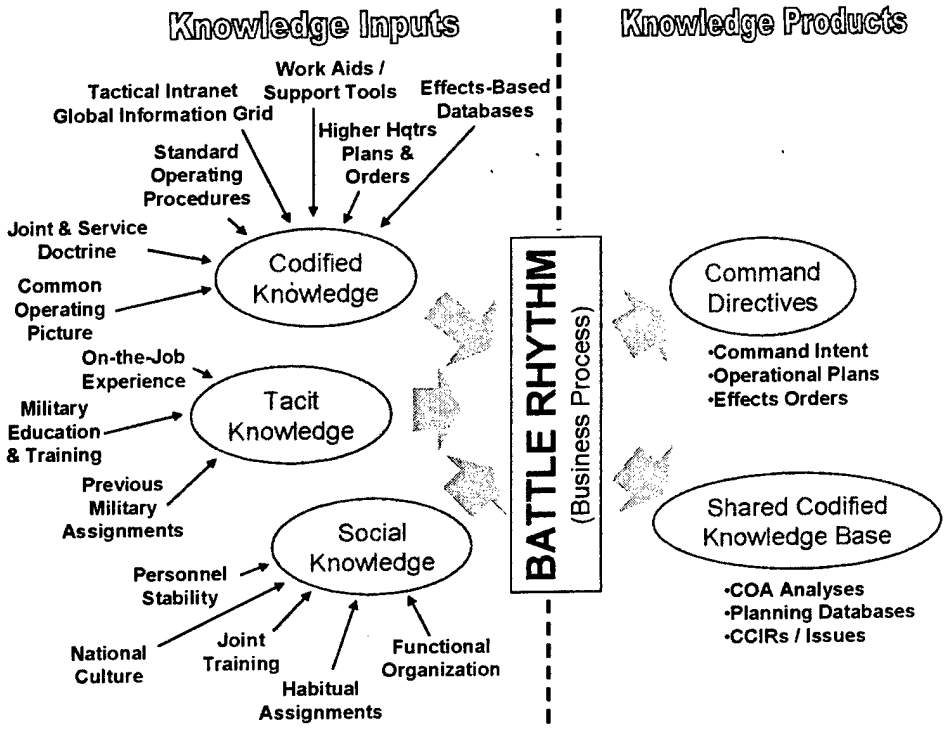

Figure 2-9. Knowledge Inputs and Products

Commodities on the input side include codified information and knowledge, tacit knowledge, and social knowledge. Codified information and knowledge includes such commodities as current situation awareness obtained from the Common Operating Picture, Joint and Service doctrine, standard operating procedures and battle books, supporting information available from the tactical intranet and Global Information Grid, information and functional knowledge embedded within work aids and decision support tools, plans and orders issued by higher headquarters, and effects-based databases developed for operations against specific adversaries. Codified information and knowledge, by definition, exists and flows within the information domain and is the easiest to explicitly represent within a C2 systems model.

Tacit knowledge resides within the cognitive domain of individuals and includes such commodities as experience and expertise acquired from previous military assignments, expertise acquired from military education and training, and experience and expertise acquired from on-

the-job training in each individual's current assignment. Such knowledge is internally organized in the form of ideology, unspoken work heuristics and guidelines, familiar paradigms, theories of action, experiential stories, and tradition. As noted earlier, it is possible for lower levels of expertise to be explicitly modeled as rule sets, agent-based processes, genetic algorithms, and neural networks. However, the difficulty of expressing tacit knowledge and expertise in explicit form suggests that modelers should consider alternative representational strategies when deemed appropriate for a given type of investigation—e.g., the representation of tacit knowledge in a synthetic manner, as outlined earlier in this chapter.

Social knowledge reflects various aspects of organizational coherence—e.g., trust, maturity of social networks, and interpersonal familiarity. Knowledge commodities within this social domain are acquired through national culture, Joint military training, habitual military assignments, the functional organization of a C2 team or organization, and personnel management policies that stabilize military assignments. The social knowledge component is the "glue" that allows individuals to collaborate and, in turn, produce a knowledge product that is greater than the sum of the individual contributions.

As shown in Figure 2-9, the three commodities of codified knowledge, tacit knowledge, and social knowledge constitute the basic "inputs" to the battle rhythm (business process) of the C2 team or organization. On the output side of this model, two forms of actionable knowledge constitute the basic products of the C2 team or organization. These products include both command directives and (increasingly for future, networked C2 systems) an enhanced, codified knowledge base that can be shared with other commands. Command directives reflect commitment to specific actions and outcomes in the form of command intent, operational plans, and effects orders. Traditionally, command directives have often specified in great detail the actions to be taken by supporting military units. For the future, however, command directives are likely to emphasize effects and intended outcomes while allowing supporting commanders to identify the most appropriate actions to take in achieving these effects and outcomes.

A second knowledge product produced by a C2 team or organization is that of an enhanced, codified knowledge base that can be shared with other commands. In the case of supporting commands, this knowledge base will likely reflect insights from course of action analyses, other

useful planning information, plus an articulation of both future information needs and those issues that the commander feels it is important for supporting commands to address. In short, this knowledge base documents the "value added" contributed by the C2 team or organization in helping other commands to (1) visualize future threats and opportunities, (2) understand issues that must be addressed along the path toward a desired endstate, and (3) benefit from the expertise and experience resident within the team or organization. At the same time, lateral commands and higher command headquarters can share this same knowledge base to gain a more accurate understanding of (1) how the C2 team or organization is visualizing the battlespace and (2) what actions and beliefs the C2 team or organization has committed itself to.

Summarizing these insights, it is clear that information and knowledge represent the basic commodities that flow into and out of a C2 team or organization. These commodities can be broken down into several classes: codified information and knowledge, tacit knowledge, social knowledge, command directives, and shared codified knowledge base. While codified knowledge and command directives are, perhaps, the easiest to explicitly model, equal attention must be devoted to the appropriate representation of the other knowledge commodities that influence overall C2 system performance. As suggested in Figure 2-9, each class of knowledge commodity provides the analyst a window into different elements of an effective C2 system—e.g., training, personnel, organization, doctrine, technology and procedures. Hence, in order to analytically address future requirements and investments in each area, it is important that future C2 systems models provide for the balanced representation of each class of knowledge commodity.

Modeling Structure—Emergent, Adaptive Processes Embedded within a Linear Framework

In terms of modeling structure, a review of the literature suggests that sensemaking and knowledge management is best represented as a set of emergent, adaptive processes embedded within an overarching linear framework. Both of these aspects are essential, although the relative emphasis given to each will evolve as one moves from the representation of current C2 teams and organizations to the examination of future C2 concepts. In a recent book that focuses on the future transformation of C2 systems, David Alberts and Richard Hayes characterize important differences that must be reflected in future C2 systems models. (Alberts & Hayes, 2003) As

shown in Figure 2-10, the development and fielding of advanced information and collaboration technologies, coupled with the reengineering of future C2 concepts and organizations enable a number of key improvements over existing C2 systems. These various changes suggest that future C2 teams and organizations will reflect a more distributed, emergent, and adaptive sensemaking and knowledge management process, as compared with today's hierarchical organizations and processes. Correspondingly, future C2 system models will have to reflect these various types of structural and process changes in order to provide the analytic foundation for assessing investment requirements and hypothesized performance improvements.

A similar evolution in C2 modeling representation is suggested by the fact that contemporary and future national security demands are increasingly involving military forces in a wider spectrum of operations, as compared with the traditional, attrition-based forms of warfare. For example, as noted by Air Force Brigadier General David Deptula in a historical review of air operations, advances in precision weaponry have made possible a transition from the massive bombing campaigns of World War II to the focused targeting of selective high value centers of gravity. (Deptula, 2001) As demonstrated during Operation Desert Storm, the employment of airpower—including both manned aircraft and long-range cruise missiles—is no longer constrained by the need to deliberately roll back air defenses prior to engaging other vital elements of an adversary's power base. Employing a concept known as *parallel warfare*, strike planners could now orchestrate the simultaneous engagement of high-value targets—thus bringing about a rapid collapse of an adversary's offensive and defensive capabilities. Concurrent with the introduction of parallel warfare was the concept of *effects-based operations*, a targeting strategy that focuses on achieving specific operational effects against an adversary, rather than merely insuring the physical destruction of a long list of facilities and other assets. Taken together, the concepts of parallel warfare and effects-based operations hold the potential for both increasing the operational impact of airpower and allowing this impact to be achieved more rapidly with a given set of airpower resources.

	EXISTING HIERARCHICAL C2 ORGANIZATIONS	FUTURE *"POWER TO THE EDGE"* C2 ORGANIZATIONS
COMMAND STYLE	By directive	Establishing conditions
LEADERSHIP POWER	By position	By competence
FORM OF CONTROL	By direction	An emergent property
DECISION MAKING	Line function	Everyone's job
INFORMATION SHARING	Hoarded	Shared
INFORMATION FLOW	Vertical, coupled with chain of command	Horizontal, independent of chain of command
INFORMATION MANAGEMENT	Push	Post-pull
SOURCES OF INFORMATION	Stovepipe monopolies	Eclectic, adaptable marketplaces
ORGANIZATIONAL PROCESSES	Prescribed, sequential	Dynamic, concurrent
INDIVIDUAL ROLES	Constrained	Empowered

Figure 2-10. Properties of Existing and Future C2 Organizations

Full exploitation of this potential, however, requires a profound change in the process by which such operations are planned, coordinated, and executed. As noted by General Deptula, early indications of such change were reflected in 1990-91 as Air Force planners attempted to shift away from the tactical targeting focus developed originally during the Vietnam War. Under this old system, Air Force target planners simply responded to lists of tactical targets provided by ground force commanders. Effectiveness of this C2 system was measured in terms of target destruction efficiency—i.e., how quickly and thoroughly could the Air Force insure destruction of the provided target list. Beginning in 1990-91, the Air Force began to supplement tactical target planners forward-deployed at Riyadh, Saudi Arabia, with a nucleus of offensive target planners from Washington. This special planning group employed the new concepts of parallel warfare and effects-based operations to revise and refocus the initial air operations plan for Desert Storm on the simultaneous attack of high-valued targets throughout a sustained air campaign. The effectiveness of these operations for rapidly degrading Iraq's military capability is now a matter of history. While Desert Storm offered an initial demonstration of this new potential, its successes were not without some unforeseen problems. For example, destruction of the electric power grid around Baghdad—originally intended to disable Iraq's air defense

system—also caused unintended consequences such as the disabling of water treatment plants that led to increased health problems in the civilian population. However, the complications exhibited with the targeting process during Operation Desert Storm were just a preview of problems that would arise during subsequent military operations.

During Operation Allied Freedom in Kosovo, air operations were envisioned by the SACEUR commander to win the race between target destruction and reconstruction. (Clark, 2001) That is, the objective was to target assets deemed critical to Yugoslavian President Milosevic faster than the Yugoslavian government could repair them or develop workarounds—thus forcing Milosevic to capitulate. In reality, however, what should have been a straight forward military planning process was complicated significantly by differences in operational perspective between military planners in Washington versus those at SACEUR headquarters. Without an introduction of NATO ground forces into the theater of operation, air planners had to revert to a focus on tactical warfare. At the same time, target nominations had to undergo a time-consuming review and approval process in Washington as the United States and its NATO allies debated over operational strategy and priorities. As a result, the advantages of information superiority and precision weaponry were frequently negated as Serbian forces began to take advantage of NATO's lengthy air operations planning cycle. (Thomas, 2000) Clearly, the targeting process needed further refinement when military operations were conducted in a complex political and diplomatic context.

Operation Enduring Freedom in Afghanistan presented a new set of challenges for conducting time-sensitive targeting operations. While the military objectives of defeating the Taliban's military power and destroying the Al Qaida's terrorism network were relatively straight forward, overall air operations were complicated by the need to preserve the regional infrastructure needed to support humanitarian aid to the Afghan civilian population. At the same time, there was confusion between the higher-level CENTCOM staff and the regional CENTAF staff regarding the definition of time-sensitive targets[6] and the level of approval authority required

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[6] For example, two classes of time-sensitive targets emerged during Operation Enduring Freedom: (1) tactical targets that represented an immediate threat or opportunity to forces on the

for executing specific target lists. While CENTAF decisionmaking tended to focus on targeting issues of tactical and operational concern, CENTCOM discussions necessarily addressed the strategic and political implications of targeting and the risk associated with unintended collateral damage. As a result, the subsequent time delays associated with identifying and resolving political, diplomatic, and legal issues within and between these headquarters were often the driving factor in mission success or failure. (LaVella, 2003) Except for some reported problems in the Combined Air Operations Center (CAOC) of sharing targeting information between the Joint Intelligence Center (JIC) and the CAOC air planners, the technical linkages in the target-to-shooter information chain were not a limiting concern. Rather, it was the intervening human collaboration and decision processes that were found to need attention and improvement.

These recent experiences underscore the complexity of moving military operations toward an effects-based planning basis. In order to accommodate the increasing range of political, diplomatic, humanitarian, and economic factors that must be considered in conjunction with military operations, the sensemaking and knowledge management process of a future C2 team or organization must be able to effectively cope with wicked problems. As shown in Figure 2-11, wicked problems demand a more collaborative and emergent C2 approach. Specifically, the management of wicked problems requires (1) the ability to evolve the problem framework along with the solution strategy, (2) the appropriate involvement of relevant stakeholders and functional experts in an emergent collaboration process, and (3) the deliberate development of shared understanding in addition to shared situation awareness.

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ground and (2) politically sensitive targets that represented fleeting opportunities to take out high-level Taliban or Al Qaida leadership.

Simple Problems	Complex Problems	Wicked Problems
CONTEXT • Stakeholders / experts agree on problem framework • Stakeholders / experts agree on solution strategy	**CONTEXT** • Stakeholders / experts agree on problem framework • Stakeholders / experts differ on effective solution strategy	**CONTEXT** • Stakeholders / experts cannot agree on problem framework • Stakeholders / experts differ on relevant solution strategy
MANAGEMENT STRATEGY • Centralized, authoritarian management system • Minimal collaboration • Shared awareness = shared understanding	**MANAGEMENT STRATEGY** • Promote constructive competition among solutions • Minimal collaboration • Shared awareness = shared understanding	**MANAGEMENT STRATEGY** • Problem framework evolves along with solution strategy • Collaborative involvement of relevant stakeholders / experts • Shared understanding must be deliberately developed
EXAMPLE • Theater-level air defense • Anti-submarine warfare	**EXAMPLE** • Destruction of Al Qaeda operations bases in theater • Neutralization of SCUD threat	**EXAMPLE** • Eliminate insurgent threat to US and coalition forces in theater

Figure 2-11. Wicked Problems and Management Strategy

Together, these insights suggest that sensemaking and knowledge management is best represented or modeled as a set of emergent, adaptive processes embedded within an overarching linear framework. The general outline of such a structure is suggested in Figure 2-12. The outermost layer of this structure is the phase of military operation. This layer captures the initial conditions of the operation, the desired endstate of the operation, and the desired pathway envisioned by the commander or key decisionmakers. In terms of modeling, the various activities and processes represented within a future C2 model can be seen as collectively moving the battlespace toward the desired endstate. The length of this operational phase will depend not just on the speed of the C2 decisionmaking process, but also on a host of other factors—e.g., the time required for rehearsal and execution of supporting courses of action, the time needed for diplomatic negotiations, the time required for various operations to have the desired psychological impact on the adversary, the time required for developing coalition or public opinion support, and so forth.

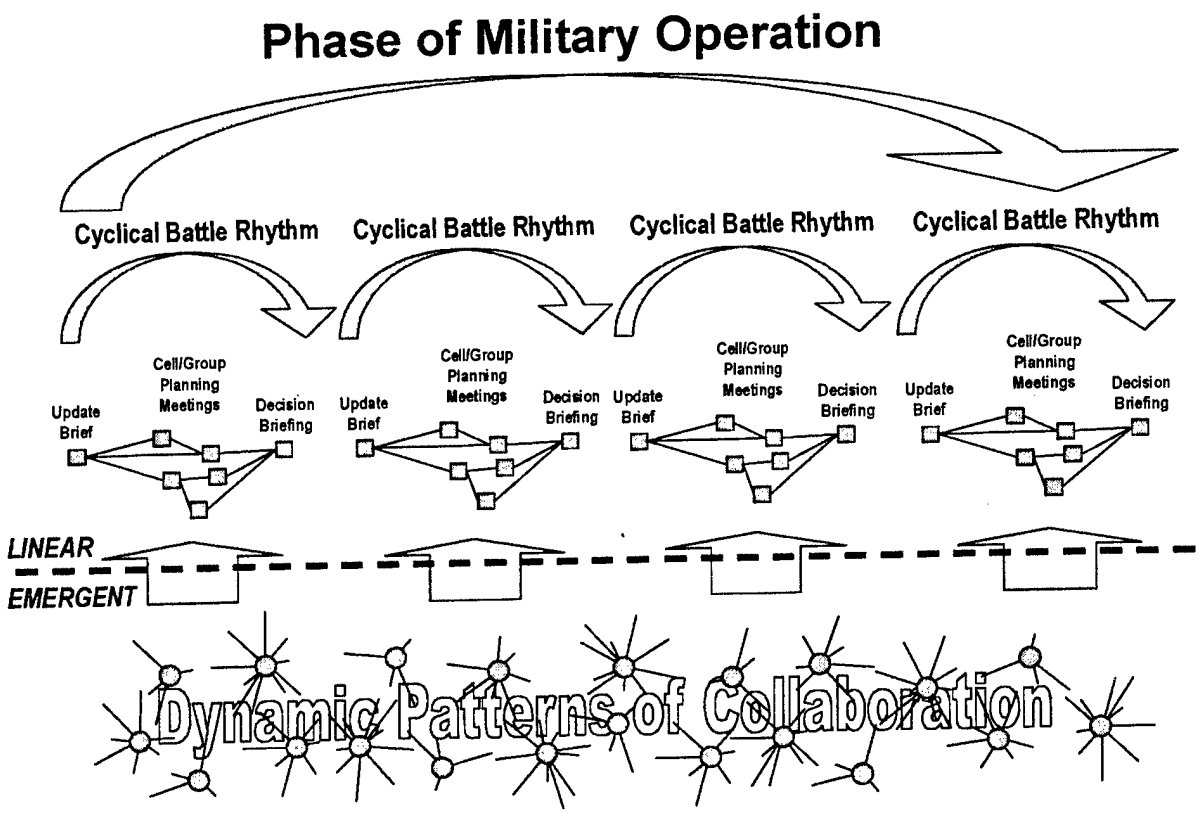

Figure 2-12. Emergent Processes Embedded within an Overarching Linear Framework

Within this overall phase of operation, however, the C2 system will execute a number of battle rhythm cycles. Currently, a typical headquarters battle rhythm cycle will extend over a 24-hour period—a length of time not to be confused with the planning horizon timeline of a given command echelon. During this daily cycle, there will nominally occur several types of repeatable events: (1) a command update briefing that brings the C2 team or organization up-to-date on the current situation, (2) a series of functionally-aligned planning meetings held by different staff cells or groups to address specific areas of concern (e.g., logistics, deep-targeting, planning), followed by (3) some type of decision briefing at which the commander or key decisionmakers commit to specific plans or actions within the nominal planning time horizon. The value of maintaining a predictable sequence of battle rhythm events is that it gives a sense of structure, guidance, and commitment to the C2 team or organization.

For the future, it is generally desired that the overall time required for decisionmaking be reduced. Concurrently, it is generally hypothesized that continued improvements in information and collaboration technology, reengineering of the decisionmaking process, improvements in

organizational coherence, and so forth will lead to the desired shortening of the decision process. This is not to say, however, that one should necessarily abandon the concept of having a predictable schedule of update briefings, planning meetings, and decision briefings as a coordination mechanism for the battle rhythm. Rather, the desire is simply to reduce the battle rhythm to something less than a 24-hour period—say, 6 hours, or even down to 1 hour.

Underlying the linearity of the operational phase and the cycle battle rhythm events are dynamic patterns of collaboration that bring together appropriate sets of functional experts and stakeholder interests to address and resolve specific issues. Activities that occur within these collaborative interactions will center around positional arguing, problem shaping, development of a common ground of understanding, and development of alternative solution paths. Because the type and number of issues will vary as a function of the specific operation, the associated patterns of collaboration will evolve in an emergent manner. However, their overarching goal is to produce and contribute actionable knowledge to sequence of update briefings, cell/group planning meetings, and decision briefings that occur over time.

Modeling Sensitivity—Obstacles and Points of Breakdown

A final set of comments deals with the ultimate purpose of analytic modeling: the desire to decompose systems in such a way as to understand their performance limitations and capabilities under different circumstances. Here, the discussion concludes with a summarization of insights regarding the basic dimensions of performance, the principal obstacles that can impede performance, and the mechanisms by which the overall sensemaking and knowledge management process can break down. Accurately capturing the essence of each of these insights should be a primary goal in future C2 system modeling projects.

Insight into the critical dimensions of C2 team and organizational performance is again provided by Alberts and Hayes in their recent look at future C2 organizations. (Alberts & Hayes, 2003) Here, they focus on the concept of agility and define this concept in terms of six dimensions:

- *Robustness*. The ability to maintain effectiveness across a range of tasks, situations, and conditions;
- *Resilience*. The ability to recover from or adjust to misfortune, damage, or a destabilizing perturbation in the environment;

- *Responsiveness*. The ability to react to a change in the environment in a timely manner;
- *Flexibility*. The ability to employ multiple ways to succeed and the capacity to move seamlessly between them;
- *Innovation*. The ability to do new things and the ability to do old things in new ways; and
- *Adaptation*. The ability to change work processes and the ability to change the organization.

Achieving C2 team or organizational agility requires an ability to overcome known types of obstacles to sensemaking and knowledge management. As discussed earlier, the principal types of obstacles include:

- *Lack of trust* (immature relationships or inadequate face-to-face contact);
- Different cultures, vocabularies, and frames of reference (lack of common ground);
- *Lack of time and meeting places* (inadequate opportunity for collaboration);
- Status and rewards go only to knowledge owners (lack of incentive for sharing);
- *Lack of absorptive capacity in recipients* (inadequate training, narrow-mindedness);
- Belief that knowledge is prerogative of specific groups (parochialism, not-invented-here);
- *Intolerance for mistakes or need for help* (failure to recognize that errors and learning are a normal part of the organizational process);
- *Inadequate expressive power provided by collaboration tools* (constrained message formats or lack of expressive tools); and
- *Inadequate or unreliable connectivity* (inadequate bandwidth or access to intranet).

In order to overcome these various types of obstacles, military developers and force planners continue to seek a variety of transformational initiatives in the design and fielding of C2 systems. These initiatives include information and collaboration technology, training and education, improved personnel management, and reengineering of staff processes and battle rhythms. Correspondingly, future C2 system models should be capable of providing insight into the following types of questions:

- Information Technology

- How should the various information systems, planning aids, and collaboration tools available within the C2 team or organization be managed to insure the efficient and effective translation of available information into situation understanding?
- How are these various systems, aids, and tools best adapted in the context of novel or emergent operational demands to insure the reliability and responsiveness of C2 team or organization decisionmaking?
- Training and Standards of Performance
- What are the expectations and performance standards of the leaders who must command the C2 team or organization and guide its operation in a complex and dynamic operational environment?
- What type of feedback should be provided to these leaders to allow them to assess and shape the C2 team or organization process to the evolving demands of a specific operation?
- What are the expectations and performance standard of the functional operators within the C2 team or organization who must not only execute their specialized tasks, but also must collaboratively engage in cross-boundary information sharing and problem solving?
- Personnel Management
- How should the tacit knowledge resources (experience and expertise) available within or to the C2 team or organization be mapped and managed to best insure that the right staff personnel or bodies of expertise are brought to bear at each step in the planning and execution processes?
- How should personnel assignments, rotations, shift changes, and other personnel movements be managed to best insure good teamwork, maturity of social networks, cross-boundary trust, and continuity of the knowledge creation process over time?
- Staff Process and Battle Rhythm
- How should the processes of information collection, filtering, interpretation, organization, and exchange within the C2 team or organization be monitored in real-time to identify and resolve specific types of technical, organizational, social, cognitive, and procedural obstacles in the target planning process?

- How are the ad hoc patterns of information exchange, collaborative problem solving, and reconciliation of stakeholder perspective differences—particularly among intelligence, information warfare, current operations, and planning personnel—best managed in support of the cyclical planning and execution battle rhythm of C2 team or organization?
- How should the overall knowledge state within the C2 team or organization be assessed and managed in real-time to insure that the C2 team or organization is responding effectively to the decisionmaking demands of the commander–i.e., what is the appropriate mix/level of situation awareness (information) and interpretation (experience/expertise) needed to produce a workable level of certainty, and what are the effective indicators of this state?
- How can the real-time indicators of overall state of knowledge within the C2 team or organization be translated into feedback and guidance for intelligence, surveillance, and reconnaissance tasking and asset management?

If these types of obstacles are allowed to develop and persist within a C2 team or organization, then the likelihood of process breakdown increases. A breakdown can be defined to occur when the normal sensemaking activities, normal patterns of collaboration, and normal patterns of decisionmaking no longer allow the team or organization to effectively understand what is happening operationally. Consequently, this causes the effectiveness of the decisionmaking process to collapse. As the decisionmaking process collapses, actions are either not initiated in a timely manner or are taken with counterproductive results. As the military force is no longer able to keep up with a changing operational environment, there follows a predictable collapse of the military operation. Various forms of breakdown (defined in terms of the mindfulness dimensions discussed earlier) include

- Small errors and failures are allowed to concatenate into catastrophic error chains;
- Sensemaking and knowledge management remain trapped or fixated on only one, over-simplified view of reality;
- Key decisionmakers, limited by a fixed set of reporting channels, ignore or remain oblivious to front-line cues that provide an indication that the operational environment is changing in complex and novels ways;

- Team or organizational processes remain in a fixed pattern of activities and interactions, and are unable to effectively adapt to newly emergent threats and opportunities; and
- Rigid adherence to formal authority and reporting structures prevents the identification of relevant information and expertise needed to develop understanding in an evolving operational environment.

If a model is to accurately reproduce the performance of a C2 system under varying conditions, then it must be design to illuminate process variability along the six dimensions of agility outlined above. At the same time, the model's process representations must adequate account for the presence or absence of each of the nine types of obstacles identified above. And finally, the model's process representations must be design to produce collective behaviors that encompass the potential for each of the forms of breakdown outlined above. These are challenging goals for the modeler. However, achievement of these goals lies at the heart of the model's analytic utility for assessing future requirements and investments in military C2 systems.

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CHAPTER 3: MODELING AS A FRAMEWORK FOR INTEGRATING COGNITIVE AND SOCIAL RESEARCH METHODOLOGIES

INTRODUCTION

At the heart of any modeling project is the task of collecting or eliciting information that can serve to build veridical representations of real-world structures and processes that are relevant to the modeling effort. Accordingly, at the heart of modeling sensemaking and knowledge management in a military C2 team or organization lays the task of collecting, eliciting, and organizing relevant characteristics of the human beings that motivate and execute these processes. This analytical task, however, represents a formidable challenge—particularly if one is modeling such processes at an operational or abstract level of decisionmaking rather than at a low-level physical task level. In this regard, the present chapter addresses the complexity of this challenge and lays out a strategy for advancing the state-of-art relative to the demands of modeling sensemaking and knowledge management in a military C2 team or organization. Specifically, the chapter addresses two areas of methodology that have emerged over the past several decades: cognitive task analysis and social network analysis. Cognitive task analysis—and more recently, cognitive work analysis—begins with a focus on the individual and attempts to understand the nature of the information, expertise, and mental strategies the individual employs in a given problem domain. By contrast, social network analysis begins with a focus on a network of individuals and attempts to understand the nature of their relationships, information exchanges, and influence on one another. Each of these areas of analysis employs different paradigms and methods, and each reflects a different academic perspective. Yet, as will be shown later in this chapter, both areas of methodology are coming to increasingly rely upon analytic modeling to provide a framework for integrating various research findings and insights. In this regard, the present project extends this trend by placing modeling activities in the context of an overall research campaign—one that uses modeling as a framework for integrating cognitive and social research methodologies.

COGNITIVE TASK ANALYSIS

The next section of this chapter provides a brief historical review of cognitive task analysis and how it has developed more recently into the more ecological field of cognitive work analysis. Part of this trend is motivated by the recognition that work environments are often complex and involve an emerging pattern of task activities in an attempt to deal with wicked problem domains. At the heart of this issue is the need to deal with knowledge in context—the proper match-up of not only appropriate information, but also appropriate areas and levels of expertise with the specific demands of the problem domain.

A Brief History of Cognitive Task Analysis

For over a century, beginning with the early laboratory work of Wilhelm Wundt at the University of Leipzig, psychologists have been attempting in one way or another to dissect and model the mental components of thought and expertise. In many respects, the laboratory methods used by Wundt in the late 1800s to identify and classify the basic building blocks of thought are not unlike the methods used today to elicit knowledge and expertise from individuals. Employing introspection techniques with trained test subjects, Wundt believed that it was possible to systematically build a "periodic table of the mind"—a contemporary paradigm borrowed from the work of Dimitri Mendeleyev in chemistry. This early work would lead other psychologists—indeed, practitioners in other fields like operations research—to develop the school of *structuralism*, the belief that large-scale systems can be best understood through their decomposition into constituent elements, functions, and relationships.

Yet, Wundt and later structural psychologists would not be without their challenges and critics. The task of analytically exploring and documenting mental structures would prove to be extremely elusive for Wundt, leading to the branching of psychology into other disciplines such as *behaviorism* that specifically deny internal mental processes as a proper subject for scientific research. For much of the early 1900s, behaviorism—the study of cause/effect in terms of external, observable behavior—dominated psychological research. It is not surprising then, when human factors researchers during World War II began to develop and refine methods for analyzing manual work tasks, that attention mainly focused on external, overt work behaviors. Such methods generally assumed a fixed task structure and were designed to focus analyst

attention on improving the flow and efficiency of various work processes. Indeed, behaviorism and human factors task analysis have become familiar paradigms associated with the industrial age.

However, beginning in the 1950s, two developments associated with the introduction of the information age would lead psychologists back to an interest in studying internal mental structures. The first development was that the number of white-collar workers began to surpass the number of blue-collar workers in the labor force. Concurrently, the second development was the recognition that computers could be employed beyond simple number-crunching to support a wide range of symbolic problem-solving activities. With these developments, it was only natural that psychologists, human factors researchers, and operations researchers would attempt once again to analyze and model the mental structure of human thought and expertise. And, just as Wilhelm Wundt adopted a familiar paradigm of his day, many of these later researchers would adopt a contemporary paradigm as a surrogate model of the mind—the Von Neumann serial processing computer. Perhaps as a lingering influence of the industrial age, adoption of this paradigm would lead researchers to characterize thought and decisionmaking in mechanical—rather than biological—terms: long-term memory storage, short-term memory registers, the mechanical flow of messages and information, serial processing architectures, and so forth. Likewise, the characterization of expertise centered on the development of large predicate rule sets—a paradigm borrowed from contemporary software engineering.

Predictably, this resurgence of interest in modeling human mental structures would face its own set of challenges and frustrations over the coming decades. As noted in an earlier chapter, artificial intelligence models of expertise grew in size by tens of thousands of rules, yet were capable of capturing only limited aspects of human expertise in specific knowledge domains. Such limitations have led some researchers to the exploration of alternative modeling paradigms such as neural networks, genetic algorithms, and agent-based processes for representing different aspects of human cognition, problem-solving, and decisionmaking. At the same time, the field of operations research would gradually disassociate itself from the field of psychology as analysts returned to a focus on modeling physical processes rather than mental processes. As a result, the past several decades of military combat modeling have struggled with the complexities of human behavior, often attempting to capture them in terms of simplified rule sets. Throughout this

period, the operations research community has occasionally "rediscovered" the importance of considering human decision processes in their models—usually marked by a flurry of workshops and seminars involving social scientists. However, such interest has typically been short-lived as the majority of operations research analysts and social scientists have found it difficult to reach across parochial academic boundaries and sustain a multidisciplinary focus on the problem.

However, one thread of research has continued the theme of structuralism in its quest to find practical ways of decomposing and modeling human thought and expertise. This thread of research has generally become known as *cognitive task analysis*, a loosely associated set of paradigms and methods employed to "yield information about the knowledge, thought processes, and goal structures that underlie observable task performance." (RSG-27, 2000) Whereas traditional task analysis methods of the mid-1900s were focused on perceptual and psychomotor control tasks—e.g., aircraft piloting, machine operation, manufacturing assembly line processes—cognitive task analysis has attempted to dissect work tasks and roles with a higher decisionmaking component—e.g., fire battalion commanders, air traffic control operators. Emerging in the early 1980s, the principal motivation of these analyses has been to support training development, job design, or the engineering of cognitive work aids.

While the field of cognitive task analysis has matured over the past 50 years, it still reflects certain assumptions that limit its utility for supporting the study of sensemaking and knowledge management, particularly in military C2 where the problem domain is often characterized as wicked or undefined. Perhaps the biggest limitation of current methods is that they presume the existence of an expert operator or decisionmaker that has been properly matched with or placed in a problem environment relevant to that individual's area of expertise. As such, the present study (1) examines current cognitive task analysis methods and approaches in light of the insights developed in preceding chapters and (2) identifies ways in which these methods and approaches can be extended to support the modeling of sensemaking and knowledge management in military C2 teams and organizations.

A number of research threads within the fields of psychology and computer science have contributed to what is currently referred to as cognitive task analysis. As noted earlier, the emergence of general purpose computation machines in the late 1950s gave rise to an interest by

psychologists in modeling human mental processes. The early computational modeling of Allen Newell and Herbert Simon (Newell & Simon, 1972), followed by the continuing work of John Anderson and others (Anderson, 1983; Anderson & Lebière (Eds.), 1998) reflected a desire to understand the basic architecture of cognition. By the 1960s, interest in supervisory control tasks led training psychologists to the systematic study of work tasks and task demands—eventually producing an experimental methodology called *hierarchical task analysis*. (Annett & Duncan, 1967). Over the next two decades, the focus of this research shifted to the study of operator error chains that produced such catastrophes as the Three Mile Island nuclear power plant accident. With an increased emphasis on accurately capturing operator requirements in the design of large scale control systems, a refined set of task analysis methods were developed under the general heading of *cognitive system engineering*. (*cf.*, Hollnagel & Woods, 1983; Roth & Woods, 1989)

The term *cognitive systems engineering* was coined by Donald Norman in the 1980s. (Norman, 1981, 1986, 1987) During this time, he saw the advent of the desktop computer as a reflection of the increasing importance of cognition in the workplace. He correctly predicted that within a few years human operators would spend the majority of their time doing higher level cognitive work (e.g., planning, problem-solving, decisionmaking, negotiating) while computers would increasingly take over physical work (e.g., data processing, component assembly, inventory movement) under the supervisory control of these operators. By combining the theories of cognitive science with engineering practices and methods, Norman reasoned that this new field would yield a new generation of computer tools that were centered about an understanding of human performance.

With the 1980s came a growing interest in expert systems and intelligent tutoring systems in the form of large sets of production rules elicited from subject matter experts—a by-product of the earlier modeling work by Newell and Simon. (e.g., Hayes-Roth, Waterman & Lenat (Eds.), 1983) Many of these expert systems applications found their way into military command and control as researchers began to explore ways of augmenting operator performance under stressful combat conditions. (*cf.*, Loberg & Powell, 1988; Fletcher, 1988) While most of these emerging applications remained focused at the individual operator task level, others—including this author—envisioned their eventual use for improving collaboration and the flow of information within a military C2 organization. (Leedom, 1988) As various expert systems projects continued

to be undertaken, there emerged a variety of cognitive task analysis methods designed to systemically analyze the knowledge and reasoning requirements of specific task areas. However, researchers have come to recognize the limitations of these methods and attempts to build expert systems eventually ran into an obstacle known as the knowledge elicitation bottleneck. As noted in an earlier chapter, tacit knowledge associated with higher levels of expertise is not always expressible in explicit, rule-based form. (Dreyfus & Dreyfus, 2002) Indeed, attempts by researchers to lead operational experts through an introspective examination of their mental task performance will often result in a "dumbing down" of their true level of expertise. Hence, it remains problematic as to the degree to which tacit expertise can be systematically decomposed and codified in meaningful form.

Nevertheless, researchers have continued to apply cognitive task analysis as part of building expert systems in a variety of situation assessment and control task settings such as military intelligence analysis (Potter, McKee & Elm, 1997), aeromedical evacuation planning (Cook, Woods, Walters, & Christoffersen, 1996; Potter, Ball & Elm, 1996), military command and control (Shattuck & Woods, 1997), space shuttle mission control (Patterson, Watts-Perotti & Woods, 1996), railroad dispatching (Roth, Malsch, Multer, Coplen & Katz-Rhoads, 1998), and nuclear power plant crisis management (Roth, Lin, Thomas, Kerch, Kenney & Sugibayashi, 1998). In each case, the specific methods of cognitive task analysis have been matched with the analytic focus and needs of the project. Other research efforts, such as the Mental Model Project underway within the Mitre Corporation, are employing cognitive task analysis in a more experimental approach to understand how human experts make decisions under conditions of uncertainty.[7] Still other research efforts have developed a variety of cognitive task analysis methods to support job design and training development for both individuals and teams. (*cf.*, Klein, 2000; Salas & Cannon-Bowers, 1997; Wall & Jackson, 1995) As a result, instead of this

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[7] The project, led by Kevin Burns, employs a poker game analogy to model how military decisionmakers think and act under uncertainty. The project's web site can be found at http://mentalmodels.mitre.org/index.htm.

field producing a single, refined approach to cognitive task analysis, a plethora of methods have emerged under the general rubric of cognitive task analysis.

Cognitive Task Analysis: Four Different Theoretical Perspectives

In a recent summary of the state-of-the-art, Robert Eggleston notes that the past two decades have produced a number of approaches to cognitive task analysis—each denoted by a specific champion, and each displaying somewhat different theoretical perspectives. (Eggleston, 2002) These different perspectives and approaches range over a complex conceptual landscape. Since they deal with abstract concepts and frameworks, they cannot be directly seen or touched by researchers. Thus, they are often debated and their utility is often in the eyes of the beholder, dependent upon the specific research or engineering challenge. Nevertheless, they reflect a range of variables thought to be useful for characterizing cognitive work.

Stewart Card, Carnegie Mellon University

Motivated by a desire to model human performance in a manner that can be expressed in engineering-style calculations for designing interactive systems, Steward Card and his colleagues at Carnegie Mellon University led an effort that produced two modeling frameworks focused on the individual operator in a cognitive task environment. The first framework, Model Human Processor (MHP), focuses on the representation of human perceptual, cognitive, and motor activities. (Card, Moran & Newell, 1983, 1986) MHP decomposes these processes in terms of both processing times and information handling constraints (e.g., information storage, memory, information chunking, reasoning). An important aspect of MHP is that it provides a set of modeling primitives and overall architecture with which to represent the perceptual, cognitive, and motor activities of a human operator.

A second modeling framework, Goals-Operators-Methods-Selection Rules (GOMS), focuses on the representation of the task environment in terms of goals and rational activities required to achieve those goals. A goal statement abstractly defines what the operator is attempting to accomplish, but not how to accomplish it. Goals, in turn, are usefully decomposed into sub-goals that can be acted upon by cognitive operators to reduce this abstract framework into a set of rational actions. Knowledge rules operate as a control function that specifies which actions to execute in a given sequence.

Overall, GOMS and MHP conceptualize work in terms of goal decomposition, problem-solving, and agent activity. By taking a reductionist perspective, this approach to cognitive task analysis presumes that any work environment can be suitably decomposed in terms of a goal framework and analyzed in terms of the sequence of actions needed to resolve each goal. Unlike other perspectives, to be discussed in subsequent paragraphs, the GOMS-MHP primitives make no distinction between work objects (e.g., pencil and paper, computer display) and their associated work functions (e.g., recording information, displaying information). It does, however, distinguish between tasks and work (a collection of $n \geq$ tasks). A task is defined as the activity that takes place between the time of goal activation and goal resolution.

In terms of military C2, the approach taken by Card *et al* seems best suited for the detailed modeling of individual system operators in well-defined task environments—say, an air defense intercept radar operator. It is not clear, however, to what extent the GOMS-MHP approach offers a feasible or effective means of modeling collaborative problem-solving and decisionmaking behaviors in a more open problem space task environment. While such a detailed modeling effort could be attempted, its costs in terms of time and resources would likely overshadow any analytical insight derived from such an undertaking.

Donald Norman, University of California at San Diego

Similar to the GOMS-MHP approach of Card *et al*, Donald Norman and his colleagues at UCSD have attempted to represent human-computer interaction as being made up of both mental activity and physical activity. (Norman, 1986) Problem-solving again reflects the basic work paradigm—a process that is articulated in terms of a seven-stage model. This model, shown in Figure 3-1, conceptualizes a goal-directed sequence of activities that relate the physical state of the system to mental understanding, evaluation, and action-taking.

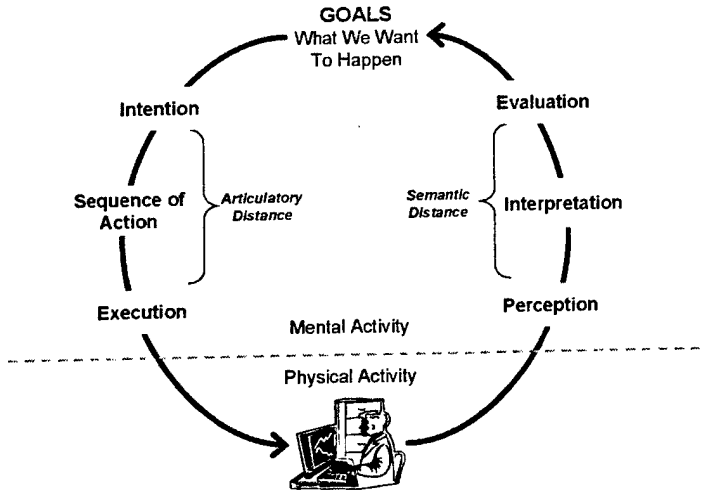

Figure 3-1. Seven-Stage Model of Activity (Norman, 1990)

While Norman's seven-stage model appears similar to the GOMS framework, it allows for specific steps to be repeated or omitted, as appropriate. In contrast to the GOMS framework, Norman's approach focuses on work primarily as a human-computer interaction. Here, he notes that many of our everyday mental models might be classified as "naïve" or "folk" understandings of the world—in contrast to the way in which a computer software designer might conceptualize a specific operational problem. (Norman, 1990) Consequently, mental work will be required at two points in Norman's seven-stage model: (1) the interpretation or semantic translation of the computer's situation display into a form compatible with the operator's mental model of the situation and (2) the interpretation or articulation of the operator's real-world intent into a form compatible with the computer program's input parameters. Measures of the mental work required at each of these points are defined by Norman in terms of two constructs: *semantic distance* and *articulatory distance*, respectively.

With regard to military C2, the cognitive task analysis model of Donald Norman extends the GOMS-MHP approach in a useful way. Specifically, it acknowledges a common phenomenon observed with many digital information systems—namely, the need for operators to expend some amount of mental effort in reconciling a computer's situation display to their own mental model of the battlespace. A current example of this problem can be seen in the Army Battle Command System (ABCS) where different components of the battlespace picture are displayed

separately on different systems. Consequently, decisionmakers must mentally integrate these various pictures into a unified whole as part of their sensemaking process.

David Woods, The Ohio State University

Following a similar line of motivation, David Woods and his colleagues at the Ohio State University focused on representing human operators in the context of both the world environment and various tools that the operators rely upon to represent that world (e.g., sensors, computer displays, decision aids). As will be discussed more fully later in this chapter, Woods' triad of *work-in-context* views cognition as a distributed phenomenon rather than something purely residing within the mind of an individual. In this regard, David Woods and Emilie Roth introduced the concept of the *cognitive triad.* (Woods & Roth, 1988) As shown in Figure 3-2, the cognitive triad reflects three important determinants of work performance: the external world or task domain, the human or machine agents that perceive and act upon this domain, and the artifacts or information representations that convey meaning about the task domain to the agents.

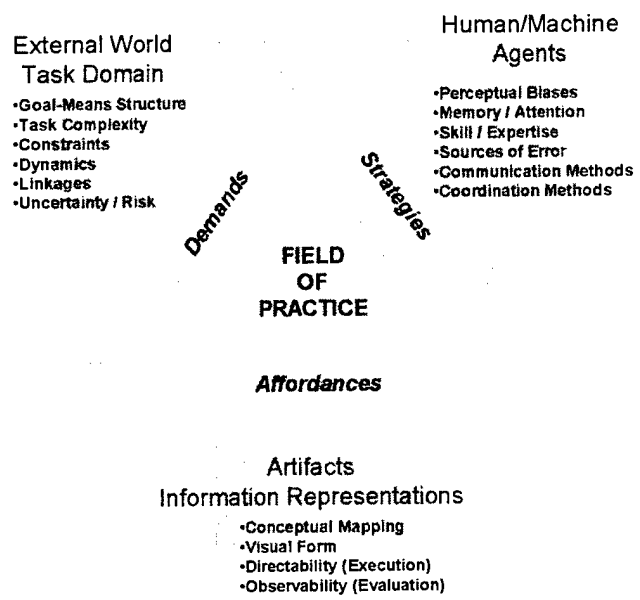

Figure 3-2. Cognitive Triad Model (Adapted from Woods, Christoffersen & Tinapple, 2000)

As a result, aspects of the world environment, the artifact and representation systems, and the operator agents can each influence how a particular operational problem is perceived, framed, and solved. The world environment provides not only certain problem goals and the information that drives the problem-solving process, but also a variety of contextual factors that can facilitate

or impede solutions, make information easier or harder to obtain, and/or make constraints more or less obvious. Representation systems (e.g., sensors, computer displays, decision aids) can implicitly frame problems in certain prescribed ways, exhibit sensitivity or insensitivity to certain types of operational changes, and either increase or lessen memory demands on the operator by the way that they store and present information. The operator brings not only problem-solving expertise and experience, but also a host of other factors (e.g., personal values/goals, emotional state, physical state) that can unintentionally interfere with main-line problem-solving. Thus, each of these components of the work triad operates in a dual manner to both (1) contribute resources to solve a problem and (2) add to the complexity of the solution process.

As part of this approach to cognitive task analysis, Woods envisioned a well-engineered system in which human decisionmakers and expert system machines would collaborate to both develop problem understandings and problem solutions. Hence, his methodological framework attempted to address the interaction of humans and machines engaging in collaborative perception and reasoning. In comparison with the positivist framework of Stewart Card, Woods' viewed problem-solving, decision shaping and decisionmaking as being related and open activities. That it, subtle changes in the dynamics of the environment can lead to significantly different problem formulations—and, hence, different solutions.

In several ways, the approach to cognitive task analysis outlined by David Woods addresses key aspects of the military C2 problem. For example, military C2 processes often exist in a highly dynamic operational environment that presents decisionmakers with a complex variety of both obvious and somewhat hidden contextual factors. Many of the computer-based information systems that these decisionmakers rely upon have embedded knowledge that implicitly filters, shapes, and distorts representations of the actual world. Military C2 personnel also shape the sensemaking and decisionmaking processes by virtue of the personal values, culture, areas of expertise, and levels of expertise that they bring to an organization. Overall, the cognitive triad model of Woods and Roth provides a useful paradigm for analysis and underscores the importance of reflecting not only the task domain and operator agents in an analytical model, but also reflecting the artifacts and information representations as well. Despite these advantages,

however, the constructs and methods developed by Woods do not offer a well-formed specification for modeling the overall process.

Jens Rasmussen, RISO National Laboratory (Denmark)

The approach to cognitive task analysis developed by Jens Rasmussen *et al* at the RISO National Laboratories is similar to that of Woods inasmuch as it considers both the problem domain and the worker domain. Like Card and Woods, Rasmussen sees work as essentially being problem-solving and decisionmaking in an open problem domain. Hence, Rasmussen's approach focuses on the adaptive nature of work processes for accommodating dynamic changes in the environment.

The approach developed by Rasmussen and his colleagues can be characterized as a multi-level set of analytic frameworks that specify different aspects of work in a particular context: (Rasmussen, Pejtersen & Goodstein, 1994)

- *Work Domain*: an abstraction of the functional and physical properties of the work domain
- *Control Tasks*: a decision ladder of tasks/states that links informational inputs to output actions
- *Control Strategies*: a set of optional strategies for carrying out each level of control task
- *Social/Organizational*: a structural description of how work tasks are distributed and managed
- *Worker Competencies*: the skill, rule or knowledge-based behaviors of each control agent

As developed by Rasmussen, a work domain can be decomposed in terms of a framework called an *abstraction hierarchy*. (Rasmussen, 1986; Rasmussen, Pejtersen & Goodstein, 1994) As first introduced in an earlier chapter (See Figure 1-1, Chapter 1), an abstraction hierarchy includes several levels of definition:

- *Purposes/Constraints*: the high-level purpose for which the system was designed
- *Abstract Functions/Priorities*: the intended causal structure of the work environment, expressed in terms of the flow of values and abstract physical properties

- *General Functions*: the basic processes carried out within the system, expressed in functional form
- *Physical Processes/Activities*: the operating characteristics of the system components
- *Physical Forms/Configurations*: the appearance and physical distribution of the system components

When combined with different levels of system detail (e.g., system, subsystem, component), the abstraction hierarchy provides a framework for decomposing the work domain into an abstraction space. An example of this abstraction space can be seen in Figure 3-3 that reflects a recent analysis of the Army's new Interim Combat Brigade Team. (Dean & Sperling, 2002)

Whole/Part	Total System	Subsystem	Functional Unit	Individual Component
Means/Ends	Strike Force	Large unit (BN CO)	Small-unit (SOD PLT CO)	Crew Operator/System
Goals & Constraints	Accomplish assigned missions within higher commander's intent and constraints. Deploy to combat theater. Preserve combat power. Sustain operations.	Accomplish assigned missions within strike force commander's intent and constraints. Preserve combat power. Sustain operations.	Accomplish assigned missions within subsystem commander's intent and constraints Preserve combat power. Sustain operations.	Accomplish assigned missions within functional commander's intent and constraints. Preserve combat power. Sustain operations.
Priorities, Flow of Values and Products	Conduct offensive, defensive, SASO operations. Analyze and anticipate mission requirements and plan. Maintain logistical support. Provide for troop sustainment. Plan & execute troop/equipment movement.	Plan and maintain unit operations, Conduct recon, offensive, defensive operations. Shape battlefield. Provide combat multipliers, logistic & troop support. Integrate with other subsystems. (Specifics vary between unit capabilities)	Gain/maintain battlefield awareness. Shape local battlefield, attack/defend Communicate needs & coordinate with other echelons.	Maintain local security, prepare for combat, execute continuous combat operations, secure checkpoints, rearm/refit
General Functions	Conduct staff analysis/planning. Conduct deliberate attack, movement to contact, raid, screen, guard, defend in sector, defend a battle position, conduct reconnaissance, perform area security, resupply and rearm, sustain.	Execute staff operations.Monitor/track/anticipate unit status.Conduct route/zone/area recon Attack/deep attack.Breach,Assault,Advance in contact.Provide indirect fires.Establish/defend battle positions.Maintain Logistic ties	Conduct local recon. Provide local indirect fires. Attack/Support by fire/Breach/Assault/Advance/Defend BP/Defend in Sector/Establish checkpoints/observation. Maintain communications. Track log. needs.	Conduct system precombat checks. Conduct patrol/observation. Identify, engage enemy targets. Maneuver. Defend individual position. Submit log. requests/needs.
Work Equipment and Processes	Execute staff operations.Monitor/track/anticipate unit status.Conduct recon operations.Attack/deep attack.Breach,Assault,Advance in contact.Provide indirect fires.Establish/defend sector.	Maintain command post, staff planning. Utilize recon & indirect assets; battlefield shapers. Conduct Cordon & Search, checkpoint ops. Maneuver small units. Anticipate/track/coordinate log. & other support.	Conduct patrols/observation. Gain contact, develop situation. Maneuver subelements. Select & prepare positions. Communicate & coordinate tactically and logistically.	Plan routes & positions. Create & execute observation & fires plan. Select, identify, & engage targets. Anticipate & maintain sit. Awareness. Know plan & execute preparations. Protect from fires.
Material Resources and Configuration	Multiple large subunits with varying capabilities: direct & indirect fires; armor protection, dismounted forces, long-range responsiveness, rapid maneuver, survivability support, battlefield shaping capability, recon & surveillance, air defense; logistics	Multiple small subunits with varying capabilities: Direct & indirect fire; battlefield shaping. Battlefield awareness & communication tools. Report consolidation/transmission. Local logistical support.	Multiple combat systems/subelements with varying capabilities: Observation & fire capabilities. Voice & digital communications systems. Report consolidation & transmission measures. Planning & preparation tools.	Individual/crewsystem. Sighting system. Voice/digital communications. Planning tools. Routine reporting systems.

Figure 3-3. Abstraction-Decomposition Space for Interim Combat Brigade Team (Dean & Sperling, 2002)

At the control task level of analysis, Rasmussen's approach includes the development of a *decision ladder* that serves to frame the control task description. As shown on the left side of Figure 3-4, an ascending sequence of tasks serves to build knowledge state regarding the problem domain. On the right side of the figure, a descending sequence of tasks transform

understanding into action. In a similar manner, a control strategy framework can be constructed to represent—in an open manner—the nature of the strategies used to accomplish each control task. That is, while the decision ladder specifies the basic nature of the problem-solving process, the control strategy framework serves to articulate the alternative ways in which each task can be carried out. Each control strategy class requires certain information processing resources in order to accomplish the control task in a particular manner. Given Rasmussen's focus on adaptation, both the control task structure and the control strategy structure are considered to be flexible and open descriptions of process that can accommodate the changing nature of the work domain.

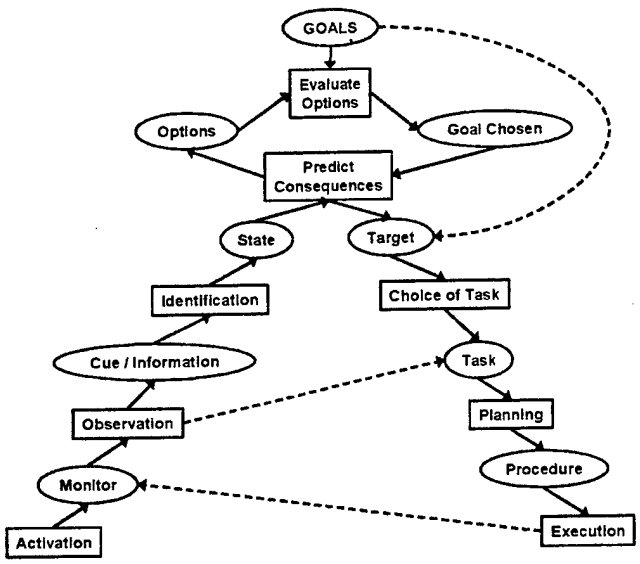

Figure 3-4. Illustration of Rasmussen's Decision Ladder

At the social/organizational level of analysis, Rasmussen's approach to cognitive task analysis specifies the nature of the work domain in terms of (1) how the work is partitioned and distributed among organizational elements and individuals, (2) what types of leadership or management control the decomposition, flow, and integration of the work elements, and (3) what types of communication patterns and constraints exist among these elements. As articulated in David Woods' approach, these social and organizational aspects of the work domain add to the complexity of the work process.

Finally, at the worker competency level of analysis, Rasmussen employs yet another framework to specify the competencies and limitations of the individual workers (control agents). This

framework specifies that cognitive control tasks can be carried out in each of several ways, depending upon the level of experience and expertise of the worker: (Rasmussen, 1983)

- *Skill-based control*: control based on automatic, psychomotor habit
- *Rule-based control*: control based on the logical execution of learned rules or rule sets
- *Knowledge-based control*: control based on the holistic application of knowledge

Of the various theoretical foundations, Rasmussen's approach provides the military C2 analyst with the most comprehensive framework for representing both problem domain and work processes. Its focus on adaptation at the control task and control strategy level is particularly suited to the complex, changing nature of military C2.

A Plethora of Methods for Conducting Cognitive Task Analysis

In addition to examining alternative theoretical frameworks for cognitive task analysis, it is also important to address the state-of-the-art regarding the methods employed for research in this area. In this regard, there exist a very large number of methods offered by different researchers. Accordingly, the North Atlantic Treaty Organization's Research and Technology Organization (RTO) undertook a comprehensive study of these methodologies during the late 1990s This international study—undertaken by Research Study Group 27 on Cognitive Task Analysis (RSG-27)—included both an analysis of the existing review literature on cognitive task analysis plus a 1997 workshop of leading experts in the field. The reviews covered methods employed with either training development or the design of expert systems and job aids published up through 1994. (RSG-27, 2000) In general, most methods begin with a preliminary phase of inquiry that attempts to identify which tasks within a job setting merit detailed attention and analysis This phase of research typically employs one or more of the following approaches: review of existing written materials such as training manuals or procedural manuals, unstructured interviews conducted with expert practitioners, questionnaires, or critical incident analysis. Of specific interest is information that will provide an indication of task frequency, task importance, task difficulty, and those aspects of the task that help distinguish between expert and novice performance. Discussions of these methods in the published literature emphasize the importance—and difficulty—of identifying true experts who are able to effectively articulate the knowledge requirements and solution strategies associated with task performance. (*cf.*, Hall, Gott

& Pokorny, 1995; Hoffman, Shadbolt, Burton & Klein, 1995; Crandall, Klein, Militello & Wolf, 1994)

As noted by RSG-27, the more effective methods of cognitive task analysis organize subsequent interviews and data collection around a knowledge representation framework that is appropriate for the specific task. Here, a variety of approaches can be employed, including the use of annotated goal-method graphs (DuBois & Shalin, 1995), precept-action-result-interpretation structures (Hall, Gott & Pokorny, 1995), mental models of tasks and their context (Crandall, Klein, Militelo & Wolf, 1994), procedural and conceptual knowledge ontologies (Benysh, Koubek & Calvez), and declarative and procedural knowledge ontologies (Williams, Hultman & Graesser, 1998). In addition to the methods employed during the preliminary phase, more formal methods of knowledge elicitation described in the literature include structured interviews, controlled observation of task performance, verbal protocol analysis (thinking out loud), withholding specific information to assess its impact, formal decomposition of critical incidents, and psychological scaling that employs multivariate statistical analysis of pair-wise comparisons. While methods such as structured interviews presumes the ability of experts to directly tap into their own mental processes, RSG-27 cautions that true expertise might remain hidden, that experts often report only a naïve understanding of their own expertise, and that such extracted knowledge will often not stand up to empirical investigation. RSG-27 also makes specific mention of semantic network methods, noting their over-representation in the literature relative to their actual utility. While semantic network methods have been usefully applied with a small set of concepts in limited or closed problem domains, this approach becomes difficult or impractical to take where task performance involves a broad set of concepts. (Olson & Biolsi, 1991)

Wicked Problem Environment and the Rise of Cognitive Work Analysis

A common theme in several recent reviews of the cognitive task analysis literature is that the plethora of available theoretical perspectives and research methodologies has yet to provide analysts with one best approach. As noted by RSG-27, *"...a very large number of particular, rather limited methods are described over and over again. But little is said about how these can be effectively orchestrated into an approach that will yield a complete analysis of a task or job. Little is said about the conditions under which an approach or method is appropriate. The*

literature is also very weak when it comes to specifying the way in which the products of task analysis should be used in designing either training or systems with which humans will interact." (RSG-27, 2000) A similar state-of-art review was conducted by Scott Potter, Emilie Roth, David Woods and William Elm. (1998) Their assessment revealed a wide diversity in (1) the techniques that are employed, (2) the conditions under which domain knowledge is obtained, (3) the type of information generated, and (4) the manner in which the information is presented. In a subsequent paper, these same researchers note that "*The potential effect of this diversity in approaches is confusion as to what the term CTA refers to, what type of results are expected to be produced for a CTA effort, and how these results will impact system development or evaluation efforts. Further, the approaches to CTA are typically labor intensive, paper-based and only weakly coupled to the design and development of advanced decision support systems. Often the CTA generates a large amount of data (*e.g., *audio and video data that must be transcribed) that is time-consuming to analyze, and produces outputs that are not easily integrated into the software development process.*" (Potter, Roth, Woods & Elm, 2000)

As discussed later, a common approach in more recent research has been to employ several CTA methods or techniques together in combination, depending upon the nature and complexity of the domain being studied. Central to this approach has been the development and use of a modeling framework to provide a structure within which to integrate various findings as they emerge from a sequence of research activities.

As researchers began to address more complex work domains, they discovered that work is not always neatly organized into a defined set of tasks and that workers are not always matched (in terms of their knowledge and skills) with the demands of the relevant problem space. For many work domains such as military C2, much of the workers' time and resources can be consumed collectively defining or agreeing upon what is the nature of the problem faced. Once the problem has been defined, multiple task strategies or work threads might be available to develop and execute a workable plan of response. The degree of variability encountered meant that analyses of such systems could no longer be expressed in terms of fixed, linear sequences of task behavior or isolated technological functions. In response, research groups such as those led by Jens Rasmussen at the RISO National Laboratories began to broaden the definition of cognitive task analysis to include several levels of analysis—e.g., work domain, control task structure, control

strategy structure, social/organizational structure, and worker competencies. As part of this movement, the increased complexity of the analysis gave rise to new terms (e.g., wicked problems), new paradigms (e.g., knowledge in context), and new theoretical frameworks (e.g., cognitive work analysis). The following section discusses each of these issues in turn.

New Terms: Wicked Problems

The complexity of modern work environments has given rise to the term "wicked problem"—a situation in which the relevant actors—workers, experts, stakeholders—must apply their own background and experience in order to mentally impose a problem framework on a given situation. (Rittel, 1984) Rather than facing a repetition of familiar goals, constraints, and work tasks, they must first collaborate in order to collectively arrive at agreement concerning the nature of the problem faced. Since response strategy is often tightly associated with perceived problem type, task behavior is no longer fixed, but varies according to the perceived nature and structure of the problem. Figure 3-5 presents a comparison of wicked problems versus other classes of problems and illustrates the increased complexity of the work analysis. At the center of this complexity for wicked problems is the need for collaboration—not just in the sense of pooling situation awareness, domain knowledge, and problem-solving skills, but also in the sense of debating and negotiating a common agreement as to relevant goals, constraints, and means-ends models.

Wicked problems, as a distinct class of problems demanding special attention by researchers, are being increasingly discussed in both the management science and information science literature (*c.f.*, Roberts, 2000; Buckingham, 1997; Conklin & Weil, 1998) Hence, it is only natural that cognitive task analysis methods be expanded to address their unique characteristics and relevant issues.

Simple Problems	Complex Problems	Wicked Problems
CONTEXT • Stakeholders / experts agree on problem framework • Stakeholders / experts agree on solution strategy	**CONTEXT** • Stakeholders / experts agree on problem framework • Stakeholders / experts differ on effective solution strategy	**CONTEXT** • Stakeholders / experts cannot agree on problem framework • Stakeholders / experts differ on relevant solution strategy
MANAGEMENT STRATEGY • Centralized, authoritarian management system • Minimal collaboration • Shared awareness = shared understanding	**MANAGEMENT STRATEGY** • Promote constructive competition among solutions • Minimal collaboration • Shared awareness = shared understanding	**MANAGEMENT STRATEGY** • Problem framework evolves along with solution strategy • Collaborative involvement of relevant stakeholders / experts • Shared understanding must be deliberately developed
EXAMPLE • Theater-level air defense • Anti-submarine warfare	**EXAMPLE** • Destruction of Al Qaeda operations bases in theater • Neutralization of SCUD threat	**EXAMPLE** • Eliminate insurgent threat to US and coalition forces in theater

Figure 3-5. Simple, Complex, and Wicked Problems

Wicked problems are particularly relevant for the study of military C2 teams and organizations. Whereas military operations have been historically defined or modeled in terms of attrition warfare conducted against a defined adversary, modern conflicts are increasingly being characterized in terms of (1) military operations conducted within the context of diplomatic, political, economic, humanitarian, and legal operations; (2) adversaries that are no longer defined strictly in terms of organized military forces, but which can span a range from international terrorist and criminal organizations to tribal clans and religious sects; and (3) desired effects that range from the kinetic destruction of facilities/units to the psychological influence of specific actors and populations.

New Paradigm: Knowledge in Context

The recognition of wicked problems has given rise to a new research paradigm: *knowledge in context*. As discussed earlier in this chapter, an aspect of this complexity was anticipated in the cognitive triad concept of David Woods and Emilie Roth. (Roth & Woods, 1988). Their model suggests that the interpretation and evaluation of information is affected by many factors—some

arising out of the task domain, some out of the operator agents, and some out of the artifacts and representations embedded in information systems and displays.

More recently, the concept of knowledge being contextually defined has become a popular topic in recent research. Knowledge in context implies that for a team or organization to successfully cope with any operational situation, it must bring together both situation awareness and an experience-based understanding of how to interpret and respond to the situation. As pointed out by John Seely Brown and Paul Duguid (1998), the core competency of any decisionmaking organization includes both explicit/codified information (the "know what") that reflects the operational environment and implicit/tacit knowledge (the "know how") that interprets and transforms this information into action decisions. While these two forms of knowledge and information work together, they flow separately within an organization. The so-called "know what" circulates with relative ease—e.g., within the common operating picture, in the case of a military C2 organization. By contrast, the organization's "know how" is embedded within the expertise of individuals or work practices of the organization and is often difficult to track, retrieve, and apply in moment-to-moment decisionmaking. Effective decisionmaking requires management of both components.

Other research has examined the issue of knowledge in context more directly. For example, Michael Muller and David Millen have shown that knowledge is often socially constructed in organizations, with key roles being knowledge gatekeepers and knowledge authority staffs. (Muller & Millen, 2001) Here, knowledge authority staffs refers to those authority figures within an organization who have the responsibility for defining what constitutes value knowledge for the organization's business process. In a more prescriptive sense, Rob Cross, Andrew Parker and Lawrence Prusack found that organizations creating more cohesive networks on knowledge related dimensions are better able to collectively solve problems, create new knowledge and transfer explicit and tacit knowledge embodied within employees. (Cross, Parker & Prusack, 2000)

New Methodological Approaches: Cognitive Work Analysis

The plethora of CTA techniques, combined with a recognition of wicked problems and the need to examine the development and application of knowledge in context, has led to the development

of more integrative strategies that begin to branch out from a focus on cognitive task analysis to the broader challenge of cognitive work analysis (CWA). (Vicente, 1999) Much of this work is motivated by the original theoretical framework of Jens Rasmussen. (Rasmussen, Pejtersen & Goodstein, 1994) Cognitive work analysis has also been referred to as socio-technical analysis because it deals with the combined effects of social, cognitive, and technological systems and their interactions. CWA grew out of field studies that attempted to analyze complex work domains that involved multiple, evolving systems and the need for workers to adapt rapidly to emergent situations. Accordingly, CWA addresses such domains through a layered and interactive set of constraint analyses. As originally defined by Rasmussen *et al*, these analyses include the work domain analysis, task control structure analysis, strategy control structure analysis, social/organizational structure analysis, and worker competency analysis outlined earlier in this chapter.

As compared with CTA, CWA takes a more ecological approach to studying the functioning of a work setting. As illustrated in Figure 3-6, CWA consists of a nested set of analyses—each focused at a different level of detail. At the outermost level, CWA attempts to develop an understanding of the work domain that provides the context for work behaviors. This understanding is developed through a decomposition of the problem space from higher level goals and constraints into various sub-problems that are attacked by different functional experts. Within each functional sub-problem area, the problem space is further described in terms of relevant means-ends structures that represent potential solution pathways. At the same time, the various sub-problems are linked by means of identifying the emergent patterns of interaction and collaboration that must occur in order to coordinate and integrate these potential solution pathways into a meaningful and coherent whole.

Organizational analysis occurs at the next level of CWA. Here, the functional sub-problems and potential solution pathways are analyzed in terms of the overall organization and flow of work; the development, flow, and organization of relevant information required by this work; and the identification of meaningful cues that trigger recognition of specific situational patterns and their corresponding solution pathways. One form of analysis at this level—social network analysis—concerns itself with identifying the relative importance of various work actors and the connective relationships that exist among them. However, as discussed later in this chapter, other types of

analysis can be conducted to explore the dynamic properties and behavior of these networks. One area of specific investigation at this level can be the identification and characterization of emergent patterns of interaction and collaboration over time and situation. Questions asked as part of such analyses include

- What motivates specific actors to seek out and collaborate with each other in a given work situation?
- What types of cognitive, social, organizational, and technological variables facilitate or impede such collaboration?
- What types of actionable knowledge are produced by such collaboration?

Activity analysis—corresponding closely to the original concept of cognitive task analysis—addresses the behaviors and information elements associated with specific tasks performed in the context of the overall work flow. Tasks can correspond to either individual work or collaborative work. At the center of task analysis is the identification of relevant issue / proposition / evidence structures that are built in order to organize available information into actionable knowledge.

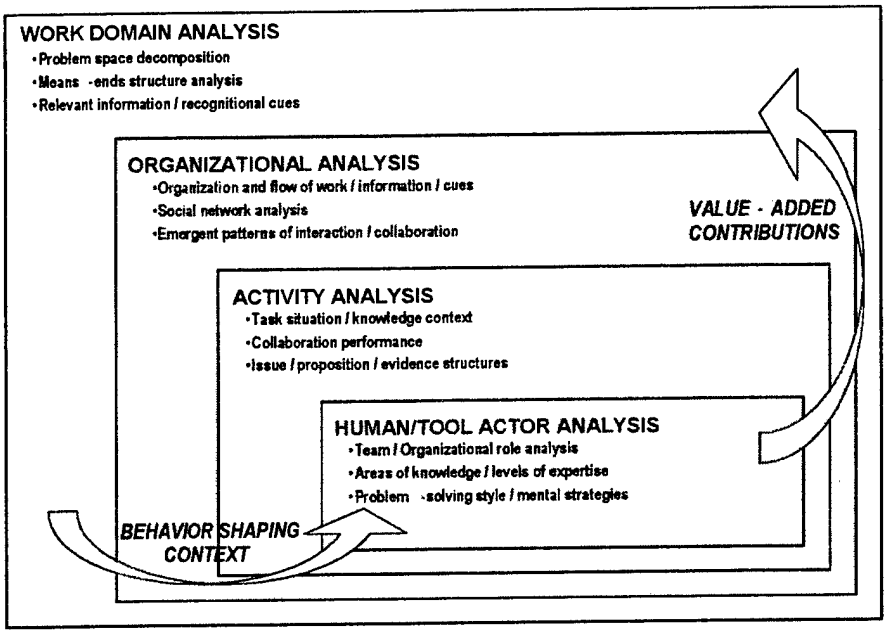

Figure 3-6. Multiple Levels Addressed in Cognitive Work Analysis

Finally, at the core of CWA is the analysis of specific human actors and information tools. This includes identification of team and organizational roles for each actor or tool, assessment of the areas and levels of expertise required, and identification of the mental strategies used for problem-solving. Also considered at this level would be human factor issues related to the cognitive workload capacity of each actor, as well as technical issues related to the processing speed or bandwidth of specific information tools.

Each level of analysis is important in two respects. Working from the outer level inward, each level of analysis defines the analytic context for subsequent levels of analysis. Conversely, working outward, each level of analysis defines the value-added contributions that provide the building blocks for the next higher level of analysis. Such an approach allows the analyst to proceed in an iterative fashion, attacking different levels of the analysis in sequential fashion as other work provides either a refined context or a refined set of building blocks. In this manner, the analyst is able to build up a corporate body of knowledge that provides both an understanding of the problem domain and the work behaviors that operate within that domain.

Cognitive Work Analysis: Four Different Perspectives

Similar to the earlier discussion of different perspectives regarding cognitive task analysis, the current literature reflects a number of different—but related—theoretical perspectives on the structure, focus, and execution of cognitive work analysis. The following discussion summarizes four of these perspectives and highlights their unique contributions regarding important elements of CWA.

Mica Endsley: Situation Awareness-Oriented Design

According to Mica Endsley and her associates at SA Technologies, Incorporated, situation awareness lies at the heart of all human decisionmaking and performance—particularly in "high consequence" systems that must reliably operate under all conditions. Consequently, it is important for CWA to (1) address the different levels of situation awareness involved in decisionmaking, (2) identify the types of operator error that can accrue at each of these levels, and (3) develop methods and system interface principles for optimizing situation awareness. (Endsley, 1999; Endsley *et al*, 2003) Levels of situation awareness and their commonly associated classes of errors articulated within Endsley's framework include

- Level 1: Situation Perception
- Data not available
- Data hard to discriminate or detect
- Failure to monitor or observe data
- Misperception of date
- Memory loss
- Level 2: Situation Comprehension
- Lack of or poor mental model
- Use of incorrect mental model
- Over-reliance on default values
- Level 3: Situation Projection
- Lack of or poor mental model
- Over-projection of current trends
- General
- Failure to maintain multiple goals
- Habitual schema

Endsley's overall approach—referred to as *SA-Oriented Design*—consists of three general steps First, key situation awareness requirements within the work domain are identified through a method called Goal-Directed Task Analysis (GDTA). GDTA is structured around a decomposition of major goals and sub-goals within the work domain. Situation awareness requirements are identified for each sub-goal, including (1) what information is needed by the operator and (2) how the information is integrated or combined to support each decision. As such, her approach differs from traditional cognitive task analysis methods inasmuch as requirements are linked to goals and sub-goals, not tasks.

Next, the approach employs a set of design principles to serve as design guidelines for optimizing the operator-system interface. These principles have been developed based on Endsley's theoretical model of the mechanisms and processes associated with acquiring and maintaining situation awareness in dynamic, complex systems. (Endsley, Bolte & Jones. 2003)

Finally, the approach employs an assessment method—Situation Awareness Global Assessment Technique (SAGAT)—to measure the degree to which the new interface design actually improves situation awareness. The measurement of situation awareness provides an objective assessment of how well the integrated design is suited to the actual challenges of the operational environment.

While some researchers consider Endsley's use of the term "situation awareness" to be too broadly encompassing of higher stages of cognitive reasoning, her methodology nevertheless addresses cognitive work in a comprehensive manner. The focus of this approach to CWA properly addresses various common types of error that can arise in the human-system interface, and her guidelines for optimizing this interface are considered useful. Importantly, Endsley's approach ecologically emphasizes the need for objective assessment in a real-world environment. As a result, the approach is considered useful for analyzing military C2 work domain, particularly at the level of the individual operator. Where this method seems to be limited—at least in its current manifestation—is at the level of collaborative work involving information exchanges and joint problem-solving among multiple operators or decisionmakers.

Gary Klein: Decision-Centered Design

The cognitive work analysis approach developed by Gary Klein and his colleagues at Klein Associates, Incorporated, focuses on decision events rather than situation awareness. This approach to CWA—referred to as Decision-Centered Design—is considered to form an important bridge between the information technology developer and the end user. It is motivated by both the complex of the technology design process and the often inability of users to accurately articulate their needs.

Unlike the approaches of Rasmussen, Vicente, and others that focus on capturing all the relevant factors and constraints that influence cognition, the Klein approach focuses on decisionmaking. This approach is justified as being more relevant in decision situations that are dominated by subjective human goals and intents, rather than situations strongly characterized by physical laws and objective processes. (Hutton, Miller & Thordsen, 2003) The general process flow of Decision-Centered Design is illustrated in Figure 3-7.

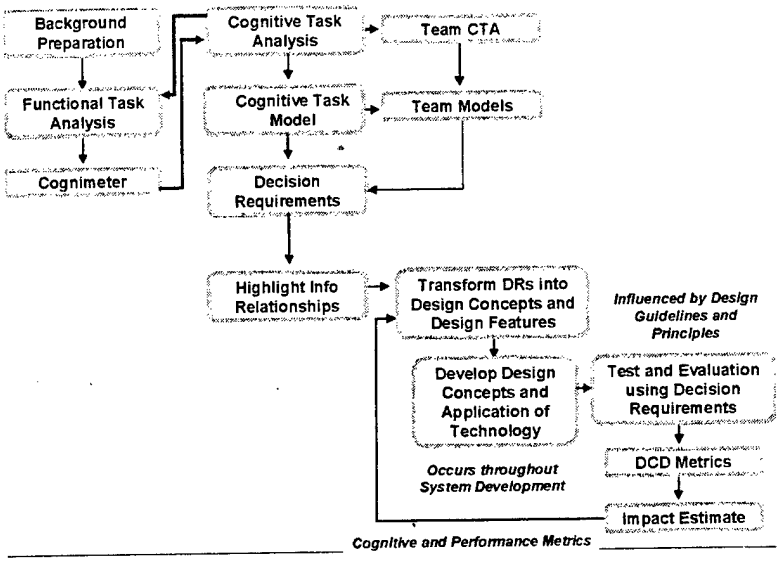

Figure 3-7. Decision-Centered Design Process

As seen in Figure 3-7, the process addresses both individual operators and teams of operators working in a given problem setting. Decision requirements within the work domain are identified and transformed into system interface design concepts and features. As with Endsley's approach, the process includes the development of measurement and assessment metrics for evaluating the final design in a real-world environment.

Like the framework of Mica Endsley, Decision-Centered Design focuses on optimizing the presentation of information to operators and decisionmakers. Rather than structuring the CWA around the concept of situation awareness, however, the Klein approach structures the analysis around key decisions made by the operator. In both cases, the SA-Oriented Design approach and the Decision-Centered Design approach generally presume a stable work domain in which the general classes of decisions can be known through operator interviews and other data collection protocols. Such an approach is useful for military C2 settings such as a shipboard control center or an air traffic control center; however, application of either of these CWA approaches becomes more problematic in wicked problem environments. Indeed, the whole notion of "optimizing" an information system interface to support a specific type of decision is questionable in a wicked problem environment—simply because the relevant classes of information and the manner in which information is best integrated cannot be known *a priori*. Rather, the cognitive challenge is one of collaboratively shaping the decision event and dynamically organizing the information in a manner that yields relevant, actionable knowledge for each emerging decision event.

Robert Eggleston: Work-Centered Design

A *worker-in-context* approach that accommodates a more open work domain is that developed by Robert Eggleston within the Air Force Research Laboratory. Identified as the Work-Centered Design approach, Eggleston's framework follows some of the thinking of Kim Vicente and defines work more broadly as the roles and responsibilities of an individual. (Vicente, 1999) In comparison with the CWA approaches of Endsley and Klein, Eggleston considers work to be more than merely the accomplishment of a preplanned sequence of tasks in some prescribed manner. That is, work is assumed to address unexpected situations and disruptions—thus requiring the human worker to possibly modify how tasks are performed in response to a given situation. An overview of the Work-Centered Design process is reflected in Figure 3-8. (Eggleston, 2003)

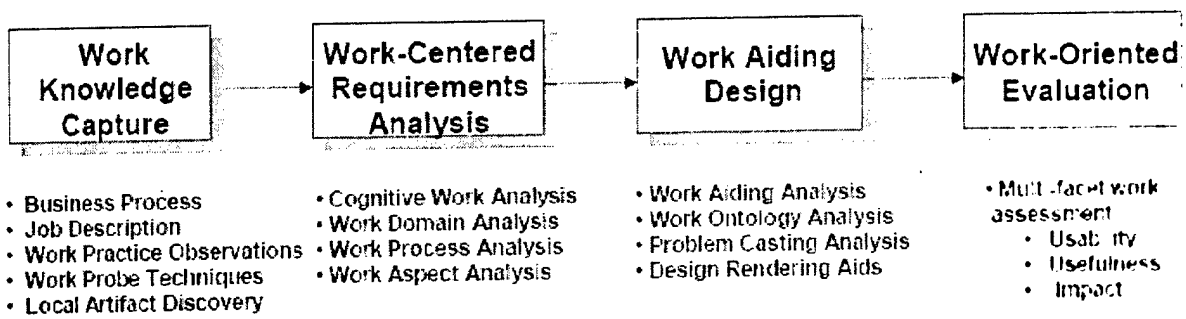

Figure 3-8. Work-Centered Design Process

Work knowledge capture includes the documentation of business processes, job descriptions, and work practices as they comprise a *work system* that is grounded within the context of the organization. Next, work-centered requirements are derived from a layered set of analyses that focus on work domain, work processes, and work characteristics—similar to approach originally developed by Jens Rasmussen. (Rasmussen, Pejtersen & Goodstein, 1994; Vicente, 1999) Here, various aspects of work requirements are separately organized according to event-independent domain properties, event-dependent process or activity properties, and operator agent strategies.

Eggleston correctly notes that the subsequent step of designing work aids is strongly influenced by the manner in which these requirements are defined and organized. Emphasized within this step is the identification and analysis of key terms and their relationships within the work domain—a process that helps to correctly retain the contextualized meaning of these terms in the

design of the work aid. Finally, two forms of aiding are considered within the Work-Centered Design approach. Direct aiding takes the form of automated machine computation that can assist in the fusion, analysis or presentation of information without human intervention or control. Indirect aiding uses representation and visualization to present the work field in a manner that guides worker understanding of the problem in a surrounding context.

As with the other CWA approaches previously discussed, the Work-Centered Design process concludes with an evaluation step. Here, however, Eggleston's methodology for evaluation provides a multifaceted framework for evaluating the usability, usefulness, and impact of the work aid on overall system performance.

The approach developed by Eggleston is highly relevant to the complex and open nature of military C2 at the operational level of decisionmaking. Like the previously discussed methods, however, it is motivated—in its current manifestation—primarily by a desire to enhance human-machine interfaces and the utility of machine-based work aids. Military C2 sensemaking and decisionmaking performance, on the other hand, are influenced not just by information technology, but also by organizational design, personnel training and experience, standard operating procedures, personnel management policies, etc. Thus, an expansion of Eggleston's Work-Centered Design process to address these additional facets of C2 system design would be an appropriate step to take in future research.

Elm, Potter Gualtieri, Roth & Easter: Applied Cognitive Work Analysis

Similar the other methodologies already discussed, the CWA approach collaboratively developed by William Elm, Scott Potter, James Gualtierei, Emilie Roth, and James Easter reflects the goal of making decision support systems transparent to the user. In this regard, the approach—referred to as Applied Cognitive Work Analysis (ACWA)—is built upon several theoretical premises: (Elm *et al*, 2002)

- Humans form a mental model of the work domain as part of their understanding and problem-solving process.
- A decision support system must itself embody a "knowledge model" of the work domain that closely parallels the mental models representative of expert human decisionmaking.

- An effective decision support system knowledge model is composed of functional nodes and relationships intrinsic to the work domain.
- An adaptation of Rasmussen's abstraction hierarchy provides the needed representation of the abstract functional concepts and relationships to form the basis for the decision support system functional knowledge model.

Applying these premises as guiding logic, the ACWA approach attempts to bridge the gap between existing CTA methods and the effective design of decision support systems. As illustrated in Figure 3-9, the approach employs a cycle of several steps to systematically transform an analysis of work domain demands into the identification of specific information visualization and decision aiding concepts that can support the decisionmaker.

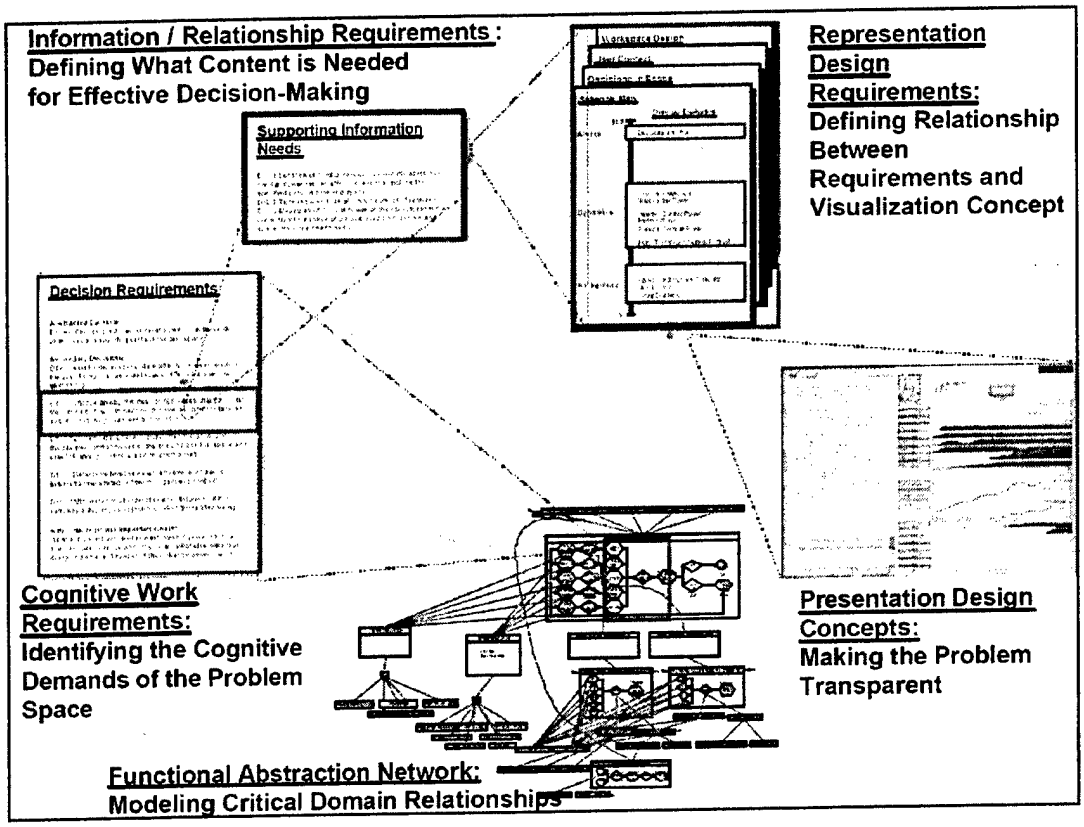

Figure 3-9. Applied Cognitive Work Analysis

The specific steps include:

- A *Functional Abstraction Network* (FAN) model is developed to capture the essential work domain concepts and work relationships that define the problem space.
- Overlaid on top of this functional model is a *Cognitive Work Requirements* (CWR) list that identifies the cognitive demands, tasks, and decisions that arise within the work domain.
- From this analysis, the supporting *Information / Relationship Requirements* (IRR) are identified and linked with the cognitive work requirements.
- Based on the information/relationship requirements, the *Representation Design Requirements* (RDR) are developed that specify what information shaping and processing are required in order to effectively articulate the information and work relationships to the user.
- Finally, the Presentation Design Concepts (PDC) are developed that implement the representation requirements in terms of specific representation (syntax and dynamics) forms for transferring the information to the user. The revolving arrow depicted in Figure 3-9 suggests that the entire process can be repeated in order to successively refine the analysis and engineering design.

Each of these CWA approaches highlights a different aspect of the work setting—e.g., situation awareness, decisionmaking, adaptation of work processes, compatibility of human/machine mental models. As such, they remind the analyst of the various facets of the work setting that must be taken into account as part of a cognitive work analysis effort. However, they are each motivated by the design of information system technology and how that technology supports a human operator. As such, the current manifestations of these CWA methods are considered somewhat limited. By contrast, it is proposed that each of these methods could be generalized to provide broad support to the modeling and analysis of military C2 organizations. That is, the focus of CWA should not be limited to the design of information technology. Rather, these same methods and frameworks can also be applied to the study of leadership and training requirements, organizational design, knowledge management process design, and so forth.

A Model-Centered, Bootstrapping Approach

The need to address cognitive work analysis in a more ecological, holistic fashion has given rise to the notion of a model-centered, bootstrapping strategy. This strategy, developed in a recent

paper by Scott Potter, Emilie Roth, David Woods, and William Elm, is illustrated in Figure 3-10. (Potter *et al*, 2000) These authors argue that the study of work requires more than the application of a single CTA technique. Rather, the development of meaningful understanding of a field of practice relies upon multiple, converging techniques. Additionally, they argue that CTA is inherently a discovery and modeling process—one that moves between two mutually reinforcing perspectives. One perspective focuses on the fundamental characteristics of the work domain and the cognitive demands they impose. Here, the goal is to understand the way the world works and to identify what factors make practitioner performance challenging. This type of analysis provides a framework for interpreting practitioner behavior and performance.

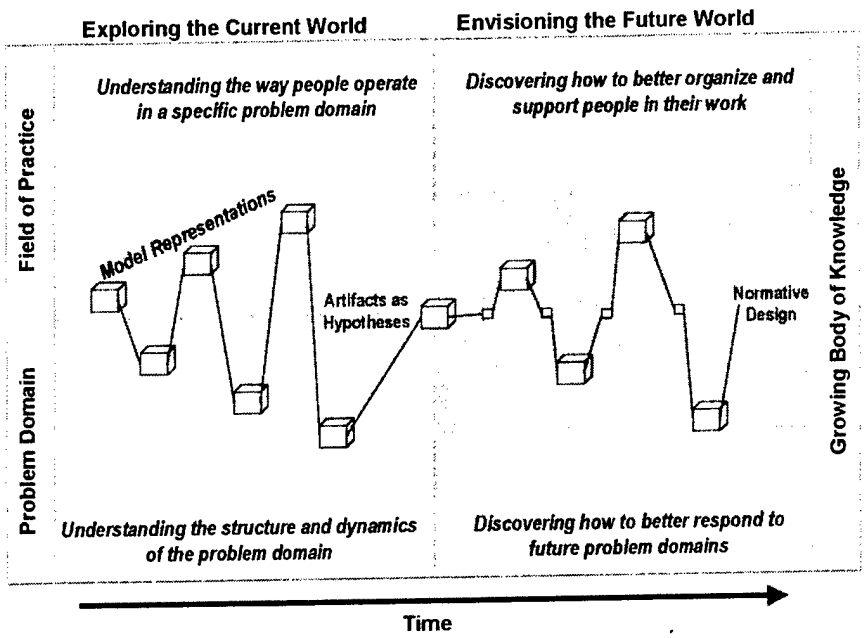

Figure 3-10. Bootstrapping Strategy for Cognitive Task Analysis

The second perspective focuses on how today's practitioners respond to the demands of the work domain. Here, the goal is to understand the knowledge and strategies that expert practitioners have developed in response to the demands of the domain. Linking these two perspectives is the development of a modeling representation that reflects an evolving set of hypotheses about the problem domain and the field of practice. Beginning at the left side of Figure 3-10, the initial modeling representation might be relatively simplistic. However, as more is learned through a campaign of field studies and experiments, this model is gradually refined and given more detail. Over time, the focus of the analysis moves back and forth between study of the problem domain

and study of the field of practice. At each step, the evolving model provides a framework for posing research questions and placing empirical findings in context. Eventually, moving to the right side of Figure 3-10, the model of the problem domain and field of practice is sufficiently mature to support the prescriptive (rather than the descriptive) study of reengineering solutions that can potentially improve overall system performance.

The model-centered, bootstrapping strategy proposed by Potter *et al* is consistent with the general goals of the present research. That is, the development of a veridical model of the sensemaking and knowledge management processes of a military C2 team or organization is thought to be an iterative analytic process that occurs over time in conjunction with a campaign of related field studies and experiments. At the same time, the development of a modeling representation serves as formal structure or framework for organizing both theory and empirical evidence. Hence, the term "bootstrapping" is used to emphasize the fact that the analytic process builds upon itself. Each step taken expands the body of knowledge, providing the opportunity for framing and exploring subsequent research questions. All the while, the modeling framework serves as the integrating architecture for assembling the body of knowledge.

SOCIAL NETWORK ANALYSIS

While the fields of cognitive task analysis and cognitive work analysis have evolved over the past several decades within the academic disciplines of human factors psychology and cognitive psychology, a separate—but related—field of analysis has arisen within the academic disciplines of sociology and mathematics. The next section of this chapter addresses the historical development of social network analysis and how it has moved from the mathematical analysis of static networks to the development of methods that can begin to address the dynamic properties of social networks. As with evolution of cognitive work analysis methods, research in the area of dynamic social network analysis has gravitated toward the use of analytic modeling to provide a more veridical basis for understanding the nature and behavior of social networks.

A Brief History Social Network Analysis

The development of social network analysis as a field of study can be traced back to the interaction of several academic lines during the early and middle parts of the twentieth century. (Scott, 1991) These various strands included (1) the development of sociometric methods that

used various mathematical methods to analyze social structures, (2) the work of Harvard researchers who developed specific methods for studying informal social configurations and cliques, and (3) the study of community structure by a group of Manchester anthropologists. These various academic lines are briefly reviewed in terms of their contributions to present day social network analysis methods.

Sociometrics: The Search for Meaningful Patterns in Social Groups

One academic line stems from the work of several sociometric analysts who were motivated by the earlier development of Gestalt psychology in Germany. Principal among these analysts were Jacob Moreno, Kurt Lewin, and Fritz Heider who all immigrated to the United States from Nazi Germany in the 1920s and 1930s. Following the traditions of Gestalt psychology, they presumed that much of life is structured by organized patterns. Hence, in various ways, they each sought to discover the nature and role of patterns in various social relationships. The work of Moreno led to the development of the "sociogram"—a graphical method of visualizing social configurations in terms of an analytic diagram of points (individuals) and lines (social relationships). Prior to this work, researchers might speak metaphorically of social relationships in terms of "webs" or "networks;" however, Moreno was the first to actually give these terms visual meaning. Figure 3-11 illustrates how a sociogram might be use to visualize the informal network of information and knowledge exchanges within a military C2 organization. In this diagram, directed arcs reflect either a one-way or two-way exchange, while the dashed circles reflect clusters of tightly connected exchanges (referred to as "cliques"). As noted in the diagram, social exchanges can extend across functional or organizational boundaries. The overall pattern of connectivity within a military C2 organization would reflect the organization's ability to integrate different areas of information and expertise into actionable knowledge.

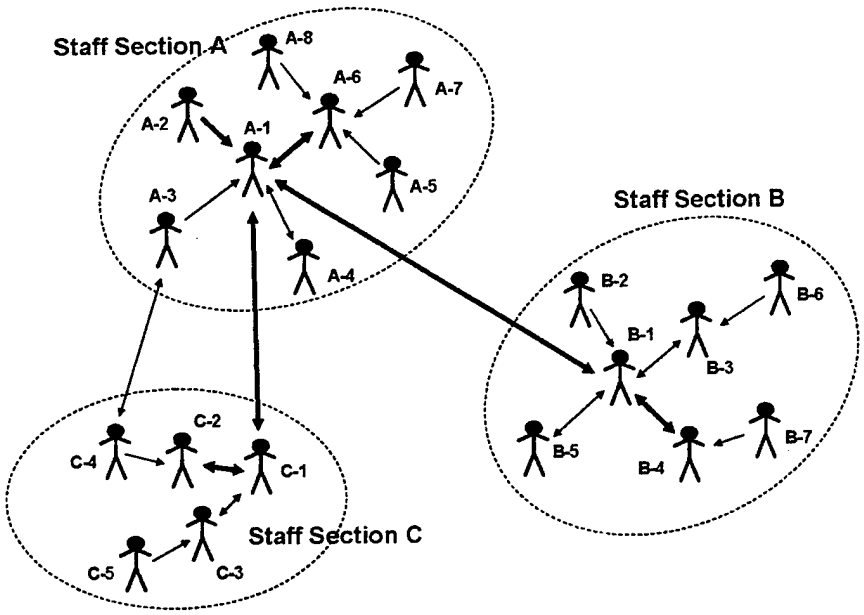

Figure 3-11. Sociogram Depiction of Informal Information and Knowledge Exchanges in a Military C2 Organization

Kurt Lewin is perhaps best remembered for the development of field theory that posited the existence of a "field" or "social space" within which a social group of individuals was located. This field was not external or independent of the group but, in fact, represented the group's perception of its environment—a concept that is related to the present day military notion of "shared situation awareness." The group and its environment were, by Lewin's definition, considered to be elements within a single field of relations. Hence, Lewin believed that the structure and properties of this field could be formally analyzed through the mathematical techniques of topology and set theory. Employing a topological approach, a social field is considered to consist of points (individuals) connected by paths (interactional or causal sequences that connect the individuals). In turn, various mathematical techniques can be used to explore discrete regions and boundaries within the field that serve as constraints to determine group behavior. While field theory proved to be a dead-end for framing social analysis, Lewin's advocacy of topology and set theory would stimulate later work by others. In particular, it served as a motivation for Dorwin Cartwright (Cartwright & Zander, 1953) and Frank Harary (Harary & Norman, 1953) to expand the application of graph theory (originally developed in Germany) to the study of group behavior. That is, Cartwright and Harary took the sociogram paradigm of Moreno and began to analyze these structures of points and lines in terms of the mathematics of

graph theory—a set of axioms and formulae that describes the properties of the patterns formed by the lines.

Fritz Heider's general contribution is seen in the area of group dynamics—specifically, the developed understanding of how an individual's attitudes or perceptions are brought into a state of balance (or agreement) with those of others whom they come into contact. That is, if person A likes person B and person B likes person C, then a state of balance exists only if person A likes person C. Combining the work of Heider with that of Cartwright and Harary subsequently extended the concept of cognitive balance to an entire group. (Newcomb, 1953) Later extensions of this work can be seen to influence the development of theories regarding "group think" within a military headquarters.

The Harvard Researchers: The Discovery of Informal Social Structures in Organizations

In parallel with the development of various sociometric methods, researchers led by W. Lloyd Warner and Elton Mayo at Harvard attempted to develop ways of decomposing social networks into their constituent sub-groups—i.e., clusters, or cliques. Motivated by the earlier fieldwork work in Australia of British anthropologist Alfred Reginald Radcliff-Brown, these researchers began to look for meaningful sub-groupings of people within communities and the work place. One study in particular derived from the research on worker efficiency at the Hawthorne plant operated by Western Electric Company. In the 1920s, psychologists found that worker productivity was enhanced by a variety of different interventions—e.g., improved lighting, heating, rest periods. Mayo's single explanation for this common effect was that workers felt a sense of greater involvement and integration into the company—due merely to their involvement in the research study. Guided by Warner, the Hawthorne investigators initiated a first-ever study of work group behavior in a natural setting—work that led to the documentation of informal social networks. Consequently, a principal contribution of this study to social network analysis was the use of sociograms to describe the actual behaviors and relationships observed in a real-world setting.

Subsequently, this methodology was expanded by Warner as part of several anthropological studies of several small communities. The methodological techniques reflected in these studies paralleled those of the sociometric tradition in many ways. Yet, there is no evidence that either

group of academicians were aware of one another's work during the 1930s and 1940s. Several years later, George Homans reanalyzed much of the original Hawthorne work and created a structural framework for distinguishing behavior as either "formal" or "informal," and dividing all behavior into three categories: activities, interactions, and sentiments. (Homans, 1950) While his work was very influential, this particular typology never received widespread use.

Manchester University: The Application of Sociometrics to the Study of Informal Structure

The formal, analytic consideration of social networks as a focus of research can be traced back to the interaction of a small group of anthropologists at Manchester University during the 1950s and 1960s. It is within this group that the ideas of the earlier schools of thought would come together to produce the framework for present day social network analysis. Specifically, the work of John Barnes, Clyde Mitchell, and Elizabeth Bott during this time period focused attention on the concept of a social "network"—an overall system or pattern of interlocking relationships that mutually influence the behavior of a group's constituents. At this same time, the concept of "role" was beginning to be seen as an important variable in the study of networks. Also, within this group of researchers, there occurred a rediscovery of the importance of sociometrics—e.g., graph theory, linear algebra—as a useful tool for analyzing the structure of networks. Finally, these research elements would combine with current theories in anthropology to focus attention on the relative importance of informal (versus formal) structures within an organization—an idea originally highlighted by the Harvard researchers.

Bringing It All Together: Set Theory, Multidimensional Scaling, and Two Popular Studies

By the 1970s, the use of structural analysis to study social networks was gaining more widespread interest. However, two mathematical innovations at Harvard University would soon provide researchers with an even more powerful set of analytic tools. (Berkowitz, 1982) The first of these innovations was the development of algebraic models of groups that employed set theory to model kinship and other relations within a social structure. This led to further applications of graph theory and other mathematics to analytically represent the concept of "role" within a social structure. The second innovation was the development of the multidimensional scaling methodology—a statistical method for translating relationships into "social distances" and mapping them into an n-dimensional social space. Figure 3-12 illustrates

how multidimensional scaling could be employed to extract meaningful social dimensions from a notional dataset obtained through interviews with members of a military C2 organization.

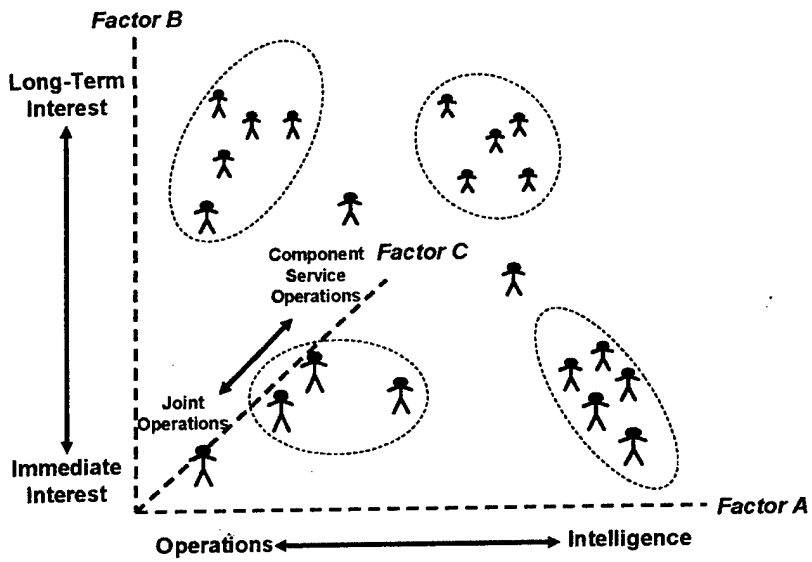

Figure 3-12. Depiction of Notional Multidimensional Scaling Solution for Military C2 Organization

Based on the patterns of the collaboration reflected in the dataset, various factors could be statistically extracted and assigned meaningful interpretations (a total of three statistically significant factors have been extracted in the example shown). Interpretation of these factors and the identification of specific clusters within the *n*-dimensional space would then provide insight into the specific types of social knowledge governing staff collaboration.

Two influential studies by several Harvard colleagues grew out of the confluence of these methodologies—although neither study was highly mathematical in nature. The first study, led by Mark Granovetter, explored the information-gathering methods used by people who are looking for new job opportunities. (Granovetter, 1974) The empirical evidence gathered by the study essentially highlighted the importance of "weak" contacts—i.e., someone outside one's normal circle of contacts—for providing relevant information in novel circumstances. The second study, led by Nancy Lee, studied the patterns of contacts used by women seeking out information on doctors who were willing to perform abortions. (Lee, 1969) This study found that the chains of contacts varied in distance from 1 to 7, with the average being 2.8 chained referrals required to link a women and a person who could provide her with relevant information. More importantly, however, the study showed the importance of informal social networks (over formal

authority structures) for gathering relevant information in novel circumstances. The public attention given to these studies reflected the power of analysis for revealing important insights and led to increased interest in the broad range of methodologies now considered as part of social network analysis.

The Essential Elements of Social Network Analysis

As defined in recent literature, social network analysis reflects a broad spectrum of algebraic and statistical methodologies that can be used to map and measure relationships and flows among people, groups, organizations, computers, and other information/knowledge processing entities. These analytic techniques range from simple counting and frequency distribution procedures, through various graph theoretic and statistical programs such as multidimensional scaling, to integrated software packages such as UCINET[8] and NetVis[9] that support the analysis and graphic visualization of social network databases. In a recent keynote address to a workshop sponsored by the National Research Council, Ronald Breiger outlined six distinctive themes that have characterized social network analysis research in recent decades: (Breiger, 2003)

Relational Measures

Measures on network nodes, arcs, and overall structure have been developed to reveal different types of relational insights. Common examples include node centrality measures such as

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[8] UCINET, distributed by Analytic Technologies, Incorporated, is a comprehensive program for the analysis of social networks and other proximity data. The program contains dozens of network analytic routines, stochastic dyad models, network hypothesis testing procedures, plus general statistical and multivariate analysis tools such as multidimensional scaling, correspondence analysis, factor analysis, cluster analysis, multiple regression, etc. In addition, UCINET provides a host of data management and transformation tools ranging from graph-theoretic procedures to a full-featured matrix algebra language.

[9] NetVis is a free open source web-based tool to analyze and visualize social networks using data from csv files, online surveys, and dispersed teams.

"degree" (the number of direct connections a node has with other nodes) and "betweenness" (a measure of shortest path distance between network pairs that include a specific node). Other measures such as "clustering coefficient" reflect the degree to which the acquaintance sets of two connected nodes overlap. Finally, "constraint" is a measure of the extent to which a node is tied to people that have a vested interest in one another.

Role Interlock

Analyses of role interlock typically focus on identifying the various ways in which actors are linked together—e.g., kinship (brother of, father of), social role (boss of, teacher of, friend of), affection (likes, dislikes, respects), cognitive (knows, holds similar views), actions (talks with, provides products to, attacks), distance (physical distance, psychological distance), co-occurrence (is in same department, has same military rank), or mathematical (is two nodes removed from). Role interlock has been modeled by means of algebraic semigroups, homomorphisms, and novel statistical procedures such as cluster analysis. Past studies where role interlock becomes a relevant issue have frequently explored patterns of collaboration and advice-seeking among actors within a business organization or community.

Equivalence

Concepts of equivalence bridge the gap between "ego analyses" that focus on individual-level ties/connections and "complete analyses" that address the overall macro structure of a network. Equivalence is defined in terms of two nodes that are placed similarly with respect to all other nodes within a specific network. Structural equivalence exists where two nodes have an identical relation to all actors in a network involving multiple types of ties. Automorphic equivalence exists where two nodes have identical types of connections to a similar (but not the same) set of actors. Studies of equivalence have been reflected in past analyses of international diplomatic, military, and economic exchanges.

Duality

Duality refers to the notion of examining a social structure from multiple perspectives when its constituent members are placed within different groups or at different organizational levels. For example, a study that focuses on the individual might define a certain set of members in terms of their holding common membership in a particular group. Conversely, an analysis might focus at

the group level and define group-group linkages on the basis of how many members they share in common. A similar duality can be reflected in studies that explore different levels within an organizational structure. In this regard, various innovative sampling techniques and analytic frameworks have been developed to specifically address dual network situations. (McPherson, 2001)

Social Influence

Studies of social influence have attempted to explore the influence of actor attitudes and behaviors on the formation and functioning of social network structures. Often emphasized within these studies has been the issue of equilibrium—how actors' attitudes and perceptions are adjusted to those held by others who have some influence on that actor. Conversely, other studies—viewing constituent members of an organization as interdependent entrepreneurs—have examined the role of equilibrium in creating the conditions for self-synchronization or self-governance.

Visualization

Recent computer science advances in the area of data visualization have led to the development of powerful methods for graphically visualizing network structures. As these methods of visualization have been advanced, they have been integrated with formal mathematical modeling techniques to provide improved methods for visualizing various network properties such as equivalence and centrality.

The Emergence of Dynamic Social Network Analysis

In large part, the field of social network analysis has presumed a certain level of stability or "stead-stateness" regarding the structure and behavior of social groups and organizations. As a result, the plethora of graphical and statistical methodologies that have emerged over the past several decades are limited to exploring the static characteristics—or topology—of a network. By contrast, there has been a growing recognition within the fields of psychology and sociology that social networks change over time in response to environmental conditions. Conversely, research on sensemaking suggests that the failure of social networks to adapt to new or novel conditions can have catastrophic consequences in terms of organizational decisionmaking and performance. In this regard, a new branch of social network analysis has begun to emerge that

focuses specifically on the exploration of a network's dynamic properties and behavior. In the recent National Research Council workshop on dynamic social network analysis (referenced earlier), several themes emerged regarding the study of dynamic social networks:

Network Effectiveness

Recent ethnographic studies have suggested that the behavioral dynamics of groups can vary dramatically—even though the groups might have a similar physical or cultural context, similar organizational goals, and similar formal structure. (Johnson, Palinkas & Boster, 2003) Such variability highlights the limitations of static performance measures for providing insight into the functioning of social networks. Understanding the root causes of this variability is essential—particularly in high-reliability settings such as military C2 teams and organizations—in order to identify appropriate types of interventions for insuring a minimum level of performance. Key variables that have been identified in this work to date include

- Distribution and relative fit of group member roles
- Agreement among group members as to individual functions and responsibilities
- Ability of group members to adapt to unforeseen events
- Redundant coverage of roles to compensate for the loss of any one member
- Agreement on group goals and objectives

Studies of dynamic social networks have also employed multi-agent forms of computational processing in order to represent links among different network actors in probabilistic form. (Carley, 2003; Macy, Kitts & Flache, 2003) Use of multi-agent simulation models have allowed researchers to explore various dynamic behaviors including (1) the ability of networks to self-repair and (2) the emergence of competing factions within a social group.

A third approach to studying network dynamics is reflected in the current study of scale-free social networks by statistical physicists. (Stanley & Havlin, 2003) Scale-free networks are networks in which the distribution of connectivity is extremely uneven—e.g., a very large number of individual nodes singularly connected to a small number of "hub" nodes. (Barabasi & Albert, 1999) Interest in understanding the properties of scale-free networks has arisen primarily because they correspond to certain types of real-world networks—e.g., hub-spoke airline route systems, the worldwide web and other computer networks, disease epidemics. Studies have

shown such networks to be resilient to random node failures, but highly susceptible to deliberate attack.

Finally, Kathleen Carley's metamatrix approach represents yet another approach to studying the behavior of social networks in the broader context of other organizational variables. (Krackhardt & Carley, 1998; Carley & Hill, 2001; Butts *et al*, 2001) Under this approach, organizations are conceived of being composed of a set of elements that fall into one of the following classes:

- *Personnel.* Individual agents within the organization (human or otherwise) which are capable of contributing labor to task performance and which form a locus for knowledge (procedural or declarative), social contacts, task assignments, and/or control of resources
- *Knowledge.* Functionally coherent elements of procedural or declarative information (generally pertaining to organizationally relevant task performance) to which agents may have access (often synonymous with human capital)
- *Resources.* Passive elements of organizational structure which act as inputs to task performance and which may be controlled by agents (often synonymous with physical capital)
- *Tasks.* Organizational objectives which must be met by a specified agent performance (usually involving resources and/or knowledge)
- *Organizations.* Organizational entities beyond the entity under immediate study (i.e., other organizations within the environment)

The organization is then defined by the set of elements, together with the dyadic relationships among these elements. It is the analysis of these dyadic relationships which lies at the heart of the metamatrix approach.

Local Structure Impact on Global Behavior

Various computational modeling approaches have been recently employed to study changes in local actor properties/behavior and their resulting impact on global behavior patterns within a social network. (Carley, 2003; Macy, Kitts & Flache, 2003) These approaches have included both multi-agent modeling paradigms and the use of Markov chain statistical models. Two recent studies have illustrated the potential application of multi-agent social network modeling to military C2 teams and organizations. In one study, a dynamic, discrete-event, multi-agent

simulation model of an intelligence organization was used to examine the impact of organization structural and policy changes on the flow and integration of intelligence information. (Behrman & Carley, 2003) In a second study, researchers conceptually articulated how such a model might be used to explore the impact of network-centric information databases and transactive memory—knowledge of who knows what—on the performance of military C2 teams and organizations. (Carley, 2002).

A roundtable discussion at the recent National Research Council workshop on dynamic social network analysis examined the role of computational simulation modeling versus the traditional methods of social network analysis—e.g., ethnography and statistical analysis. On the one hand, a continued emphasis on the empirical study of real-world social groups is necessary in order to help modeling analysts distinguish real patterns of behavior versus wishful thinking. On the other hand, the use of computational models allows deeper investigation of causal factors and the exploration of possible—rather than predictive—behavior. Combining these arguments results in the same type of bootstrapping, model-experiment-model strategy articulated earlier in this chapter in connection with cognitive work analysis.

PUTTING THE PUZZLE TOGETHER: TWO METHODOLOGICAL TRADITIONS WITH A COMMON PURPOSE

Having reviewed the historical development and current state of both cognitive task analysis and social network analysis, it is now appropriate to address how these different methodological traditions relate to one another. In doing so, we discover several things. First, they are each motivated by a similar goal: the discovery of laws of human behavior that can be used to predict and improve future performance. Next, each tradition employs mathematical paradigms to structure empirical findings into meaningful insights that can be used to both explain human behavior at a deeper level and generalize those explanations to other settings. Finally, both methodological traditions have recently evolved to recognize that analytic modeling plays a central role in the development of a useful body of knowledge. To borrow a familiar metaphor, the fields of cognitive task analysis and social network analysis are like story of the committee of blind men examining an elephant—each describing different parts of the same animal, but from different isolated perspectives. Having recognized the complementary nature of these perspectives, it is now time to integrate them into a single, purposeful research strategy.

A Comparison of Common Themes

As illustrated in Figure 3-13, cognitive task analysis and social network analysis reflect a number of common themes. Cognitive task analysis—and, more recently, cognitive work analysis—provides a systematic approach to studying the cognitive structure of individual practitioners in various work settings. This expertise is typically described in terms of a state-action-goal linkage structure. In turn, expertise—or tacit knowledge—is placed in the context of work-relevant tasks. Finally, work tasks are understood in the ecological context of problem domain, organizational structure, social culture, training, and so forth. Similarly, social network analysis—and, more recently, dynamic social network analysis—provides a systematic approach to studying the interactive behavior of social groups in various work settings. This behavior is typically described in terms of an actor node-relation-boundary linkage structure. In turn, this structure places individual behavior in a specific social context. Finally, social behavior is understood in the ecological context of roles, familiarity and affections, physical and psychological distance, and so forth.

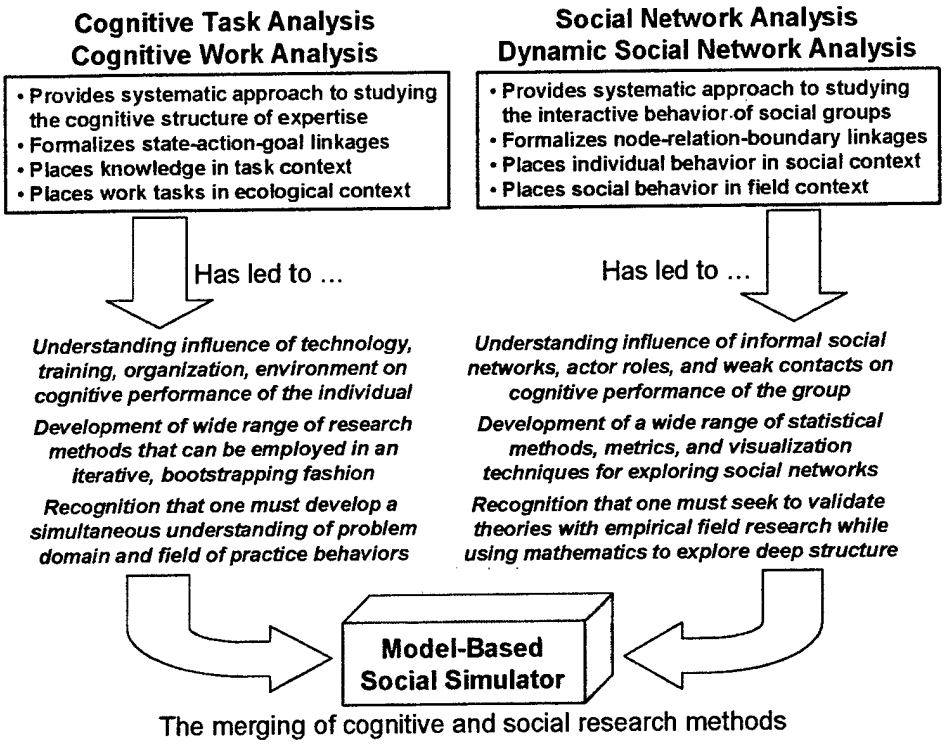

Figure 3-13. Comparison of Methodological Traditions

As cognitive task analysis and social network analysis have evolved over the past several decades, they have each led to comparable types of understandings, developments, and recognitions. Cognitive task analysis has led to greater understanding of how information technology, training, organizational structure, and work environment influence the cognitive performance of the individual. Likewise, Social network analysis has led to greater understanding of how informal social networks, actor roles, and weak contacts influence the cognitive performance of groups. Cognitive task analysis has led to the development of a wide range of data collection and research methods that can be employed in an iterative, bootstrapping fashion to represent cognitive structures and functions of the individual. Likewise, social network analysis has led to the development of a wide range of data collection and research methods, metrics, and visualization techniques that can be employed to explore the structure and functioning of social networks. Finally, cognitive task analysis—as it has developed into the broader domain of cognitive work analysis—has led to the recognition that one must simultaneously understand both problem domain and field of practice in order to link cognition with meaningful action in the real world. Similarly, social network analysis has led to the recognition that the empirical validation of theory and the mathematical exploration of possible outcomes reflect two essential sides of the research coin.

As depicted in Figure 3-13, the recent trend within each of these methodological traditions has been the increased use of discrete event simulation modeling. As argued by Scott Potter, Emilie Roth, David Woods, and William Elm (Potter *et al*, 2000), such modeling attempts to build an analytic understanding of both the problem domain and field of practice—thereby providing a common framework for accumulating and extending both theory and empirical evidence. Similarly, social network researchers such as Kathleen Carley, Michael Macy, James Kitts, and Andreas Flache have employed agent-based computational modeling in order to better understand the dynamic properties of social networks. (Carley, 2003; Macy, Kitts & Flache, 2003) In both cases, modeling serves not only to organize empirical findings in terms of interpretable paradigms, but also to explore the potential implications of these findings for future settings. Employing an iterative, bootstrapping strategy, recent advances within each methodological tradition have demonstrated the power of a model-experiment-model research campaign.

Merging and Extending the Two Methodological Traditions

The present project extends the trend just noted by placing modeling activities in the context of an overall research campaign—one that uses modeling as a framework for integrating cognitive and social research methodologies. Building upon the past, it is suggested that the next generation of military C2 modeling should exploit the range of data collection and analysis methods that have emerged from cognitive task analysis and social network analysis. From the tradition of cognitive task analysis, this includes methods that allow isolation, identification, organization, and interpretation of the types of knowledge practitioners employ to accomplish specific work tasks:

- Review of existing written materials such as training manuals or procedural manuals,
- Unstructured interviews conducted with expert practitioners,
- Questionnaires,
- Critical incident analysis,
- Structured interviews,
- Controlled observation of task performance,
- Verbal protocol analysis (thinking out loud),
- Withholding specific information to assess its impact,
- Formal decomposition of critical incidents, and
- Psychological scaling that employs multivariate statistical analysis of pair-wise comparisons.

From the tradition of cognitive work analysis, this includes methods that organize an understanding of cognitive work into a hierarchical structure:

- Work domain analysis to identify the high-level purposes, priorities and values, functions, and physical resources of a work domain;
- Activity analysis to identify the specific work tasks that are carried out in the work domain;
- Strategy analysis to identify different information gathering, problem-solving, and collaboration strategies for carrying out each work task;

- Socio-organizational analysis to identify how work responsibilities are distributed across a team or organization; and
- Worker competencies analysis to identify the competencies (areas and levels of expertise) required by workers to carry out the work of the system.

From social network analysis, this includes methods and metrics that facilitate exploration, identification, and visualization of relationships within a social network setting:

- Graphical depiction of functional, authority, and social relationships within team or organization in terms of directed graphs, sociograms, and other visualization methods;
- Analysis of physical, social, or psychological distance estimates via multidimensional scaling to reveal explanatory factors underlying patterns of interaction and collaboration within a team or organization; and
- Analysis of multiple attribute sets across a group of actors via clustering algorithms to reveal central roles and meaningful grouping variables (a multivariate statistical technique that can be used to complement multidimensional scaling).

Looking to the future, the integrated findings and insights developed from a review of current sensemaking and knowledge management literature enhances the theoretical foundation that can inform and focus the application of existing cognitive task analysis and social network analysis methodologies. Specifically, this literature provides a theory-driven model of knowledge creation that

- Addresses both positivist and constructivist modes of cognition and sensemaking;
- Identifies unique actor roles at different levels within an organizational sensemaking process;
- Identifies work task differences specifically associated with wicked problem spaces; and
- Explicitly defines codified knowledge, tacit knowledge, and social knowledge as three essential inputs to collaborative sensemaking.

At the same time, the current literature suggests that actionable knowledge is best represented as a state of information organization, rather than as a finite commodity to be managed. Knowledge state, in turn, is defined in terms of a networked set of goals, hypotheses, and organized

evidence—a network that, in the case of shared knowledge, socially defined by various functional experts and stakeholders. State deficiencies can be defined in terms of specific metrics such as ambiguity, uncertainty, complexity, and equivocality. Since the network characteristics of knowledge state are, in some ways, similar to the characteristics of social networks, it seems reasonable to investigate whether insights regarding one type of network might help to inform our understanding of the other.

Finally, the current literature on sensemaking and knowledge management provides a new set of paradigms for organizing our thinking about cognition and social networks. The "organization as amplifier of individual knowledge" paradigm usefully directs research attention to the importance of *ad hoc* project teams in the knowledge creation process. The "organization as a marketplace of information" paradigm offers a way of visualizing the impact of various cognitive, social, and technological obstacles on the flow and exchange of information within a group or organization.

How these various facets of research potentially come together is illustrated in Figure 3-14. Cognitive task analysis and social network analysis—each a product of multidisciplinary thinking in the past—have evolved to the point of recognizing the power of discrete-event simulation for representing and exploring the deep structure of cognitive behavior at the individual, group, and organizational levels. At the same time, they each bring a rich tradition of data collection and analysis methodologies that can be used in concert with simulation modeling to document and organization our understanding of cognitive behavior at each level.

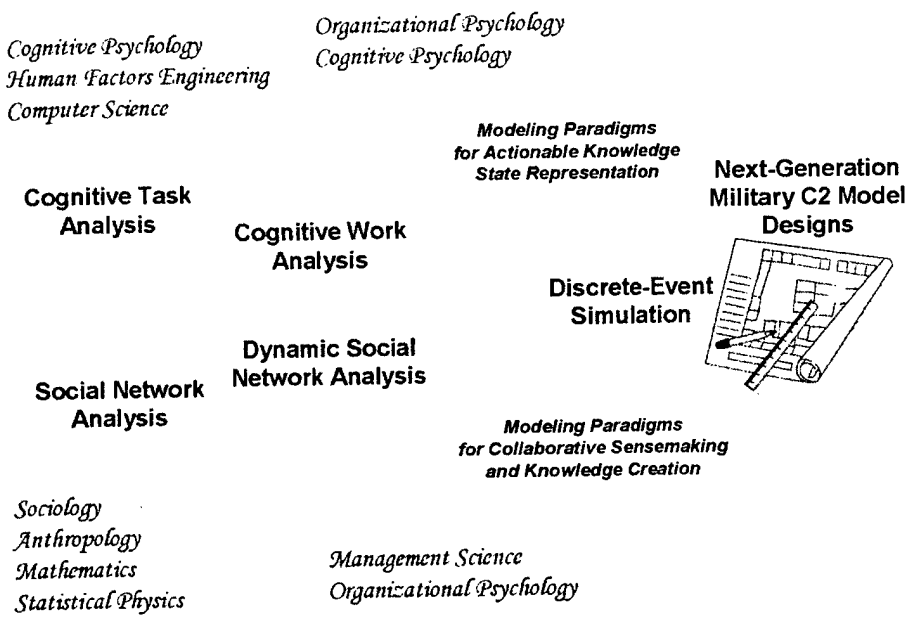

Figure 3-14. Next-Generation Military C2 Model Designs

The present study has shown that current research literature on organizational sensemaking and knowledge management provides various modeling paradigms that can further guide and focus the application of these methodologies—specifically in the areas of actionable knowledge state representation, collaborative sensemaking, and knowledge creation. As a result, this constellation of research theory and methodology provides the enhanced basis for developing the next-generation military C2 models—models that are capable of

- Explicitly representing the "value added" of military C2 systems in terms of their ability to collect, interpret, and organize available information into goal-specific actionable knowledge;
- Explicitly representing knowledge creation as a collaborative process occurring across a group or organization of different functional experts and stakeholders;
- Explicitly representing the "command" aspect of military C2 in a wicked problem environment, as opposed to merely reflecting simplified "control" algorithms; and
- Explicitly representing the impact of various ecological factors—doctrine, training, personnel management, organizational structure, technology—on work task behaviors at the individual, group, and organizational level.

SUMMARY

In summary, this chapter has examined two methodological traditions that can each support the development of future military C2 models. Cognitive task analysis—and, more recently, the broader field of cognitive work analysis—provides a set of theories, data collection and analysis methods, and overall research strategy that can be used to structure future modeling projects. Specifically, this methodological tradition places individual cognitive work tasks in an organizational and social context and emphasizes the developed understanding of both problem domain and field of practice. While most of the more recent methods of cognitive work analysis have been motivated by the design of information technology and decision aids, it is proposed that these various methods could be easily generalized to address the analysis and modeling leader and training requirements, organizational design, knowledge management process design, and other factors influencing the performance of military C2 organizations. Social network analysis—and, more recently, dynamic social network analysis—provides a complementary set of theories, data collection methods, and visualization and analysis methods that can be used to organize our understanding and representation of cognitive behavior at the group and organization level. As with the field of cognitive work analysis, most of the social network analysis methods can be easily generalized to support the modeling and analysis of military C2 organizations.

A review of more recent literature suggests that each of these methodological traditions are increasingly embracing the use of discrete-event simulation modeling to provide both (1) a framework for integrating an evolving body of knowledge and insights and (2) a means for exploring the deep structure of cognitive behavior at the individual, group, and organizational level. The findings of the present study complement these traditions by providing a set of modeling paradigms—specifically, paradigms for representing actionable knowledge state, collaborative sensemaking, and knowledge creation—that can further guide and focus the application of these methodologies. Combining these methodological traditions with the findings of current literature on sensemaking and knowledge management provides the enhanced basis for developing the next-generation military C2 models.

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CHAPTER 4: CASE STUDY: SENSEMAKING AND KNOWLEDGE MANAGEMENT FOR EFFECTS-BASED TARGETING

INTRODUCTION

Having described a framework for actionable knowledge (Chapter 1), outlined the key facets of an organizational sensemaking and knowledge management process (Chapter 2), and discussed the fields of cognitive work analysis and social network analysis (Chapter 3), this final chapter presents an application of this conceptual work to a current area of military C2. Specifically, the area selected for this demonstration is the area of effects-based targeting. Effects-based targeting derives its name from the newly emerging topic of effects-based operations (EBO).

What is EBO?

EBO is a transformational concept that shifts the emphasis of military force application from simple attrition to the achievement of specific coercive effects on an adversary. The concept began to appear in military writings around the beginning of the 1990s and was underscored by both (1) the fall of the Soviet Union and disintegration of the Warsaw Pact and (2) the rapid military victory achieved against Iraqi forces in Operation Desert Storm. Both of these events stimulated new ways of thinking about how military forces should be employed to achieve political goals. While the roots of EBO can be traced back to Sun Tsu and other historical military theoreticians, its basic principles were obscured during the Cold War as military planners thought of operational outcomes primarily in terms of force exchange ratios and attrition-based defeat mechanisms. With the advent of new types of asymmetric and unconventional adversaries, military writers began to "rediscover" how military operations are but one of several instruments of national security policy that can be employed to prevent crises, shape adversary thinking, and—if necessary—bring an adversary into compliance with a stated national or international goal. Additionally, recent operations such as Allied Force, Enduring Freedom, and Iraqi Freedom have illustrated the complexity and difficulty of orchestrating military operations within a coalition environment.

While a formal definition of EBO does not exist, Paul Davis offers a reasonably useful summary: "*Effects-based operations are operations conceived and planned in a systems framework that*

considers the full range of direct, indirect, and cascading effects, which may—with different degrees of probability—be achieved by the application of military, diplomatic, psychological, and economic instruments." (Davis, 2001) In its most elementary form, EBO can be defined as a way of thinking about planning, executing, and assessing military operations that focuses on achieved results—and the explanation of how those results came about—rather than on physical actions (e.g., sorties flown, rounds fired). As noted by Maris McCrabb, EBO "*spans the gamut of military operations from humanitarian relief to major theatre war. It accounts for lethal and non-lethal applications of force delivered kinetically or via non-kinetic modes. EBO incorporates and expands upon traditional approaches such as targets-based and strategy-to-task. ...The goal of an effects-based approach is tracing and understanding how those actions affect the attacker or enemy commander's behavior. Functions are defined as broad, fundamental, and continuing activities. Processes, or activities, are how work—tasks--is done. For commanders, the most basic activities are planning, executing, and assessing operations. EBO is a method for accomplishing those tasks.*" (McCrabb, 2002)

The Challenges of Developing an Effective EBO-Based Targeting Process

Despite the recent plethora of papers, books, and articles that have been written on EBO, it remains a debated concept without hard operational definition. In terms of basic ontology, EBO introduces a variety of terms such as "*indirect effects*," "*cascading effects*," "*center of gravity*," "*psychological and political will*," that are intuitively appealing, but which are difficult to operationally define and measure. In terms of operational strategy, EBO implies the need to coordinate and synchronize lethal combat actions with intelligence operations, information operations, psychological operations, humanitarian operations, civil-military affairs operations, economic aid and rebuilding programs, legal constraints, criminal investigations, and other instruments of national security policy. Yet, few, if any, analytic tools are available to assist military planners in addressing and reconciling the diverse set of goals and performance measures represented across these different areas. Indeed, it is likely that a combination of both quantitative and qualitative analysis will likely be required to address these diverse facets of the problem domain. (Davis, 2001) Finally, in terms of organizational structure, constituent elements, and process, EBO reflects the need for new leadership and thinking skills, new models of decisionmaking, new information support tools, new organizational structures, and new command and staff procedures. Yet, the Services and Joint commands have yet to develop a comprehensive framework for reengineering military C2 in ways that will enable better

management of EBO at both a tactical and strategic level. All of these challenges suggest that much work remains to be done with regard to developing an effective EBO-based targeting process.

In this regard, it is useful to briefly review the history of EBO and its impact on targeting in recent military operations.

Parallel Warfare and Effects-Based Operations

As noted by Air Force Brigadier General David Deptula in a historical review of air operations, advances in precision weaponry have made possible a transition from the massive bombing campaigns of World War II to the focused targeting of selective high value centers of gravity. (Deptula, 2001) As demonstrated during Operation Desert Storm, the employment of airpower—including both manned aircraft and long-range cruise missiles—is no longer constrained by the need to deliberately roll back air defenses prior to engaging other vital elements of an adversary's power base. Employing a concept known as parallel warfare, strike planners could now orchestrate the simultaneous engagement of high-value targets—thus bringing about a rapid collapse of an adversary's offensive and defensive capabilities. Concurrent with the introduction of parallel warfare was the concept of effects-based operations, a targeting strategy that focuses on achieving specific operational effects against an adversary, rather than merely insuring the physical destruction of a long list of facilities and other assets. Taken together, the concepts of parallel warfare and effects-based operations hold the potential for both increasing the operational impact of airpower and allowing this impact to be achieved more rapidly with a given set of airpower resources.

Emerging Complexities in the Targeting Process

Full exploitation of this potential, however, requires a profound change in the process by which such operations are planned, coordinated, and executed. As noted by General Deptula, early indications of such change were reflected in 1990-91 as Air Force planners attempted to shift away from the tactical targeting focus developed originally during the Vietnam War. Under this old system, Air Force target planners simply responded to lists of tactical targets provided by ground force commanders. Effectiveness of this command and control (C2) system was measured in terms of target destruction efficiency—i.e., how quickly and thoroughly could the

Air Force insure destruction of the provided target list. Beginning in 1990-91, the Air Force began to supplement tactical target planners forward-deployed at Riyadh, Saudi Arabia, with a nucleus of offensive target planners from Washington. This special planning group employed the new concepts of parallel warfare and effects-based operations to revise and refocus the initial air operations plan for Desert Storm on the simultaneous attack of high-valued targets throughout a sustained air campaign. The effectiveness of these operations for rapidly degrading Iraq's military capability is now a matter of history. While Desert Storm offered an initial demonstration of this new potential, its successes were not without some unforeseen problems. For example, destruction of the electric power grid around Baghdad—originally intended to disable Iraq's air defense system—also caused unintended consequences such as the disabling of water treatment plants that led to increased health problems in the civilian population. However, the complications exhibited with the targeting process during Operation Desert Storm were just a preview of problems that would arise during subsequent military operations.

During Operation Allied Freedom in Kosovo, air operations were envisioned by the SACEUR commander to win the race between target destruction and reconstruction. (Clark, 2001) That is, the objective was to target assets deemed critical to Yugoslavian President Milosevic faster than the Yugoslavian government could repair them or develop workarounds—thus forcing Milosevic to capitulate. In reality, however, what should have been a straight forward military planning process was complicated significantly by differences in operational perspective between military planners in Washington versus those at SACEUR headquarters. Without an introduction of NATO ground forces into the theater of operation, air planners had to revert to a focus on tactical warfare. At the same time, target nominations had to undergo a time-consuming review and approval process in Washington as the United States and its NATO allies debated over operational strategy and priorities. As a result, the advantages of information superiority and precision weaponry were frequently negated as Serbian forces began to take advantage of NATO's lengthy air operations planning cycle. (Thomas, 2000) Clearly, the targeting process needed further refinement when military operations were conducted in a complex political and diplomatic context.

Operation Enduring Freedom in Afghanistan presented a new set of challenges for conducting EBO-based targeting operations that were considered time-sensitive. While the military

objectives of defeating the Taliban's military power and destroying the Al Qaida's terrorism network were relatively straight forward, overall air operations were complicated by the need to preserve the regional infrastructure needed to support humanitarian aid to the Afghan civilian population. At the same time, there was confusion between the higher-level CENTCOM staff and the regional CENTAF staff regarding the definition of time-sensitive targets[10] and the level of approval authority required for executing specific target lists. While CENTAF decisionmaking tended to focus on targeting issues of tactical and operational concern, CENTCOM discussions necessarily addressed the strategic and political implications of targeting and the risk associated with unintended collateral damage. As a result, the subsequent time delays associated with identifying and resolving political, diplomatic, and legal issues within and between these headquarters were often the driving factor in mission success or failure. (LaVella, 2003) Except for some reported problems in the Combined Air Operations Center (CAOC) of sharing targeting information between the Joint Intelligence Center (JIC) and the CAOC air planners, the technical linkages in the target-to-shooter information chain were not a limiting concern. Rather, it was the intervening human collaboration, sensemaking, and decision processes that were found to need attention and improvement.

Within the past year, several technological improvements have focused on improving target planning collaboration and decisionmaking within the CAOCs located at Prince Sultan Air Base, Saudi Arabia (supporting Operation Enduring Freedom) and Al Udeid Air Base, Qatar (supporting Operation Iraqi Freedom). In one area, the Automated Deep Operations Coordination System (ADOCS)—originally developed by DARPA for the U.S. Army—has been deployed to enhance joint and coalition target planning by providing automated monitoring of air and land force status plus access to a wealth of intelligence and weaponeering information. At the same time, staff collaboration has been potentially improved through the deployment of

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[10] For example, two classes of time-sensitive targets emerged during Operation Enduring Freedom: (1) tactical targets that represented an immediate threat or opportunity to forces on the ground and (2) politically sensitive targets that represented fleeting opportunities to take out high-level Taliban or Al Qaida leadership.

InfoWorkSpace, a network-based collaboration tool that facilitates virtual conferencing, instant messaging, white boards, and shared documents. However, while such tools provide potential improvements in the flow and management of information, the basic staff process remains primarily sociocognitive in nature as human experts engage in collaborative debate and problem solving in a complex and evolving operational environment. As pointed out in recent studies of staff collaboration during Millennium Challenge 02 and the U.S. Navy's WESTPAC 2001-02 deployment during Operation Enduring Freedom, the addition of automated collaboration tools do not, by themselves, insure effective sociocognitive functioning of a military staff. (Leedom, 2002) If these basic cognitive and social variables are not addressed as part of the overall reengineering of the CAOC, then serious flaws and obstacles are likely to remain in the time-sensitive targeting process.

The Requirement for Real-Time Knowledge Management

Future joint and coalition military operations will present a complex environment for EBO-based targeting—one increasingly characterized by civilian and infrastructure centers of gravity, evolving coalitions and political factions, competing military and humanitarian agendas, and the potential for tactical operations to have immediate and far-reaching operational and strategic implications. (USJFCOM, 2003) Thus, there is no single, magic solution to EBO. As pointed out by General Dennis Reimer, "*there is a certain danger in placing too much emphasis on precision engagement and unproven 'silver bullets.' ...This has implications on the tactical and operational levels and also limits the options available to the National Command Authorities (NCA). ...Yet history has shown that the human dimension of warfare cannot be countered by technology alone. War is essentially an expression of hostile attitudes.*" (Reimer, 1997)

Implied in this future is the need for a well-trained and efficiently-organized command and staff system—a knowledge-based weapon system that is capable of rapidly and accurately tailoring airpower operations to the demands of operational strategy and national interests. As a knowledge-based weapon system, the "value-added" of the military C2 organization to force effectiveness is its ability to provide the Joint air commander with not only situation awareness—i.e., the common operating picture of the battlespace—but also situation understanding in the form of actionable knowledge. Actionable knowledge, in turn, can be defined in an operational context to mean a dynamic, integrated visualization or understanding of

- The emerging or projected threats and opportunities relevant to the assigned mission objectives, battlespace environment, and imposed operational constraints;
- The preferred means of responding to these threats and opportunities with available airpower resources—including both kinetic destruction and information warfare operations; and
- The manner in which the projected air operations must be coordinated/synchronized with other actions or methods to bring about the desired effect on an adversary or to achieve some other goal of national security policy.

The Emphasis of Technological Investment over Reengineering Organizations and Processes

The above definition actionable knowledge is consistent with theories of warfare that have been handed down over time since Sun Tsu. However, building actionable knowledge within a military C2 organization has only been recently recognized as a multidimensional challenge—one that must consider organizational design, information technology, personnel training and experience, and the process framework and procedures that integrate these elements into an effective system. In this regard, it is useful to note several recent Air Force studies that speak to these dimensions and their relevance for EBO-based targeting. In each case, study findings warn of the danger of emphasizing technological investment over the need for reengineering organizations and processes.

The first study—a masters thesis written by T.W. Beagle while a student in the School of Advanced Airpower Studies at the Air University—examined several historical air operations and concludes that

> *"senior decisionmakers have always been interested in creating specific effects rather than simply destroying targets; however, as a whole, the USAF has been inconsistent in employing effects-based operations across the spectrum of conflict. American airpower has accomplished its most significant improvements at the tactical level of war, but is less reliable in creating operational and strategic effects."* Continuing, Beagle notes that *"airpower has become very effective at producing direct, physical effects, and it is becoming increasingly capable of*

creating certain widespread systemic effects. Generally, though, the ability to even predict, much less generate, specific psychological effects remains yet a hope and may, in fact, act as a virtual ceiling on the potential of effects-based operations." (Beagle, 2000)

More specifically, this study focused on weaknesses and obstacles associated with planning, executing, and assessing EBO-based targeting operations. In each case, technological advances were often negated by an outdated military C2 process that failed to adequately manage the process of creating and sharing actionable knowledge. Regarding planning, Air Force planners did not have control over establishing political and strategic objectives, both of which determine the focus of subsequent air operations. Likewise, Air Force planners were historically constrained by higher levels of command regarding their selection of targets for accomplishing specific objectives. For example, during Operation Desert Storm, targets in downtown Baghdad were essentially declared "off limits" by General Schwarzkopf after the bombing of an underground bunker in the Al Firdos compound inadvertently killed 313 civilians. Finally, in those instances where Air Force target planners were allowed greater latitude, gaps in intelligence analysis became more significant and pronounced as attention shifted from the destruction of physical facilities to the desired creation of specific psychological and political effects. For example, while Desert Storm planners were able to dissect Iraq's electrical power distribution system, they had almost no intelligence regarding the specific infrastructure of Iraq's nuclear capabilities.

With the fielding of the B-2 bomber and advanced precision weapons, the Air Force had the capability to attack over a dozen individual targets with a single aircraft sortie. The resulting increased demand for intelligence soon drove the Air Force to improve its ISR collection system. However, there did not occur a corresponding improvement in target analysis capability. As noted by Beagle,

in virtually every case examined in this study, airpower planners failed to do any detailed analysis of the enemy himself. There was no concerted effort to study the enemy's culture or history in an attempt to understand him psychologically. This failure occurred even though psychological effects were often among the most

important objectives sought. Overall, while planning for physical and some systemic effects significantly improved, planning for psychological effects remained more hope than calculation. (Beagle, 2000)

A similar story of technological improvement negated by process obstacles is seen in the execution of EBO-based targeting operations. On the one hand, the fielding of JDAMs has made all-weather, precision attack of targets a reality. In fact, it is no longer a matter of hitting a target, but a matter of what point on the target to hit. Blanketing switching stations and power lines with carbon-filled wires can now cause massive short circuits to occur without permanently damaging an electrical grid. Yet, as noted by Beagle, "*planners frequently failed to tell operators what effects they wanted to create. This failure affected not only aim point selection, munitions choice, and weapons delivery, but other aspects of effects-based operations as well.*" (Beagle, 2000)

Finally, the assessment of target damage has remained a persistent problem. In the years that followed the Viet Nam war, improvements in ISR capability were generally not applied to the bomb damage assessment (BDA) area. One example from Desert Storm reveals that while an intelligence headquarters was reported to be "25% destroyed" after an attack, the report failed to mention that the facility had been evacuated by intelligence personnel—thus achieving 100 percent of the intended functional effect. This illustration points out a simple process failure: either planners failed to provide the analysts with the original effects criteria, or the BDA analysts understood little about the functionality and behavior of the adversary's systems. In either case, planners were unable to receive timely and accurate feedback—thus negatively impacting on their ability to plan subsequent operations.

The second study reflects the findings of a special "tiger team" that was sent to assess command and staff operations within the CAOC located at Prince Sultan Air Base. It suggests that little changed between Operation Desert Storm and Operation Enduring regarding the emphasis of technological investment over organizational process reengineering. In this review, the team noted that

...the Air Force has used a technical approach to building the AOC weapon system, but has not addressed the "human factor" or culture of C2, which is the real shortfall in AOC combat capability. We have great systems, but are not

manning the weapon system with trained/skilled professionals into a well-understood organizational structure employing combat proven processes. (PSAB CAOC Tiger Team, 2002)

The dimensions of the "human factor" issue become apparent when considering the size and complexity of the CAOC. As pointed out by the Air Force study, the CAOC staff has varied in recent operations between 465 and 1900 personnel, with the smaller representing an artificial constraint imposed by a host nation government. Within this number are represented several hundred joint personnel from other Services and over one hundred coalition personnel from partnering nations. Typical duty shifts last 14-19 hours per day, extending over 60 days without time off—a pace that rapidly degrades human performance and which cannot be maintained indefinitely. Continuity of operations has also been hampered by the Air force's personnel rotation policy of changing over the entire CAOC staff every 90 days with relatively untrained people. This results in a staff process that continually lacks experience and interpersonal familiarity between the CAOC leadership and its operators. Rampant confusion over individual roles, reporting relationships, and coordination requirements are further brought about by the fact that a given facility might be expected to perform the functions of several different headquarters—e.g., Combined Force Air Component Commander (CFACC) Headquarters, CAOC, Regional Joint Task Force Headquarters, and Air Force Forces (AFFOR) Headquarters.

A final study conducted by the Air Force Scientific Advisory Board focused on the future challenges of developing predictive battlespace awareness—a key element of EBO-based targeting. In this study, the Board raised several issues about the "stovepipe" nature of intelligence, surveillance, and reconnaissance (ISR) support and its apparent disconnect with operational strategy and command intent. (USAFSAB, 2002) The Board acknowledged the relevance of effects-based operations and the importance of establishing the CAOC as a weapon system, and it noted that interaction and cooperation between the intelligence and operations staff elements continues to improve. However, the Board added that commanders need to further emphasize this critical relationship—i.e., organize intelligence gathering and fusion more closely around the operational decisionmaking framework of the commander. Specifically, this report recommended that the Air Force should

...implement a new approach to ISR tasking that incorporates a single collection management strategy, planned correlation, and a problem (rather than sensor) focus. This approach should facilitate a tight link between tasking and exploitation. A common misconception is that the AF already has the data it needs to feed PBA; data sorting tools are all that are missing. The reality is the prevailing collection management approach (which concentrates on single sensors and collection missions rather than coordinated / correlated sensing to resolve a particular awareness problem) results in accumulation of too much data, often of the wrong type.

Finally, the report noted the need for cultural change within the CAOC, a movement toward a culture of prediction. But in order to establish such a culture, commanders and their staffs "*...must be evaluated by metrics and standards of performance.*"

Comprehensive Modeling Approach

Summarizing the insights and recommendations of these three studies, it is concluded that the reengineering of future EBO-based targeting operations cannot rely upon technology alone to achieve improvement. Rather, this task should be approached as a multidimensional challenge—one addressing in a coherent manner the following issues:

- Information Technology
- How should the various information systems, planning aids, and collaboration tools available within a military C2 organization be managed to insure the efficient and effective translation of available information into situation understanding?
- How are these various systems, aids, and tools best adapted in the context of novel or emergent operational demands to insure the reliability and responsiveness of decisionmaking?
- What is the tradeoff between planning tools that attempt to predict 2nd and 3rd-order effects of a specific attack against an adversary versus greater reliance upon information systems that can support real-time situation awareness and situation understanding?
- Leadership and Training

- What are the expectations and performance standards of the leaders who must command the targeting process and guide its operation in a complex and dynamic operational environment?
- What type of feedback should be provided to these leaders to allow them to assess and shape the targeting process to the evolving demands of a specific operation?
- What are the expectations and performance standard of the functional operators within the targeting who must not only execute their specialized tasks, but also must collaboratively engage in cross-boundary information sharing and problem solving?
- Personnel Management
- How should the tacit knowledge resources (experience and expertise) available within or to the targeting process be mapped and managed to best insure that the right staff personnel or bodies of expertise are brought to bear at each step in the planning and execution processes?
- How should personnel assignments, rotations, shift changes, and other personnel movements be managed to best insure good teamwork, maturity of social networks, cross-boundary trust, and continuity of the knowledge creation process over time?
- Staff Process and Battle Rhythm
- How should the processes of information collection, filtering, interpretation, organization, and exchange be monitored in real-time to identify and resolve specific types of technical, organizational, social, cognitive, and procedural obstacles in the target planning process?
- How are the ad hoc patterns of information exchange, collaborative problem solving, and reconciliation of stakeholder perspective differences—particularly among intelligence, information warfare, current operations, and planning personnel—best managed in support of the cyclical planning and execution battle rhythm?
- How should the overall knowledge state within the military C2 organization be assessed and managed in real-time to insure that it is responding effectively to the decisionmaking demands of the Joint Air Commander and Joint Task Force Commander—i.e., what is the appropriate mix/level of situation awareness (information) and interpretation (experience/expertise) needed to produce a workable level of certainty, and what are the effective indicators of this state?

- How can the real-time indicators of overall state of knowledge within the military C2 organization be translated into feedback and guidance for ISR tasking and asset management?
- Organizational Design
- How should the various steps of the targeting process be partitioned or integrated across the military C2 organization?
- How does this partitioning impede or facilitate effective collaboration among functional experts and stakeholders?—between planning, execution, and assessment phases of the targeting process?

To address these types of questions, the analysis of EBO-based targeting operations requires a comprehensive modeling approach—one that considers the nature of each of these elements and their impact on overall process performance. Accordingly, the remainder of this chapter discusses how the concepts and frameworks presented in the earlier chapters can be applied to represent critical elements of an EBO-based targeting process.

As will become evident in the remaining discussion, the goal of this modeling representation is to provide analysts with a balanced, 1st-order representation of each of the critical elements: information technology, leadership and training, personnel management, staff process and battle rhythm, and organizational design. Such an approach stands in contrast to other research that attempts to build decision support tools which contain detailed functional representations of an adversary or which incorporate various EBO decision algorithms. Rather, the present modeling approach presumes that much of the analysis will take place in the minds of collaborating experts. Hence, the surrogate representation of actual expertise will be limited to that level of detail necessary for veridical simulation of the command and staff process.

ACTIONABLE KNOWLEDGE WITHIN THE EBO PROBLEM DOMAIN

A key aspect of organizational sensemaking and knowledge management is the manner in which the organization conceptually views the problem domain. A military C2 organization does not typically have direct access to the reality of the battlespace. Rather, its decisionmaking process is framed by the mental construction of that reality, based on both informational inputs to the organization and the conceptual frameworks reflected in human expertise, doctrine, and the

designs of the supporting information technology. Hence, the modeling of the organization's sensemaking and knowledge management processes are framed by this constructed—not actual—reality of the battlespace. In the present case, the constructed reality of interest is that developed within—and relevant to—the EBO-based targeting process.

Two issues of the EBO problem domain are worthy of discussion as they provide the overall framework for defining actionable knowledge within a targeting process. The first issue deals with the representation of the adversary. That is, how does the targeting process effectively characterize an adversary? First, an adaptation of Rasmussen's abstraction hierarchy can be used to decompose an adversary system into various centers of gravity, functional elements, units and physical objects within the battlespace, and—finally—observable cues and indicators that provide the means for a military C2 organization to mentally reconstruct and analyze this system. Second, one must consider the question of what constitutes "military value" within a center of gravity and develop a framework for defining the relative importance of each functional element. Third, each functional element must be defined in terms of effective defeat mechanism—i.e., physical destruction, psychological influence, functional disruption. Finally, one must account in a dynamic sense for how these centers of gravity will evolve over the course of a military operation as the adversary reacts to actions taken by friendly forces.

The second issue deals with the linking of the targeting process to the overall operational concept or strategy of the Joint commanders. That is, how does the targeting process effectively support the goals and intent of the Joint commanders? First, an adaptation of the issue-proposition-evidence framework discussed in Chapter 1 can be used to decompose a commander's vision of the operation into different phases, critical challenges for each phase, strategies for overcoming each challenge, the corresponding functions that have to be defeated within the adversary system, and the desired targets and effects that are associated with these functions. Second, this representation must include various types of operational, cultural, social, legal, and other types of constraints. Nominally, these constraints will be associated with the potential for unintended consequences should they be violated by specific targeting operations. Third, there is a dynamic interaction between operational strategy and target value in the sense that friendly force operations—e.g., maneuver—can be used to influence targeting priorities by causing the adversary to commit to specific actions that expose his force to attack. Finally, this

representation must reflect the strategy or process by which the commander manages risk and uncertainty. Here, competing strategies include (1) reliance upon a fixed target development cycle that attempts to predict 2nd and 3rd-order effects within the adversary system versus (2) a more adaptive target development cycle that is designed to adjust the execution of target strikes on the basis of real-time situation awareness and understanding.

Representation of the Adversary in Terms of Centers of Gravity

A popular concept discussed in a number of EBO research papers is the notion that an adversary may be usefully described in terms of *centers of gravity*. The term center of gravity has been commonly used in Joint doctrine to describe the basis for developing both operational and tactical plans.[11] Joint Publication 1-02 defines centers of gravity as "*Those characteristics, capabilities, or sources of power from which a military force derives its freedom of action, physical strength, or will to fight.*" (JCS, 2003) The concept is derived from the original work of Carl Von Clausewitz who used terms such as *centra gravitates* and *Schwerpunkt* to describe the most advantageous point at which to strike a blow against an adversary. (Von Clausewitz, 1832)

In a recent paper published by the Army War College, Antulio Echevarria argues that Clausewitz's concept of center of gravity does not imply either a point of strength or a point of weakness. Rather, a center of gravity is considered to be those points within an adversary's entire structure or system that has the necessary centripetal force to hold that structure together. This is why Clausewitz wrote that a blow directed against a center of gravity will have the greatest effect. (Echevarria, 2002)

In a similar fashion, Air Force thinking with regard to centers of gravity has been influenced by various models of national power that are seen to be derived from Hans Morgenthau's classic list of elements of national power. These elements included (Morgenthau, 1985)

- Geography;
- Natural Resources;

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[11] For example, see Joint Publication 5-00.2, *Joint Task Force Planning Guidance and Procedures*, 13 January 1999.

- Economic or Industrial Capacity;
- Military Strength and Preparedness;
- Population;
- National Character and Morale; and
- Quality of Government

Two similar models in particular are posited by John Warden and Jason Barlow. In his *Five-Ring Model*, John Warden views an adversary in terms of five concentric system components: (Warden, 1995)

- Leadership (e.g., government, command and control)
- Organic Essentials (e.g., energy resources, raw materials, facilities required for their conversion)
- Infrastructure (e.g., industry, transportation networks, electrical grids)
- Population (e.g., workers, civilian population, morale)
- Fielded Military (e.g., soldiers, military forces)

Using this model, Warden argues that historically campaigns were generally waged against only the outermost rings (military forces, population) because nations lacked effective means for targeting the more important inner rings. However, Warden notes, "*Technology has made possible the near simultaneous attack on every strategic- and operational-level vulnerability of the enemy.*" (Warden, 1995) Thus, an EBO-based targeting strategy is one that seeks to influence an adversary within all five rings simultaneously.

Jason Barlow, by contrast, notes that not every nation will display various elements of national power with comparable value. (Barlow, 1993) Here, Barlow presents a *Model of Dynamic National Elements of Value* that includes leadership, industry, armed forces, population, transportation, communications, and alliances. Within this model, the value of each element of power will not only vary from one country to the next, but also vary within a given country as a function of the effects of war. Employing the terms strategic paralysis, Barlow argues that a military targeting strategy should be based on "*attacking or threatening national-level targets that most directly support the enemy's war-making efforts and will to continue the conflict.*" (Barlow, 1993)

More recently, Maris McCrabb has placed the models developed by Warden and Barlow in the broader context of EBO-based thinking and coalition operations to demonstrate the critical importance of a systems approach to center of gravity analysis. (McCrabb, 2002) Tracing an emphasis on systems analysis that dates back to instructors in the U.S. Army Air Corps Tactical School, McCrabb argues that target analysts have traditionally focused on "*the connections and dependencies between and within these systems that formed an 'industrial web' where attacks against one element in the web would ripple throughout the web causing more problems then just the immediate damage done.*"

Similarly, a review of current Joint campaign planning doctrine suggests a more complex definition for center of gravity. Figure 4-1, taken from Joint Pub 5-00.1, defines center of gravity in terms of a number of characteristics. (JCS, 2002a) Given this complexity, this Joint doctrinal publication states,

> *The most effective method for planners to conduct an analysis of the adversary's COGs to identify its critical vulnerabilities is to visualize the COGs in terms of a system—i.e., what are its functional components (critical requirements) and how do they relate to one another? What elements within this 'system' protect, sustain, or integrate its various elements or components? Once a detailed systemic analysis is completed, the planners should then try to identify the critical vulnerabilities within that system.*

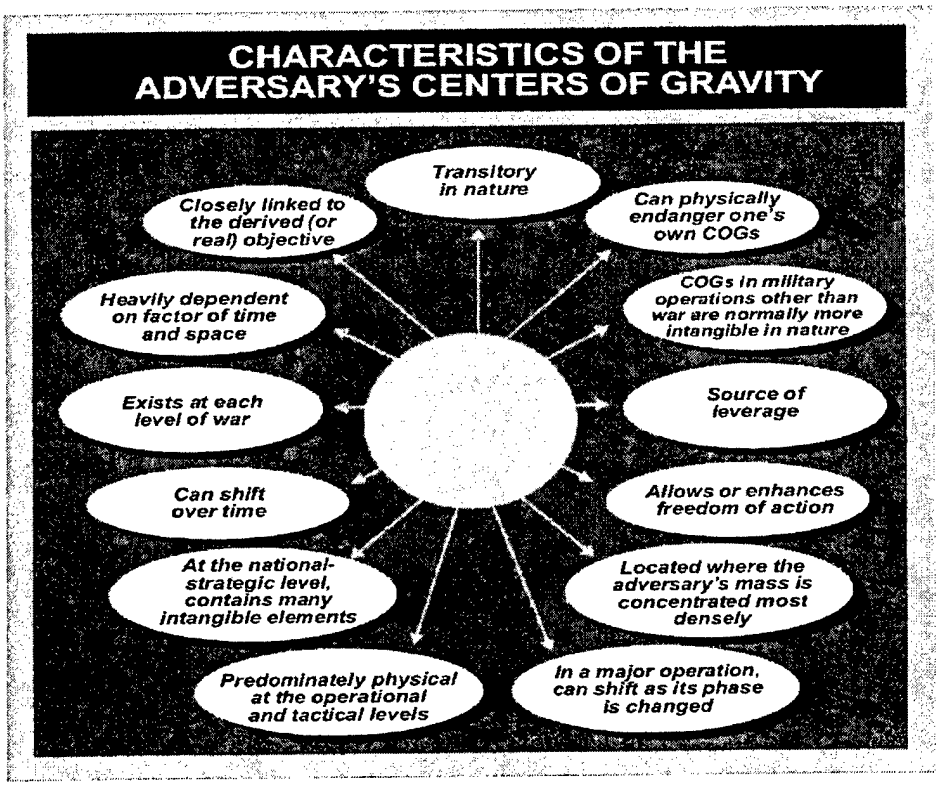

Figure 4- 1. Characteristics of Center of Gravity (Joint Pub 5-00.1)

Another concept associated with center of gravity in Joint doctrine is the notion of "*decisive point*." Decisive points are not centers of gravity, themselves. Rather, they represent the keys to attacking or defending them. Decisive points might be a geographic place, a specific key event, or an enabling system that allows commanders to gain a marked advantage over the adversary and greatly influence the outcome of the operation. (JCS, 2002a)

In the same regard, it is important to consider that a military operation will typically have several defined phases—e.g., (1) deter and engage, (2) seize initiative and set conditions, (3) execute decisive engagement, and (4) transition to stability operations. Accordingly, each phase will have different objectives that demand that an adversary structure or system be examined from a different perspective.

Linking Center of Gravity to Operational Strategy

As pointed out by Major Soew Hiang Lee in a thesis at the Air Command and Staff College, many different interpretations of Clausewitz's terms abound in recent military literature. (Lee, 1999) As reflected in Figure 4-2, these definitions emphasize various aspects of an adversary

such as concentration of "*mass*," "*critical vulnerability*," "*hub of power and movement*," and "*something the enemy must have to continue military operations*." In his thesis, Soew Haing Lee argues that confusion regarding the definition of center of gravity has often persisted among commanders in wartime. For example during Operation Desert Storm, General Schwarzkopf (reflecting the dynamic model of Barlow cited earlier) defined the Iraqi centers of gravity as

> *...that thing that if you destroy it, you destroy his ability to wage war. The centers of gravity were Saddam Hussein himself because of the highly centralized leadership. I don't mean personally destroyed. I mean the ability to function. Number two, the Republican Guard. And number three, his chemical, biological and nuclear capability. It doesn't take a genius to figure out that if those things are gone, his ability to wage war is to all intents and purposes finished. (Friedrich, 1991)*

However, the initial targeting briefing developed by the Air Force's Checkmate Team listed ten centers of gravity—with the Republican Guard and SCUD missiles being notably absent: national leadership, leadership C2, electricity production, oil production for internal consumption, military production, railroads, airfields, ports, strategic air defense, strategic chemical warfare capability. By contrast, ground force commanders—influenced by recent graduates of the Army's SAMS planning course—listed only a single center of gravity, the Republican Guard. (Lee, 1999)

Definitions for Center of Gravity

(1) Center of gravity is "not a source of strength, but rather a critical vulnerability."

(2) Center of gravity is "always found where the mass is concentrated most densely." Alternative but popular version: center of gravity is "a strength not a vulnerability."

(3) "One must keep the dominant characteristics of both belligerents in mind. Out of these characteristics a certain center of gravity develops, the hub of all power and movement, on which everything depends . . . the point at which all our energies should be directed."

(4) Centers of gravity are "those characteristics, capabilities, or locations from which a military force derives its freedom of action, physical strength, or will to fight."

(5) The center of gravity is "something the enemy must have to continue military operations—a source of his strength, but not necessarily strong or a strength in itself."

(6) Center of gravity is something that if affected (i.e., destroy, disrupt, neutralize, or delay) can cause cascading deterioration that prevents the foe from achieving his aims and allows the achievement of our aims.

Sources: (1) Fleet Marine Force Manual 1, *Warfighting*, 1989, 85; (2) "Book 6—Clausewitzian Interpretation," *On War*, 485; (3) "Book 8—Clausewitzian Interpretation," *On War*, 595–96; (4) Joint Publication 3-0, *Doctrine for Joint Operations*, 1995, III-20 (similar in Air Force Doctrine Document 1, *Air Force Basic Doctrine*, 1997 and Field Manual 100-5, *Operations*, 1993); (5) Naval Doctrine Publication 1, *Naval Warfare*, 28 March 1994, 35; and (6) author's adaptation.

Figure 4-2. Alternative Definitions of ***Center of Gravity*** (Lee, 1999)

Subsequent debate has arisen over exactly what forced Saddam Hussein to capitulate during Operation Desert Storm. Some argue that it was not the loss of the Republican Guard, but rather the threat of losing other paramilitary forces that kept Hussein's family in power that forced his eventual capitulation.

Moving to more recent conflicts suggests a similar pattern of confusion regarding the strategic objectives of targeting. During Operation Enduring Freedom, the initial air campaign focused on targeting air defense, command and control, political targets, infrastructure, and military training bases, and military storage areas—all of which contributed to the rapid fall of the Taliban government in Afghanistan. Yet, as argued by Carl Conette, much of this air campaign lacked grounding in an agreed upon national strategy regarding the restoration of a friendly government in Afghanistan, the U.S. position regarding the Northern Alliance tribes, the relationship with Pakistan, and the final disposition of the al Qaeda leadership. (Conetta, 2002) Indeed, it has been argued by others that the rapid execution of overwhelming military operations often fails to provide adequate time for diplomatic negotiation and coalition-building. (Vego, 2002)

Linking Centers of Gravity to Operational Strategy

Lessons developed from earlier military operations assisted U.S. commanders in recognizing the need for close collaboration in setting targeting priorities during Operation Iraqi Freedom. Indeed, the wicked problem nature of many Joint operations underlined this need. In this regard, a key strategy early on was the notion of separating mainline Iraqi military forces from the central leadership in Baghdad. Combined Force Command (CFC) operational objectives for the initial high intensity phase of combat were listed as (USCENTAF, 2003)

- Defeat or compel capitulation of Iraqi forces;
- Neutralize regime leadership;
- Neutralize Iraqi TBM / WMD delivery systems;
- Control WMD infrastructure;
- Ensure the territorial integrity of Iraq;
- Deploy and posture CFC forces for post-hostility operations, initiating humanitarian assistance operations for the Iraqi people, within capabilities;
- Set military conditions for provisional/permanent government to assume power;
- Maintain international and regional support;
- Neutralize Iraqi regime's C2 & security forces; and
- Gain and maintain air, maritime and space supremacy.

Translating this guidance into actual targeting missions produced the strategy-to-task mission results summarized in Figure 4-3.

Mission Area (Center of Gravity)	CFACC Apportionment	Target Nominations	Targets on JIPTL	Targets Struck
Maintain air supremacy	14.1%	2,374	2,124	1,441
Defeat or force capitulation of Iraqi army and support follow-on security-stability operations	50.7%	17,521	12,893	234 *(Fixed Site)* 15,592 *(KI/CAS)*
Prevent non-combatant forces from impeding CFC operations	1.2%			
Maintain maritime supremacy	1.0%	72	113	
Secure regional and international support	0.0%			
Support joint reception, movement and integration of follow-on force elements	0.0%			
Suppress Iraqi regime's ability to command Iraqi forces and govern state	9.8%	4,782	4,559	1,799
Establish and operate secured airfields and aerial ports of debarkation	0.0%			
Support special operations forces operations	12.5%	4,278	3,711	832
Suppress Iraqi TBM and WMD delivery systems	10.2%	1,515	1,840	
Neutralize and control WMD infrastructure	0.5%			

KI/CAS = Kill Box Interdiction / Close Air Support
JIPTL = Joint Integrated Prioritized Target List

Source: (USCENTAF, 2003)

Figure 4-3. Operation Iraqi Freedom Targeting Summary

Despite the media attention given to the "*shock and awe*" of precision bombing against key leadership targets in Baghdad, much of the Combined Force Air Component Commander's (CFACC) targeting support was apportioned to the ground force commanders as they moved rapidly to defeat Iraqi ground forces defending Baghdad and other key cities. As can be seen from these data, over half of the targeting was focused on defeating or forcing the capitulation of the Republican Guard and regular Iraqi army forces. Of these targets, nearly all (98.5%) were engaged dynamically by means of swing missions that either operated as close air support (CAS) or interdicted Iraqi ground targets in predesignated "*kill boxes*." Other major centers of gravity receiving targeting attention included defeat of Iraqi air defense installations, defeat of regime C2 installations (including political leadership), support of special operations forces, and the suppression of tactical ballistic missile and weapons of mass destruction delivery systems.

In addition to the flexible use of kill boxes against Iraqi ground forces, targeting operations also demonstrated new and ad hoc types of real-time support arrangements among conventional ground forces, air forces, and special operations forces. (Noonan, 2003) For example in northern Iraq, Iraqi forces learned to anticipate the presence of special operations forces in an area when they detected high-altitude vapor trails of U.S. air forces. In essence, the Iraqi's knew that these vapor trails predicted precision bombing runs; hence, they were able to use them as a cue to seek dug-in protection. In a move that successfully threw these Iraqi forces off balance, the special

operations teams called in unexpected fire support from 105mm Howitzers belonging to the 173rd Airborne Brigade—thus convincing the Iraqi forces that they were not safe at any time or any where.

The interaction between air and ground forces during Operation Iraqi Freedom demonstrated an important aspect of the wicked problem nature of setting Joint targeting priorities. Here, it was recognized by U.S. military planners that ground force maneuver can be used to force the adversary into actions that increase the priority and availability of certain target sets. As reported by LtGen Wallace, Commander of the Army's 5th Corps, "*There were episodes in the fight when operational maneuver caused the enemy to react; when the enemy reacted, it allowed us to employ joint fires against him which, in turn, allowed our operational maneuver to be more successful.*" (1stBCD, 2003) As a result, the Army established the 1st Battlefield Coordination Detachment (1st BCD) to operate within the Combined Force Air Component Command (CFACC) headquarters at Prince Sultan Airbase, Saudi Arabia. This detachment served as a conduit for collaborative planning and information sharing between CFACC headquarters and the Combined Force Land Component Command (CFLCC) headquarters at Camp Doha, Kuwait.

Another aspect of Operation Iraqi Freedom was the predominant use of interdiction kill boxes in Operation Iraqi Freedom—a procedural mechanism developed to achieve closer targeting coordination between air and ground elements. In the after-action review prepared by the Army's 3rd Infantry Division, it was noted that "*air support had a major impact on the battlefield. Air support proved highly successful both in shaping operations as well as in the close fight. The division utilized air support for a number of different missions including shaping, armed recce, counterfire, and CAS.*" (3rd Infantry Division, 2003) A great deal of this success was attributed to the use of predefined interdiction kill boxes that could be procedurally opened and closed over time to allow the Air Force a free "hunting zone." However, this concept was not without its limitations. Here, the 3rd Infantry Division's after-action review continues,

> *One of the challenges with the fixed kill box concept is that it does not allow for flexibility once friendly forces approach an open kill box. The division's desire to attack targets on the high payoff target list (HPTL) or high value targets (HVT) was nullified. Conflicts arose when the Air Force destroyed targets as they were acquired instead of what the maneuver commander wanted destroyed.*

A second problem reported with kill boxes during Operation Iraqi Freedom was confusion over whether specific targets within a kill box would be engaged with air resources or ground resources. As noted by Army personnel assigned within the 1st BCD,

> *Unfortunately, the software systems designed to communicate targets earmarked for strike are not designed to communicate kill-box information. Kill boxes within the TBMCS constitute airspace. Missions planned to airspace within the ATO do not retain the ASR number in the USMTF message sent back to AFATDS; therefore, CFACC missions to attack CFLCC targets planned to kill boxes do not parse in AFATDS to show the CFLCC and his staff the air support planned. As a result, the CFLCC could not get automated feedback from the CFACC on which of the targets he had nominated that the CFACC planned to service. This lack of feedback was a source of great consternation as the war kicked off. (Kelly & Andreasen, 2003)*

As will be discussed later in this chapter, the dynamic influence of ground operations on the targeting process suggests that the modeling of an adversary's structure and system cannot be done statically or in isolation. Rather, it must be modeled in the context of an on-going operation.

Need to Consider Cultural, Social, and Other Dimensions

Operation Iraqi Freedom also demonstrated new challenges to the targeting process. While the defeat of convention military forces proved to be a relatively straight forward task, addressing other, more asymmetric elements of the operation proved difficult. For example, one of the key elements of Saddam Hussein's power base—the Fedayeen Saddam and various groups of foreign volunteers—represented an unexpected and difficult center of gravity to target. The Fedayeen Saddam—a group founded by Saddam Hussein's son, Uday, in 1995—was reported to be comprised of 30,000-40,000 young paramilitary soldiers recruited from regions loyal to Hussein. Two elements of the Fedayeen Saddam that contributed to their characterization as a center of gravity included (1) their possession of advanced weapons transferred from the Republican Guard and (2) their political reliability and fierce loyalty to the Hussein regime. Targeting these paramilitary forces depended upon effective and rapid integration of all-source intelligence—

including the effective collection and exploitation of HUMINT. For example, as the 3rd Infantry Division approached Baghdad, its operations transitioned to an emphasis on stability and support operations (SASO). Here, and throughout Operation Iraqi Freedom, the division encountered

> *many examples of the Iraqi effort to counter our strengths and exploit our weaknesses. To avoid air strikes and frustrate targeting efforts, the Iraqis dispersed their forces and hid them under palm trees or in urban areas, often parking artillery or armor systems right next to schools or private residences. They also set fire trenches to try to obscure targeting. The Iraqis conducted some nonlinear, simultaneous operations, coercing citizens and recruiting foreigners to conduct ambushes and suicide attacks against coalition forces. Again, these fighters wore civilian clothes and used civilian transportation to complicate friendly targeting. (3rd Infantry Division, 2002)*

At this point, the division increasingly relied upon HUMINT and SIGINT resources—provided by the division's Military Intelligence Battalion—to provide situation awareness and input to the targeting process.

As operations transition from the more traditional phase of high intensity combat to SASO, definition of the adversary's centers of gravity becomes more problematic. Important, defining characteristics of each center of gravity will include cultural, social, religious, and economic dimensions, as well as the more traditional physical and geographic dimensions. In this regard, Desmond Saunders-Newton and Aaron Frank identify eight information sets needed for defining critical centers of gravity in EBO-based targeting operations:[12] (Saunders-Newton & Frank, 2002)

- *Technical*: the physical characteristics of the adversary's force elements (e.g., sensors, weapon systems, people, and other actors)
- *Geographic*: the position of these elements within the physical battlespace

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[12] Actually, this paper defines these information sets to include similar data for friendly forces. However, the present discussion addresses only the representation of the adversary's system.

- *Infrastructure*: the technical and functional connections that are possible among these elements (value-neutral with respect to the adversary's preferred way of making these connections)
- *Organizational*: the formalized relationships, hierarchies, and networks that exist among these elements (value-neutral with respect to the adversary's normal routines and strategies for adaptation under pressure)
- *Sociopolitical*: the social and political objectives of the agents, organizations, institutions, and actors within the adversary's system (that which gives life and motivation to the system)
- *Psychological*: the influence of emotions, identity, morale, and other nonmaterial factors that influence adversary decisionmaking
- *Context*: the parsing of relevant technical, geographic, infrastructural, organizational, sociopolitical, and psychological into situational models that provide the context for identifying specific targets (a set of theories, hypotheses, and perspectives)
- *Dynamics*: the explanatory causal models that predictively link action and outcome relative to the situational models (a set of theories, hypotheses, and perspectives)

In identifying these information sets, these authors argue, "As the sets of information expand, not only do engagement options increase, and in some cases decrease as previously attractive courses of action become unattractive as more information becomes available, but also a deeper, more meaningful effects-based targeting and engagement plan can be developed, culminating in an understanding of how military operations will produce desired political outcomes. The U.S. military has already employed such a planning philosophy, albeit with mixed results, in the air campaign during Operation Desert Storm and later in Kosovo. Each of these cases reveals the potential of effects-based targeting as well as the inherent difficulties associated with its implementation." Thus, as discussed earlier, EBO-based targeting is sensitive to the strategies and courses of action employed by the commander to defeat or influence the behavior of the adversary. A change in strategy or course of action will influence the relative significance of different centers of gravity and, thus, change the goals and objectives of EBO-based targeting.

In addition to reconciling potential targets with operational strategy, it is important that targets be identified in accordance with other constraints. Such constraints might have a basis in legality, in

politics, in morality, or in the desire to deconflict targeting operations with other intended effects—e.g., psychological or informational. During Operation Desert Storm, for example, "CENTCOM target intelligence analysts, in close coordination with the national intelligence agencies and the State Department, produced a joint no-fire target list. This list was a compilation of historical, archeological, economic, religious and politically sensitive installations in Iraq and Kuwait that could not be targeted. Additionally, target intelligence analysts were tasked to look in a six-mile area around each master attack target for schools, hospitals, and mosques to identify targets where extreme care was required in planning." (OSD, 1992) Similar no-fire constraints were developed for both Operation Enduring Freedom in Afghanistan and Operation Iraqi Freedom.

Traditional forms of targeting have focused on the decomposition and analysis of industrial systems within an adversary's country. Accordingly, Air Force targeting guidance specifies that consideration should be given to the following set of factors when analyzing an adversary's overall system: (USAF, 1998)

- *Importance and Significance* is the determined measure of the target's military, economic, political, psychosocial, or geographic importance and significance. For example, the small city of Tikrit, Iraq had little military value, but great political value in Operation Iraqi Freedom since it was the hometown of Saddam Hussein.
- *Depth* is a measure of the time required before disruption of a component's activity affects the system output.
- *Reserves* are the quantity of stored resources that the adversary can use when the normal supply of the resources are disrupted by an attack. The importance of reserves is influenced by the estimated length of the operation and the adversary's ability to adapt to using the reserves.
- *Cushion* is the amount of resources that can be diverted from other uses when the military's normal supply of the resources is disrupted by an attack. For example, if an adversary's military forces are using only ten percent of the country's petroleum production, then it might be possible to divert the remaining percentage from civilian use to military use.

- *Capacity* is a measure of the production potential of a given resource. Capacity measures have relevance in longer operations, but not in the short run.
- *Economic Value* is a measure of the value (scarcity) of the elements used to produce a resource—e.g., skilled workers, sophisticated equipment, and specialized facilities.
- *Reconstitution* is a measure of the adversary's time and cost to rebuild the resource producing function after its disruption by attack.
- *Geographic Location* is a measure of whether the target falls within the effective range of weapons that can be used to attack it. With modern stand-off, precision weapon systems, this factor has become less significant; however, a potential political problem might exist if these weapons must be operated over a neutral country.
- *Concentration or Dispersal* is a measure of the relative distribution of target components within an overall target complex. This measure impacts on the number of individual desired impact points that might be required.
- *Mobility* is a measure of the target's ability to relocate over time, thus complicating the designation of an appropriate impact point or kill box.
- *Countermeasures* is a measure of the adversary's ability to protect the target with the use of terrain (e.g., bunkering), emissions control, camouflage, and active defenses

A review of these factors suggests that they were developed in an era when strategic targeting was often focused against the industrial capacity of the adversary's country. With modern conflict, however, it is not clear that these same measures would suffice in identifying targets against an asymmetric adversary that is not necessarily tied to a specific country—e g , al Qaeda. More recently published Joint targeting doctrine explicitly addresses effects-based operations (JCS, 2002b) Here, targeting doctrine speaks in terms of the following categories of effects

- *Direct Effects* include the immediate, 1st-order effects of destroying a specific facility, disrupting a specific function, or creating a specific psychological influence.
- *Indirect Effects* include the delayed or displaced 2nd and 3rd-order consequences of the military action.

This same guidance also describes both direct and indirect effects as having three fundamental characteristics that qualitatively impact the influence they exert on adversary capabilities. (JCS, 2002b) These include

- *Cumulative Effects* refers to the notion that multiple targeting actions can produce effects that compound over time to achieve an influence on an adversary that is greater than the sum of the individual actions.
- *Cascading Effects* refers to the notion that targeting actions at the strategic level can have a ripple-down influence on lower-level, tactical operations conducted by the adversary.
- *Collateral Effects* refers to the notion that targeting actions can produce unintended (usually undesirable) consequences regarding people, installations, or operations that are not the direct object of the targeting actions.

It is significant to note that, while this more recent doctrine identifies the need to consider indirect, cumulative, cascading, and collateral effects in the development of targets, little or no detail is provided regarding the analytic methods or means of doing so. To date, the consideration of "soft" factors and the analysis of indirect 2nd and 3rd-order effects remain more of an art form rather than a science. In this regard, Desmond Saunders-Newton and Aaron Frank outline a number of challenges: (Saunders-Newton & Frank, 2002)

- The development of EBO-based analysis tools will significantly challenge long-held concepts central to the practice of military operations research. These concepts include optimization, reductionism, prediction, and deductive reasoning. Integration of the social sciences into operations research will not just be a matter of adding new factors into existing models. Rather, I will involve the development of new mindsets regarding the methods and role of analysis in sensemaking and decisionmaking.
- Data and information required to drive these new types of analysis must be readily available or rapidly and reliably acquired. Analysis will necessarily rely upon large quantities of both classified and open-source information as input.
- Given the closely-tied nature of EBO to political objectives, analysis of EBO-based targets must be effectively monitored with independent measures of effectiveness so as to prevent operations devolving into a series of action where the ends justify the means.

- EBO-based targeting requires deep understanding of the political context of a conflict in order to fully develop an understanding of their consequences. This requires time. During the Cold War, the United States had over 40 years to develop a deep understanding of the context and consequences of actions that might be taken against the Soviet Union. Paradoxically, the United States will not have the luxury of long periods of time to study future adversaries. Thus, it is not clear to what extent EBO-based actions can be effectively reconciled with long-term strategic objectives.

Time Sensitivity of Target Value

In addition to the dimensions just discussed, Joint doctrine also defines the concept of "*time-sensitive*" and "*time-critical*" targets. (USJFCOM JWC, 2002) In a sense, time-sensitivity reflects both an aspect of the target, itself, and the capabilities of the systems available to act upon that target. Nevertheless, it is important to consider this dimension when discussing the basic representation of the problem domain. As shown in Figure 4-4, time-sensitive targets can be classified into a number of different categories. (JCS, 2002b) *Scheduled* targets are planned targets upon which fires are to be delivered at a specific time. *On-call* targets are those that do not have fires scheduled to be delivered at a specific time. However, they are known to exist in an operational area and are located in sufficient time for deliberate planning to meet emerging situations specific to campaign objectives. *Immediate* targets are those that have been identified too late, or not selected for action in time to be included in the normal targeting process, and therefore have not been scheduled. Immediate targets have two subcategories: unplanned and unanticipated. *Unplanned immediate* targets are those that are known to exist in an operational area but are not detected, located, or selected for action in sufficient time to be included in the normal targeting process. Targets identified within predefined and activated kill boxes would fall into this major category. Finally, *unanticipated immediate* targets are those that are unknown or unexpected to exist in an operational area but, when detected or located, meet criteria specific to campaign objectives. As discussed later in this chapter, the use of predefined kill boxes potentially facilitates the designation and attack of immediate targets. However, the concept of a "kill box" target speaks more to the C2 process by which the attack is carried out, rather than to a specific characteristic of the target, itself.

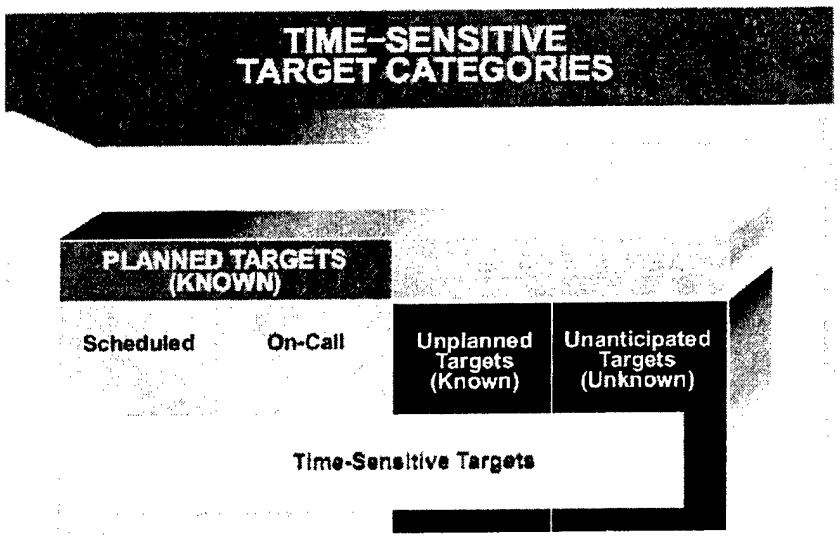

Figure 4-4. Time-Sensitive Targeting Categories (USJFCOM JWC, 2002)

Building a Model of Actionable Knowledge in the EBO Problem Domain

As discussed in Chapter 1, actionable knowledge is best represented as a state of information organization, rather than as a commodity. In the context of EBO-based targeting operations, the state of information organization refers to what is known about targets that conform to command intent and guidance relative to the total number of objects that could be potentially attacked within the battlespace. Such a definition conforms to the basic notion of effects-based operations: "*operations conceived and planned in a systems framework that considers the full range of direct, indirect, and cascading effects, which may—with different degrees of probability—be achieved by the application of military, diplomatic, psychological, and economic instruments.*" (Davis, 2001) Analytically, EBO-based targeting operations can be compared to the challenging task of finding the right set of needles beneath a haystack, rather than merely finding any needle. This task is illustrated in Figure 4-5, where the object of targeting is to focus effects against those specific objects that directly contribute to achieving command intent while avoiding unintended effects against other objects within the battlespace. Given the large number of other potential objects within the battlespace, focusing a limited number of effects against a relatively small validated target set will require tailored development and effective management of actionable knowledge within the military C2 system.

How a military C2 system responds to this challenge is further illustrated in Figure 4-6. Conceptually, the battlespace is envisioned to contain a number of adversary centers of gravity that are defined—as discussed earlier—in terms of various relevant dimensions. Each of these centers of gravity can be decomposed into functions and effects, work processes, and physical objects. Each of these objects provides observable cues in the form of physical and informational characteristics that can be collected with different intelligence systems. Rather than directly perceiving each of these objects, the military C2 system builds its understanding of the battlespace through the collection, analysis, and organization of these various cues. The entire process is shown in Figure 4-7.

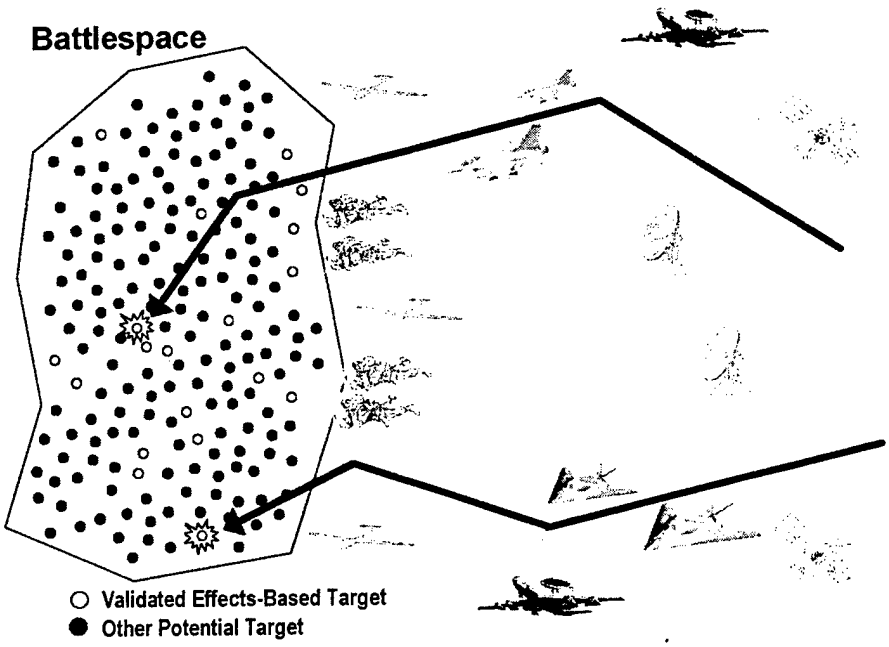

Figure 4-5. Finding Validated Effects-Based Targets within the Battlespace

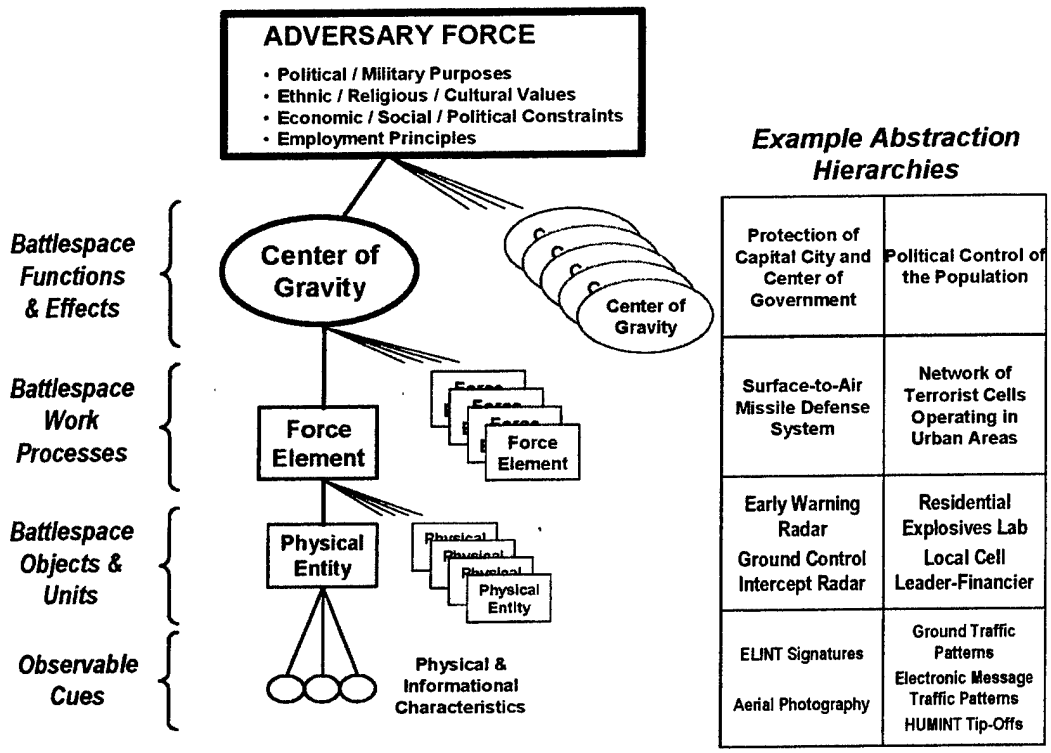

Figure 4-6. Abstraction of an Adversary's Centers of Gravity into Observable Cues

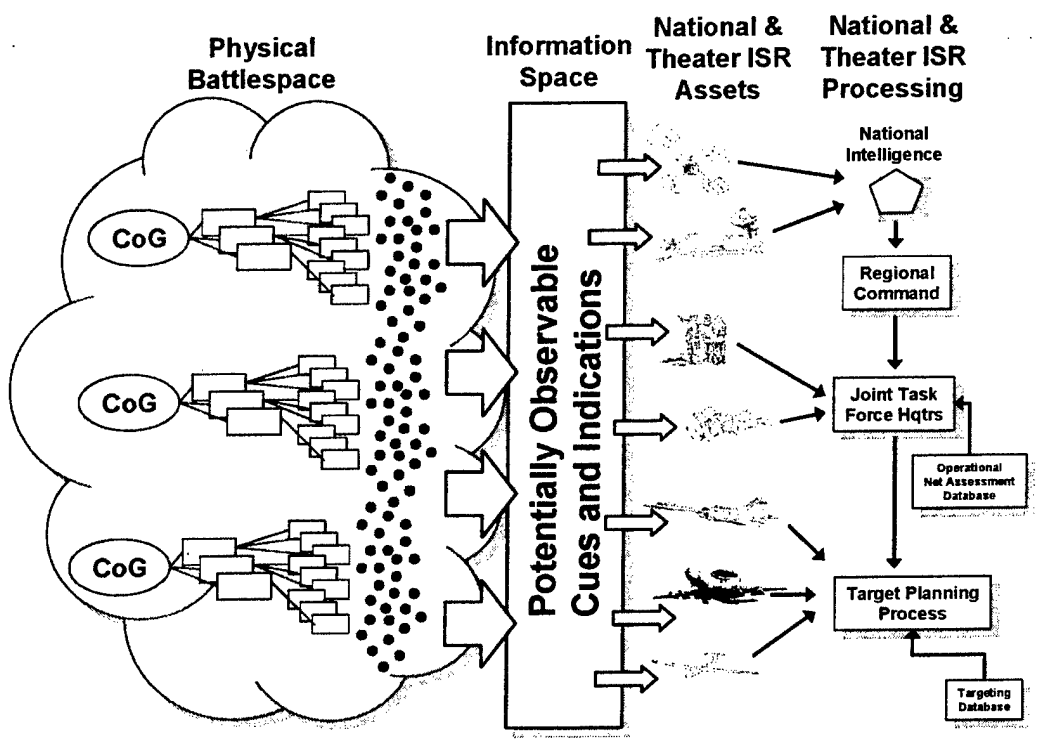

Figure 4-7. Transforming Battlespace Cues into Actionable Knowledge for EBO-Based Targeting

As seen in Figure 4-7, potentially observable cues and indications associated with valid EBO combine with cues and indications of other battlespace objects to form the military C2 system's information space. These cues and indications are collected and assessed by a variety of intelligence systems and organizations, ranging from national intelligence systems and organizations, down through theater-level systems and organizations, to tactical level systems and organizations. Potentially, all of this information could flow into the target planning process. However, as will be discussed later in this chapter, various organizational characteristics and impediments can serve to either block the flow of relevant information or result in overloading analysts with too much information. Thus, the overall performance of the EBO-based targeting process will be influenced by the ability of the military C2 system to (1) filter the available cues and indications, (2) direct this relevant information to personnel with appropriate expertise to interpret and associate this information with potential targets and (3) integrate and organize the resulting associations into actionable target knowledge.

Having described an overview of the process, the discussion now presents a hypothetical modeling case that is based on recent military operations in Afghanistan and Iraq. Following the adaptation of Beach and Mitchell's image theory discussed in Chapter 1, the hypothetical case begins with the representation of the BLUE force self image and trajectory image shown in Figure 4-8. (Beach & Mitchell, 1987) Here, we see that the BLUE force has been designated two roles: (1) leader of a coalition military force charter to bring peace and security to the scenario region and (2) a force that has been authorized use of armed intervention. Designation of these roles will affect both (1) the need for collaboration among coalition partners and (2) the limitations placed on the targeting process.

- Self Image – What is our role in this operation?
  1. Leader of a coalition military force established to bring peace and security to the region
  2. The coalition military force is authorized use of armed intervention
- Trajectory Image – What are we attempting to accomplish in this operation?
  1. Restore legitimate government to nation
  2. Eliminate terrorist bases
  3. Prevent foreign terrorist volunteers from entering nation
  4. Maintain popular support

Figure 4-8. Hypothetical Self Image and Trajectory Image of BLUE Force

The trajectory image corresponds to higher-level command intent—what the BLUE force commander has been given as a set of goals or end-states to achieve. They include (1) the restoration of a legitimate government to the scenario nation, (2) the elimination of sanctuary terrorist bases that are a world-wide threat, (3) the prevention of other terrorist groups from entering the scenario nation, and (4) the maintenance of popular support for the coalition forces.

Next, the modeling representation must develop an action image and projected image for the military operation—i.e., the specific actions that will be taken to achieve the end-states, together with the criteria for measuring success in each phase. Figure 4-9 illustrates how the action image and projected image might be developed for this hypothetical modeling case.

• **Phase I - Set conditions for rapid and decisive entry and occupation of nation**	**Success Criteria**
– Neutralize regime's ability to command armed forces	Nodes/networks destroyed
– Build internal social networks for gaining intelligence and popular support	Networks established
– Achieve and maintain air superiority	Nodes/networks destroyed
– Neutralize WMD delivery systems	Delivery systems destroyed
– Maintain popular support by avoiding unanticipated negative consequences	Negative incidents avoided
• **Phase II - Execute decisive operation to remove regime and eliminate terrorist bases**	
– Separate regime from populace and armed forces through information campaign	Effective messages delivered
– Neutralize remaining WMD delivery systems	Delivery systems destroyed
– Seek capitulation of the armed forces, rather than their destruction	Units destroyed / capitulated
– Neutralize close family members and key leaders of regime	Individuals neutralized
– Avoid unnecessary destruction or disruption of vital services to populace	Utilities in operation
– Separate paramilitary forces from populace and neutralize their effective organization	Leadership / units destroyed
– Identify and destroy facilities for WMD development and storage	Facilities destroyed
– Identify and destroy terrorist bases, including foreign national volunteers	Bases / units destroyed
– Maintain popular support by avoiding unanticipated negative consequences	Negative incidents avoided
• **Phase III - Transition nation to stability and security operation that enables formation of new government**	
– Separate populace from remnants of radical movement	Effective messages delivered
– Neutralize remaining close family members and former key leaders of regime	Individuals neutralized
– Identify and neutralize remaining elements of paramilitary forces	Leadership / units destroyed
– Identify and neutralize remaining terrorist elements, including foreign volunteers	Bases / units destroyed
– Maintain popular support by avoiding unanticipated negative consequences	Negative incidents avoided

Figure 4-9. Action Image and Projected Image (Success Criteria) for the Hypothetical BLUE Forces

The action image reflected in Figure 4-9 depicts a typical three-phase operation. Phase I sets the enabling conditions for rapid and decisive entry and occupation of the scenario nation by coalition forces. Actions during this phase focus on (1) neutralizing the regime's ability to command its armed forces, (2) the use of special operations forces to build regional social networks that can be used to gain intelligence and popular support, (3) the achievement of air superiority, and (4) the neutralization of weapons of mass destruction (WMD) delivery systems. The last action—avoiding unanticipated negative consequences—is actually expressed as a constraint on the targeting process. That is, the targeting of attacks and effects should avoid causing collateral damage or unanticipated 2nd and 3rd-order effects that will reduce popular support for the coalition's entry and occupation of the nation.

Phase II actions address those steps needed to gain rapid and decisive entry and occupation of the country. Of specific note is the desire to separate the regime and its loyal paramilitary forces from both the populace and the nation's regular armed forces. These actions are intended to support the elimination of the regime and its paramilitary organization while retaining the regular armed forces to defend the nation under a future government. The selective nature of these actions implies that the targeting military units must be carefully planned and executed. Other

challenging actions within this phase include (1) the selective neutralization of close family members and loyal tribal figures who occupy key leadership positions in the current regime and (2) the avoidance of unnecessary destruction or disruption of vital services and utilities within the nation. Remaining actions deal with the issues of WMDs and terrorist operations. As in Phase I, the targeting of attacks and effects should avoid causing collateral damage or unanticipated 2nd and 3rd-order effects that will reduce popular support for the coalition's entry and occupation of the nation.

Phase III actions support the transition from major combat operations to security and stability operations (SASO) that enable the process of nation rebuilding to commence. Targeting operations during this phase continue to focus on the neutralization of old regime figures, the neutralization of remaining paramilitary supporters of the regime, and the elimination of terrorist groups harboring within the nation. As with the first two phases, targeting operations must avoid unintended consequences.

In order to reflect these images within the hypothetical case study, the modeling representation must articulate the battlespace in terms of relevant adversary centers of gravity and their corresponding effects, processes, and objects. Figure 4-10 illustrates how this might be done for the hypothetical modeling case. Here, the adversary—the old regime of the scenario nation—is hypothesized to have three major goals or purposes: (1) maintain its own power base, (2) influence regional politics, and (3) provide sanctuary for a transnational terrorist organization. These three goals or purposes are supported by five employment principles or centers of gravity—bases of power that, if neutralized, will result in the defeat of the regime. As illustrated in Figure 4-10, each of these centers of gravity can be decomposed in terms of effects, work processes, and associated objects within the battlespace. Ultimately, these objects become the focus of EBO-based targeting in order to (1) disrupt the key work processes and (2) neutralize the corresponding adversary centers of gravity. Finally, it should be noted that the abstraction hierarchy shown in Figure 4-10 presents the decomposition of centers of gravity in a somewhat linear fashion. In actuality, there exist a number of interactions and nonlinearities among the various effects and work processes. The degree to which these interactions and nonlinearities are represented in the hypothetical case would depend upon the relative level of detail provided in the modeling representation.

PURPOSE	EMPLOYMENT PRINCIPLES	OPERATIONAL EFFECTS	WORK PROCESSES	OBJECTS
Maintain regime in power	Maintain loyalty of key regime figures through family ties	Close family members keep key regime figures in check through bribes and perks	Day-to-day contact (telephonic or face-to-face) between close family members and key regime figures	Close family members, high-level command centers, selected communication systems, meeting sites, motorcades, personal residences, government administrative centers
	Maintain loyalty of populace through religious leaders/centers	Religious leaders/centers generate information campaign to keep populace in check	Daily religious meetings and public TV/radio broadcasts used to disseminate information campaign	Religious meeting facilities, religious leaders, TV/radio broadcast facilities
	Control or eliminate dissident groups through paramilitary force	Paramilitary use intimidation, assassinations, and mass executions to eliminate dissident groups	Paramilitary utilize neighborhood social networks to identify dissidents, then use small cell groups to carry out intimidation and executions	Neighborhood social networks, paramilitary cell groups, weapons caches
Influence regional politics	Maintain regional influence through development and possession of WMDs	Possession of WMDs demonstrate national and cultural power in region	WMDs are manufactured in dual-use facilities/labs, and stored in secret, secure locations	Dual-use facilities/labs, WMD storage sites, WMD delivery systems
Provide sanctuary base for transnational terrorist group	Maintain security of sanctuary base with national armed forces	Armed forces maintain physical security of terrorist bases	Armed forces maintain physical security of national borders and airspace	Military C2 centers, military C2 communication networks, army units and facilities, air defense units and facilities, naval units and facilities, airfields, POL and munitions storage areas, terrorist training bases, foreign/national terrorists groups

Figure 4-10. Adversary Abstraction Hierarchy for Hypothetical Modeling Case

As suggested by Figure 4-10, the modeling representation would have to reflect the types of objects listed in the right-hand column for each center of gravity. In turn, each object would have to be characterized in terms of the types of physical and informational cues and indications that might be displayed during the course of the hypothetical scenario—e.g., imagery, communication and electronic signals, radar imagery, human reconnaissance and intelligence reports, and so forth. Finally, these cues and indications would be embedded within the background noise of cues and indications associated with other (irrelevant) objects on the modeled battlespace. The sum of these cues and indications would then comprise the information space within which the modeled C2 organization would operate. Accordingly, to enable proper representation of these objects, the modeling case must include a depiction of the specific types of cues and indications that would stream from each major intelligence source available to the modeled C2 organization. A summary of these sources for the hypothetical modeling case is

illustrated in Figure 4-11. Specific EBO-based target elements are listed in the left-hand column. Shown next is an indication of how the target element is portrayed in the model: fixed, mobile, or emergent. Finally, the remaining columns indicate the types of intelligence information that would be reflected in a stream of messages and reports provided to the modeled C2 organization.

Target Element	Fixed	Mobile	Emergent	National Intelligence	Other Agencies	Theater / Tactical Intelligence, Surveillance, and Reconnaissance				
						Database	IMINT	SIGINT	RADINT	HUMINT
Regime family members and key leaders		×		×	×	×		×		×
Government administrative centers	×			×	×	×				
Government communication systems and networks	×			×		×				
Regime meeting sites (bunkers, residences)	×		×	×		×				×
Regime motorcades			×					×	×	×
Regime personal residences	×		×	×		×				×
Religious meeting facilities	×				×	×				×
Religious leaders		×		×	×	×				×
TV / radio broadcast facilities	×					×		×		
Neighborhood social networks	×			×	×	×				×
Paramilitary units (cells, units, technical vehicles)		×		×		×	×	×		×
Paramilitary weapons caches	×		×							×
Dual-use facilities / laboratories	×			×		×				
WMD storage sites	×		×	×		×	×	×	×	×
WMD delivery systems		×		×		×	×	×	×	×
Military C2 centers	×	×		×		×		×		
Military C2 communication systems and networks	×	×		×		×		×		
National army units (armor, infantry, artillery)		×		×		×	×	×	×	×
Air defense units and sites (SAM, EW, GCI)	×	×		×		×		×	×	
Naval units (ships)		×		×		×	×	×		
Airfields	×			×		×				
Transportation infrastructure (roads, bridges, tunnels)	×			×		×				
Public utilities (electric, water, sewer)	×			×		×				
POL and munitions storage areas	×			×		×			×	×
Terrorist training bases	×			×		×	×	×		×
Terrorist groups (national and foreign volunteers)		×	×	×						×

Figure 4-11. Sources of Cues and Indications Information for EBO-Based Target Elements

In order to deal with this information, a military C2 organization must reflect the structure and procedures needed to match this information with appropriate types of personnel expertise. Such a match-up enables the information to be properly filtered, interpreted, associated, and organized into actionable knowledge for the targeting process. For the hypothetical modeling case, Figure 4-12 presents a summary of the types (and levels) of expertise that might be required for properly transforming these cues and indications into actionable knowledge. Here, following the categories of expertise defined in Chapter 1, three levels of required expertise are denoted in Figure 4-12: *novice*, *competent*, and *expert*. (Dreyfus & Dreyfus, 2002) Thus, the modeling representation would require each type of message to be processed by personnel possessing the

requisite level of expertise in order for the cues and indications to be successfully filtered, interpreted, associated, and organized into actionable knowledge. For example, targeting an air defense unit or site would require expertise regarding (1) the physical and technical characteristics of the target, (2) the geographic location of the element, (3) the functional role of the element within the overall air defense system, and (4) the operational status of the element. By contrast, targeting a renegade religious leader would require expertise regarding (1) geographic location of the leader, (2) the position or role of the leader within the regime, (3) the likely consequences of targeting the leader vis-à-vis the cultural and religious attitudes of the populace, and (4) the likely psychological and social consequences of targeting the leader vis-à-vis the regime's leadership structure. In this second example, the likelihood of unanticipated negative consequences would be much higher than that in the first example.

Target Element	Fixed	Mobile	Emergent	Relevant Dimensions of Required Expertise						
				Physical / Technical	Economic	Geographic	Organizational	Cultural / Religious	Psychological /Social	Operational
Regime family members and key leaders		×		N	E	C	E	C	E	
Government administrative centers	×			C	C	C	E	C	C	
Government communication systems and networks	×			E	C	C	C			
Regime meeting sites (bunkers, residences)	×		×	E		E	E		C	
Regime motorcades			×	E		N	E		C	C
Regime personal residences	×		×	E		E	E		C	
Religious meeting facilities	×			C	N	C	E	E	E	
Religious leaders		×				C	E	E	E	
TV / radio broadcast facilities	×			C	C	C	C	C	E	C
Neighborhood social networks	×			N	N	C	C	E	E	
Paramilitary units (cells, units, technical vehicles)		×		E		C	E	C	C	E
Paramilitary weapons caches	×		×	E		C		C		E
Dual-use facilities / laboratories	×			E	E	C	E			
WMD storage sites	×		×	E		E	E			C
WMD delivery systems		×		E		E	E			E
Military C2 centers	×	×		E		C	E		C	C
Military C2 communication systems and networks	×	×		E		C	C			C
National army units (armor, infantry, artillery)		×		E		C	C		C	E
Air defense units and sites (SAM, EW, GCI)	×	×		E		E	E			C
Naval units (ships)		×		E		E	E			C
Airfields	×			E		C				
Transportation infrastructure (roads, bridges, tunnels)	×			E	E	C		N	C	C
Public utilities (electric, water, sewer)	×			E	E	C	C			
POL and munitions storage areas	×			C		C				C
Terrorist training bases	×			C		C			E	
Terrorist groups (national and foreign volunteers)		×	×	E		C	E	C	C	

Required Level of Expertise: E = Expert C = Competent N = Novice

Figure 4-12. Requisite Levels of Expertise Required for Each EBO-Based Target Element

To illustrate how this process might work for different classes of EBO targets, let us consider three examples. The first example deals with a relatively traditional and straight forward type of target, an air defense early warning radar site. Figure 4-13 illustrates the general targeting process. The term "general" is used in this example because the various functions included within the process have not yet been associated with a specific C2 organization or element.

In this particular case, three forms of information are available to assist the target development process. First, a technical definition of the radar site is available from a theater intelligence database that provides descriptions and standard target reference numbers for this and other air defense sites known to exist in the scenario nation. Second, current imagery is available that verifies the location of the site and identifies any surrounding structures that must be protected from collateral damage. Finally, SIGINT emissions intercepts are available that show the radar site is currently operational. In this particular case, all of this information is available to a single analyst who possesses the technical, geographic, and organizational expertise needed to integrate this information into actionable knowledge. Following arguments presented in Chapter 2, the actionable knowledge reflects both *know how* (an understanding of what the target represents functionally and the relative importance of the target to a center of gravity) and *know what* (the precise location of the target and its surrounding structures).

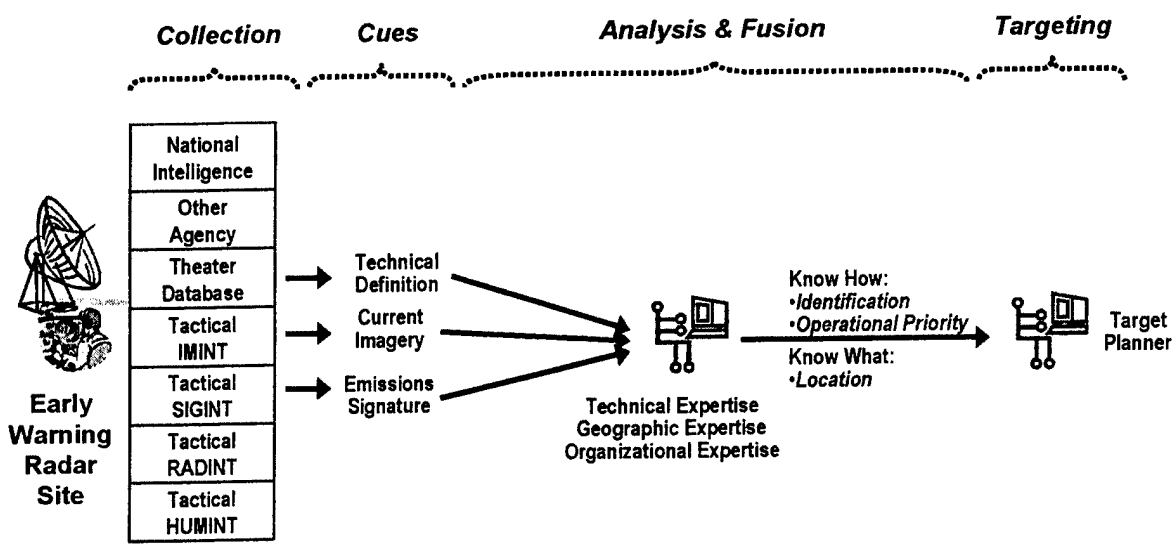

Figure 4-13. General Targeting Process for an Early Warning Radar Site

A slightly more complicated example is presented in Figure 4-14. This figure depicts how targeting operations might be conducted against a key regime leader. In this hypothetical case, four types of information are available from intelligence sources reporting to the military C2 organization: (1) the psychological profile of the leader developed from national intelligence sources, (2) the role of the leader within the regime that is provided by a theater intelligence database, (3) a tactical intercept of a telephone conversation revealing the daily plans of the leader, and (4) an eyewitness HUMINT report indicating that the leader has just entered a particular suburban residence for a secret meeting.

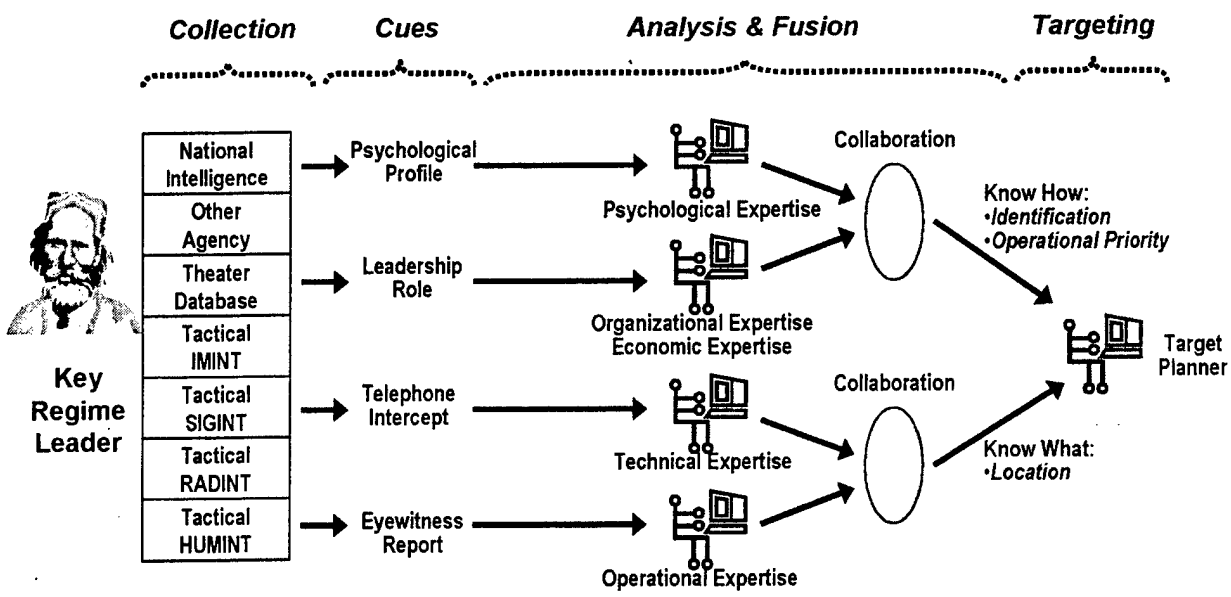

Figure 4-14. General Targeting Process for a Key Regime Leader

In this case, however, each of the individual pieces of information arrive via different channels within the military C2 organization, and they must be initially processed by different personnel possessing unique types of expertise. Accordingly, there must occur some level of collaboration between the person with the psychological profile information and the person with the organizational and economic expertise to develop the "*know how*" context for identifying and prioritizing the specific key leader as a useful EBO-based target. Likewise, there must occur collaboration between the technical expert receiving the SIGINT report and the operational expert processing the HUMINT report to establish the "*know what*" location of the key leader. Finally, the products of both collaboration events must be passed in a timely manner to a target planner in order for an attack to be quickly executed while the leader is still occupying the

residence. By comparison to the targeting of fixed air defense sites, this type of target development process is seen to be more complicated and time-sensitive.

Finally, the last example illustrates an even more complex targeting process that requires some level of interaction between planning and execution. In this case, the intended target is a specific army ground unit that has failed to capitulate and is still engaging BLUE ground forces, Figure 4-15. This targeting scenario is complicated however, by the immediate presence of other army units that have capitulated – that attack of which would result in a negative unanticipated consequence.

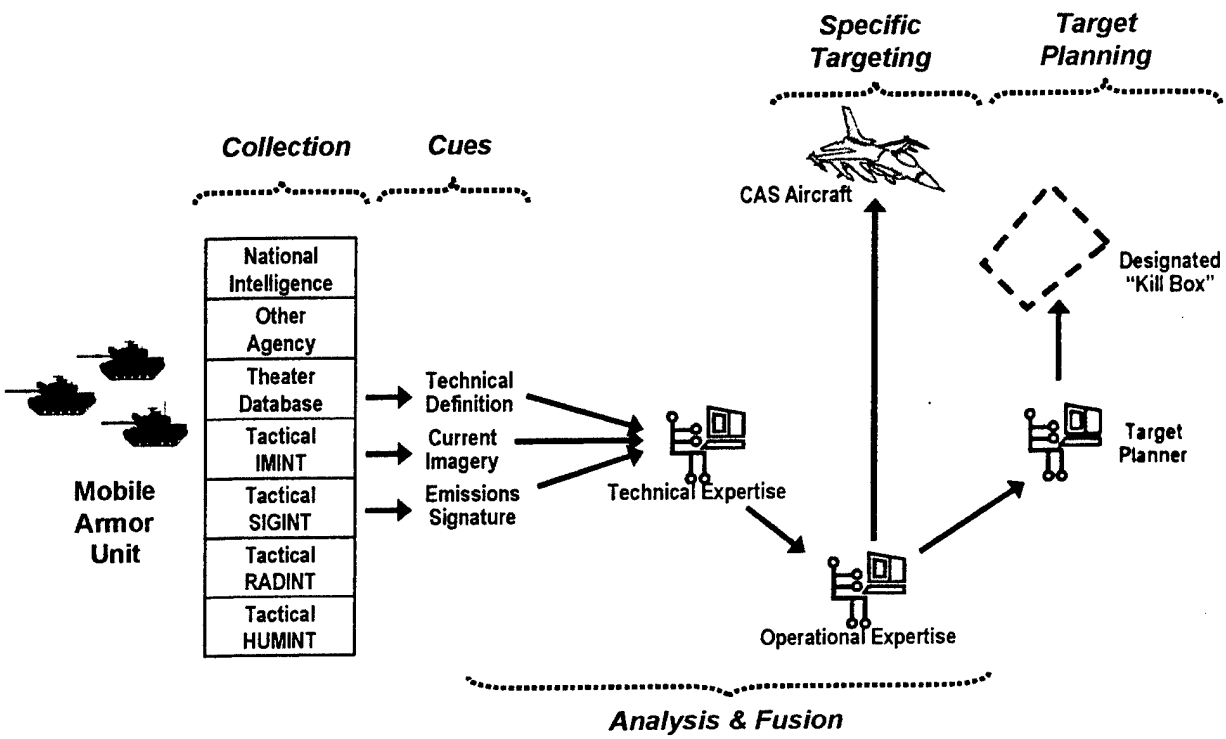

Figure 4-15. General Target Process for an Army Unit That Is Still Resisting BLUE Forces

As in the first example, three forms of intelligence information are available to a technical expert who can interpret and organize them into a meaningful description of the target element. However, in this case, a second expert is required—perhaps, a forward observer—who can provide the operational expertise that distinguishes this particular resisting unit from other nearby units that have already capitulated. Following the procedures employed during recent U.S. military operations, the target planner would have already established a designated kill box that authorizes supporting CAS aircraft to engage ground targets with minimal coordination with BLUE ground forces. However, in this case, providing the CAS aircraft free engagement

authority within the kill box would likely result in the unintended destruction of army units that have already capitulated. Hence, for the EBO-based targeting process to work effectively, there must exist some provision for the operational expert to pass specific intelligence information to the pilot of the CAS aircraft so that the resisting army unit can be distinguished from other nearby units. That is, actionable knowledge is only developed when the operational expert and CAS aircraft pilot collaboratively distinguish the appropriate ground target from other nearby adversary objects within the battlespace. Thus, in comparison to the first two cases, this type of targeting scenario represents a significant challenge—one not yet met by today's C2 organizations and procedures.

RELEVANT CYCLES, STRUCTURES, ROLES, AND WORK THREADS THAT DEFINE THE EBO TARGETING PROCESS

The discussion now turns to the relevant cycles, organizational structures, staff roles, and staff work threads that define an EBO-based targeting process. This section begins with a doctrinal look at the current Joint targeting process, as defined in various Joint publications. Next, the discussion highlights observations and lessons learned from Operation Enduring Freedom and Operation Iraqi Freedom. Finally, the section concludes with a summary of the key process features that should be represented in the modeling of future EBO-based targeting operations.

A Doctrinal Look at the Joint Targeting Process

Numerous doctrinal publications speak to various aspects of the Joint targeting process. From a review of these publications, it is possible to describe this process in terms of (1) the general steps that define the overall targeting cycle, (2) the key organizations involved in carrying out these steps, and (3) the key staff roles and work threads reflected in these organizations.

General Steps in the Targeting Cycle

As illustrated in Figure 4-16, the Joint targeting cycle consists of six general steps or phases that transform command intent and guidance into specific targeting effects and operations. (JCS, 2002b) The cycle begins with the development and articulation of the Joint Commander's objectives, guidance, and intent. In terms of EBO-based targeting, this vision is articulated in terms of adversary centers of gravity and *decisive points* that are deemed to contribute to the defeat of those centers of gravity. Since there might be more decisive points than a commander

can control, destroy, or neutralize, care must be taken to allocate resources to those considered most important. One of the initial tasks in the targeting process is to translate these centers of gravity and their associated decisive points into a series of discrete operational tasks. Operational tasks are further broken down into elements and measures of effectiveness (MOE). The development of MOEs provides the commander with a set of yardsticks for measuring the progress and success of operations, as well as assessing the requirements for follow-on action.

The second phase in this cycle includes the identification and validation of specific targets that best achieve the designated elements and operational tasks. Here, it is important for targeting operations to influence the establishment of intelligence requirements that, in turn, drive the employment of battlespace sensor platforms, scout teams, and other intelligence collection resources. Analysis of targets typically adopts a systems perspective of the adversary in order to both (1) develop target detail and (2) create an understanding of how the various targets functionally link to a specific center of gravity. In this regard,

> *Target development is made most effective by accessing the greatest possible breadth of subject matter expertise and information regarding the functioning of the systems that support adversary behaviors. This research is improved by expanded contact beyond that normally available within a JFC's planning staff, to include national interagency groups. (JCS, 2002b)*

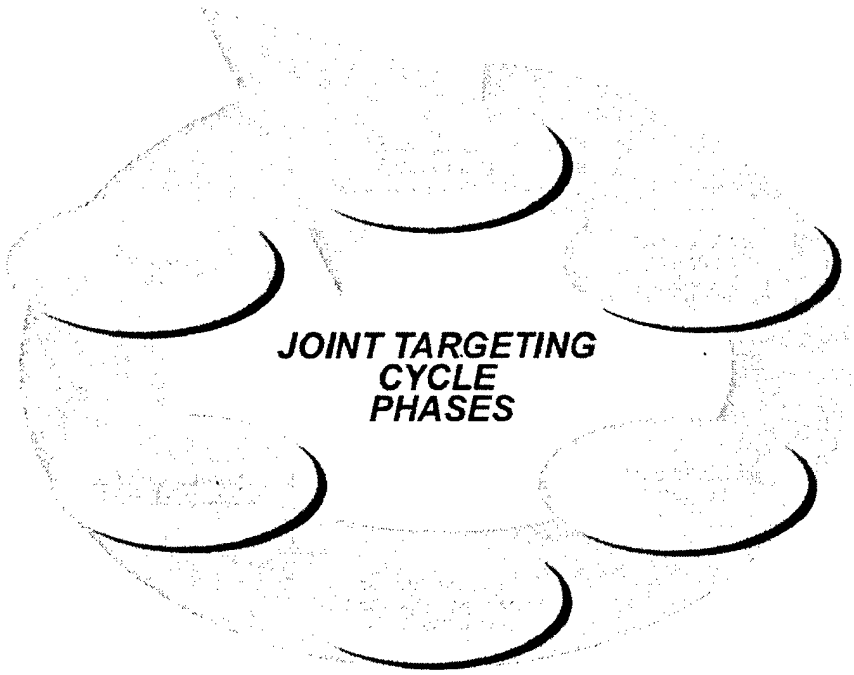

Figure 4-16. Joint Targeting Cycle (JCS, 2002b)

The capabilities analysis phase involves the analysis and estimation of the lethal and nonlethal effects that can be achieved against each nominated target. In this phase, various methods can be used to estimate effects, including both computational models and human expertise. The goal of this phase of the process is to determine the most effective and efficient means of achieving the desired effects on each target, given the resource limitations of the Joint force. As discussed later, each Component Service has access to the target data during this phase in order to assess their relative ability to attack different targets. Once these analyses have been completed, their results—referred to as *Target Nomination Lists* (TNL)—are consolidated and compared to determine which Component Service force elements are best matched against the requirements of each target.

The fourth phase of this process cycle consists of vetting the TNLs from each Component Service through various coordinating bodies to ensure compliance with the Joint Commander's objectives, guidance, and intent. This vetting process also serves to maximize the net effectiveness of the available forces and ensure that the most efficient methods are being paired with each target. Once the Joint Force Commander has approved the *Joint Integrated Prioritized Target List* (JIPTL), tasking orders are prepared and released to the Component Service

Command for execution. Two additional lists—the *no-strike list* and the *restricted target list*—are also identified at this time to designate battlespace objects that are either (1) off-limits to attack due to political, religious, moral, social, legal, or other constraints or (2) restricted to non-lethal types of effects. A key aspect of this phase is the documentation of the analytic threads that trace targets and effects back to the control, destruction, or neutralization of specific centers of gravity. Here, Joint doctrine notes,

> *Making the factors used in joint force planning available to the operations planners, and providing them real-time collaboration capability with other component and joint force-level targeting specialists, enables adjustment and fine-tuning of operational planning. It also provides a channel to discuss mitigation of risk for the attacking force, since variations in tactics may be required that could affect the results achieved at the target; the joint targeting process must be aware of these variations and adjust expectations accordingly. This is a critical path of information flow that reduces the likelihood of confusion between what was expected at the joint force level and what was actually achieved during execution. Ultimately, the exchange of information at this phase and the reconciliation of a common operating picture are critical elements in the last phase of the joint targeting process where outcomes are analyzed and future actions are determined. (JCS, 2002b)*

Mission planning and force execution is carried out by the Component Service Commands. Here, the Joint targeting process assists tactical mission planners by providing them direct access to information and reasoning used during the capabilities analysis to link targets, effects, centers of gravity, and warfighting objectives. Given the dynamic and emergent nature of military operations, the Joint targeting process monitors the execution of these missions in order to maintain initiative through flexibility.

The final phase of the targeting cycle is combat assessment—an activity that is performed at both the Joint and Component Service levels of command. Combat assessment is considered to be an essential part of operations inasmuch as it provides the Joint commander with the feedback needed to maintain an accurate picture of the battlespace.

Joint—Component Service Interaction within the Joint Targeting Process

It should be pointed out that the Joint targeting cycle depicted in Figure 4-16 is actually a collaborative process carried out at both the Joint and Component Service levels simultaneously. Illustrated in Figure 4-17 is a characterization of how staff responsibility for each phase of this process is distributed.

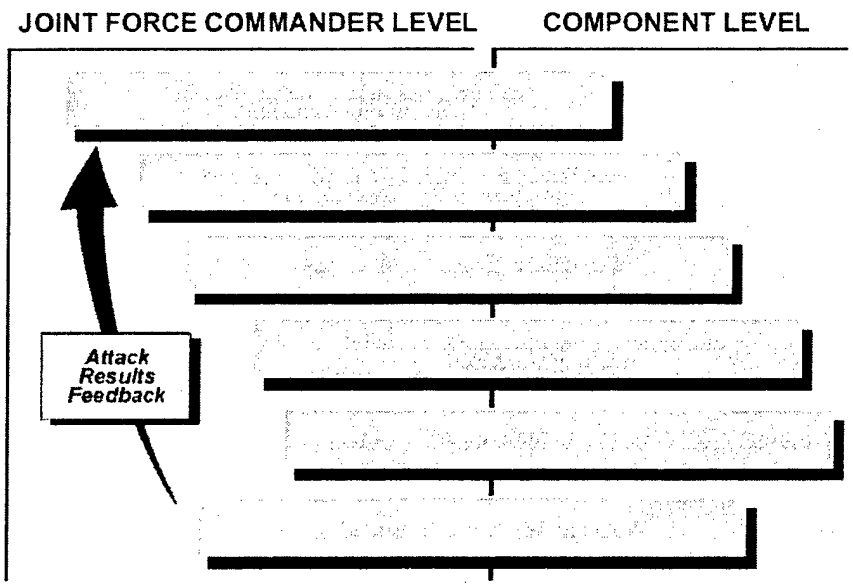

Figure 4-17. Distribution of Staff Responsibility for Joint Targeting (JCS, 2002b)

Moving to the Component Service level of command reveals a slightly different interpretation of the targeting cycle. For example, as shown in Figure 4-18, land forces and maritime forces employ a four-phase cycle that includes *decide*, *detect*, deliver, and *assess*. By contrast, as shown in Figure 4-19, air forces employ their own six-phase cycle that includes *objectives and guidance*, *target development*, *weaponeering*, *force application*, *execution planning and force execution*, and *combat assessment*. While these cycles differ outwardly from the Joint targeting cycle, they each retain the same essential elements of sensemaking, analysis, and decisionmaking.

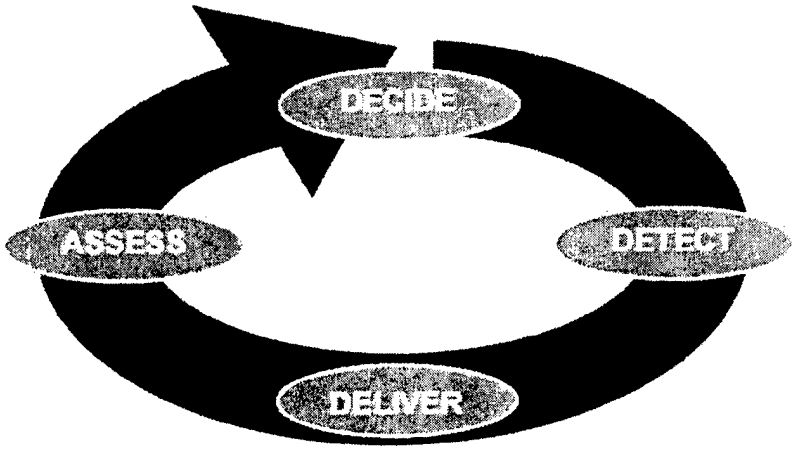

Figure 4-18. Land / Maritime Force Targeting Cycle (JCS, 2002b)

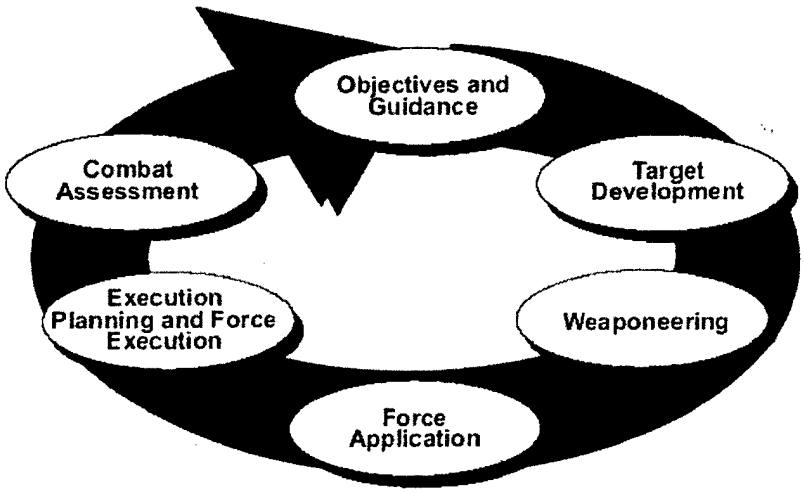

Figure 4-19. Air Force Targeting Cycle (JCS, 2002b)

Targeting Activities Within the Joint Task Force Headquarters

As noted in Figure 4-17, targeting operations are distributed among both Joint and Component Service level command centers. At the Joint Task Force (JTF) level, targeting operations are focused in several key staff elements in the headquarters structure illustrated in Figure 4-20. Specifically, these elements include

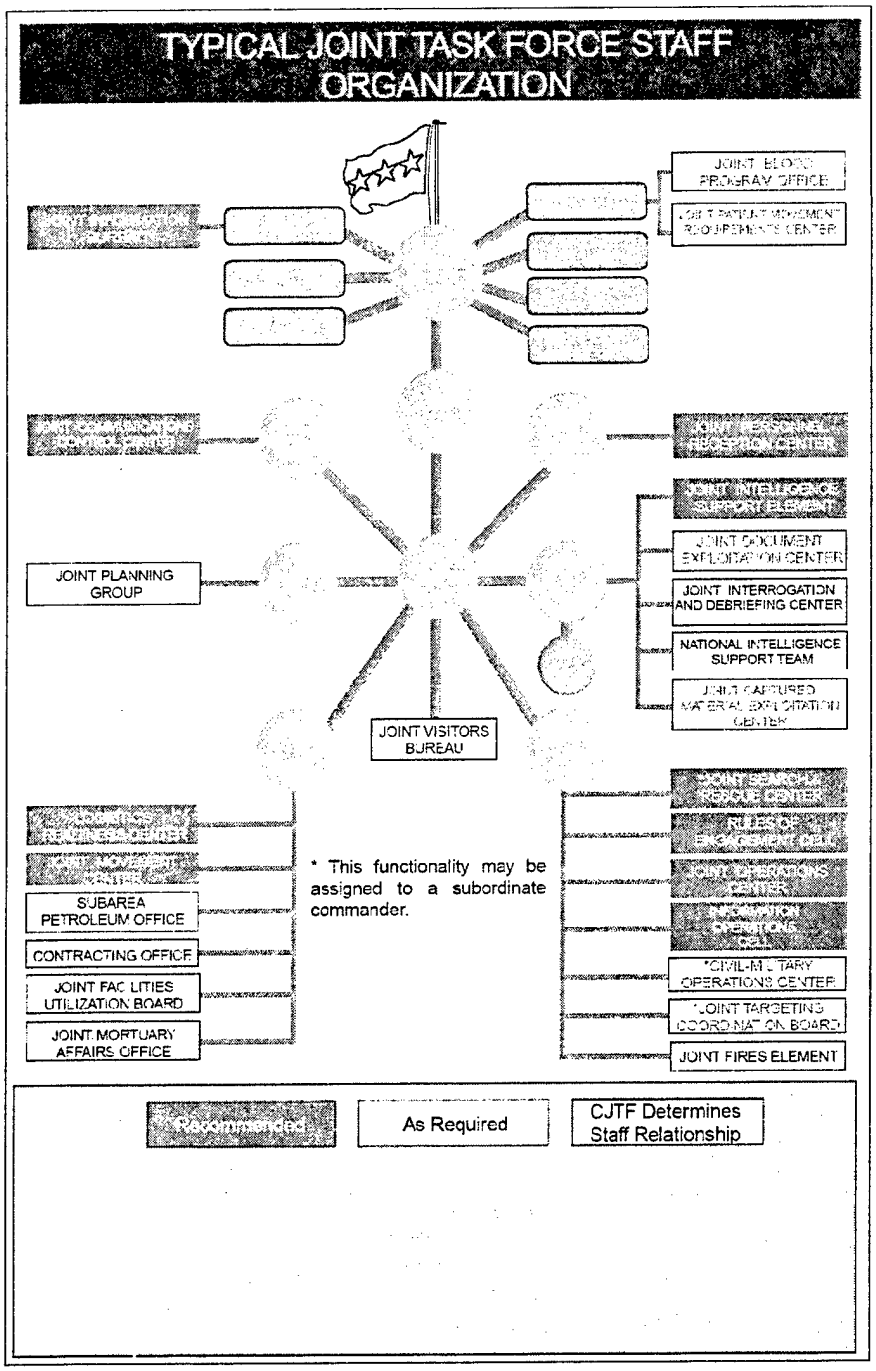

Figure 4-20. Joint Task Force Headquarters (JCS, 2002b)

- *Joint Targeting Steering Group* (JTSG). This is a high-level group established by the Joint Commander to assist him in developing targeting guidance and reconciling competing requests for assets among the Component Service Commands. It is typically composed of appropriate Service, functional component, national agency, multination, and Joint Staff (combatant commander level) representatives.
- *Joint Targeting Coordination Board* (JTCB). This board, organized by the Joint Commander, typically serves as an integrated oversight center and Joint review mechanism for the Joint Commander. The JTCB is usually led by the Deputy Joint Commander and performs the following functions: (1) reviews targeting information; (2) develops targeting guidance and priorities; (3) refines the JIPTL; (4) maintains awareness of the restricted targets, Special Operations Force (SOF) operating areas, and areas of BLUE reconnaissance so as to avoid operational conflicts and fratricide; (5) maintains a macro-level view of the Joint Operating Area (JOA) to ensure compatibility with the Commander's operational concept; and (6) ensures that Information Operations (IO) considerations are adequately addressed in the targeting process. The JTCB is normally located within the J-3 Operations Division; however, it's placement within the staff is determined by the Joint Commander.

The Joint Task Force Headquarters operates on a battle rhythm or daily operational cycle that generally conforms to the notional schedule illustrated in Figure 4-21. While much of the sensemaking and knowledge creation within the staff occurs in an emergent manner, the cyclical framework of the battle rhythm allows the staff to develop an information flow process—planned backwards from major events—in order to ensure that actionable knowledge is available when needed for key decisions. (JCS, 1999) As seen in Figure 4-21, a typical battle rhythm includes both recurrent planning meetings and various types of informational and decision briefings. Attendance by key leaders within the staff is usually prescribed by tactical operating procedures (TacSOP).

TIME	EVENT	LOCATION	PARTICIPANTS
NOTE:	SHIFT CHANGE	JOC	BATTLE STAFF/OTHERS AS REQUIRED
EVENT	TARGETING MTG	BRIEFING ROOM	AS REQUIRED
TIME	SITUATION UPDATE TO CJTF	BRIEFING ROOM	CJTF, DCJTF, CofS, IG, J-1, J-2, J-3, J-4, J-5, J-6, CJTF's PERSONAL STAFF COMPONENT LIAISON, OTHERS AS REQUIRED
IS SITUATIONALLY DEPENDENT	PLANS UPDATE TO CJTF	BRIEFING ROOM	CJTF, DCJTF, CofS, IG, J-1, J-2, J-3, J-4 J-5, J-6, CJTF's PERSONAL STAFF, COMPONENT LIAISON OTHERS AS REQUIRED
	CJFT's CONF CALL TO COMPONENTS	BRIEFING ROOM	CJTF, COMPONENT COMMANDERS
	JPG	JPG	JPG
	JTCB MEETING	BRIEFING ROOM	DCJTF, J-2, J-3, JFACC COMPONENT LIAISON, OTHERS AS REQUIRED
	DAILY STAFF BRIEF	BRIEFING ROOM	CJTF, DCJTF, CofS, IG, J-1, J-2, J-3, J-4, J-5, J-6, CJTF's PERSONAL STAFF, COMPONENT LIAISON, OTHERS AS REQUIRED
	SHIFT CHANGE	JOC	BATTLE STAFF/OTHERS AS REQUIRED
	JPG	JPG	JPG

CJTF commander, joint task force
CofS chief of staff
DCJTF deputy commander, joint task force
IG inspector general
J-1 Manpower and Personnel Directorate of a joint staff
J-2 Intelligence Directorate of a joint staff
J-3 Operations Directorate of a joint staff
J-4 Logistics Directorate of a joint staff
J-5 Plans Directorate of a joint staff
J-6 Command, Control, Communications, and Computer Systems Directorate of a joint staff
JFACC joint force air component commander
JOC Joint Operations Center
JPG joint planning group
JTCB Joint Targeting Coordination Board

Figure 4-21. Joint Task Force Headquarters Battle Rhythm (JCS, 1999)

Targeting Activities Within the Joint Force Air Component Command Headquarters

At the Component Service level, each command headquarters has staff elements corresponding to the Joint target process at the JTF level. In the case of air operations, the Joint Force Air Component Commander (JFACC) will operate a Joint Air Operations Center (JAOC) that serves to translate target nominations and taskings into actual mission. Figure 4-22 provides an illustration of a typical JAOC structure.

Joint targeting operations within JAOC are a collaborative process, involving several other staff elements. Internally, the Joint targeting process is coordinated with ground force maneuver operations via the Army's Battlefield Coordination Element (BCE), an Army staff detachment collocated within the JAOC. (Dept of Army, 1996a) Figure 4-23 illustrates the various points at which the BCE staff collaborates and interacts with Air Force staff members. As seen in this diagram, this collaboration occurs throughout the entire targeting cycle from intelligence preparation of the battlespace (Intelligence Division), through target development (Combat Plans

Division), to the monitoring and assessment of Joint air operations as they are executed (Combat Operations Division).

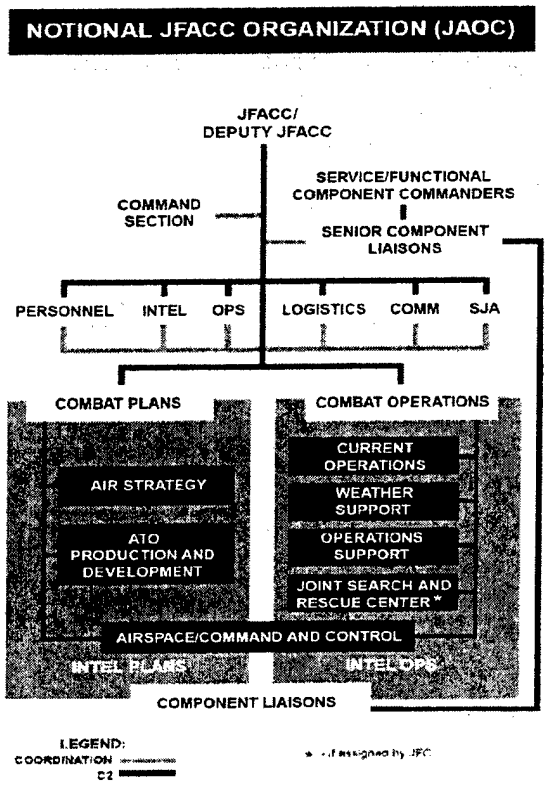

Figure 4-22. Joint Air Component Command Headquarters (JCS, 1994)

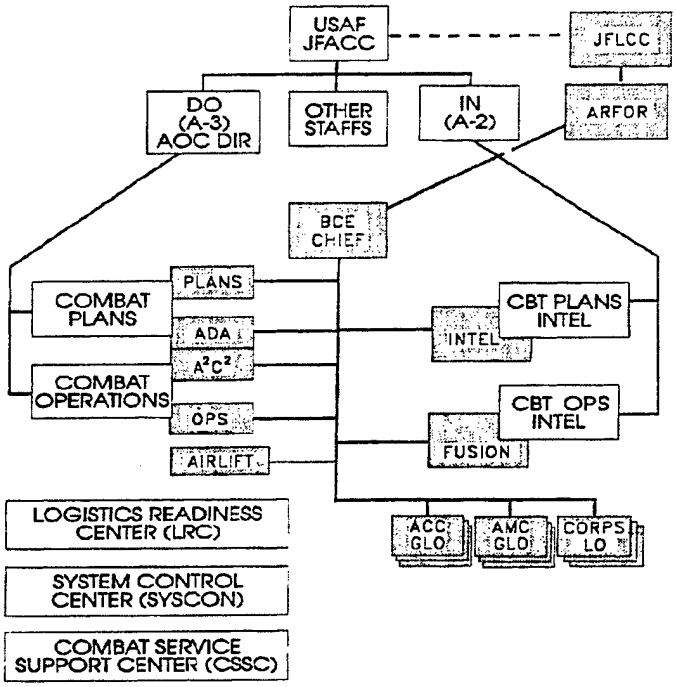

Figure 4-23. Points of JAOC-BCE Staff Collaboration and Interaction (Dept of Army, 1996a)

The BCE performs several sensemaking and knowledge management functions within the JAOC. (Dept of Army, 1996B) First, it serves as the Joint Force Land Component Commander's (JFLCC) representative to the JAOC, ensuring that the JFACC and his staff understand the JFLCC's intent, scheme of maneuver, and concept of operations for employing different elements of combat power. Secondly, it communicates JFLCC decisions and issues to the JAOC. Third, it monitors and interprets land force operations for the JAOC, passing both operational information and air support requirements to those developing the Air Tasking Order (ATO). Typically, these projections and requirements are framed within a 24-96 hour planning horizon. Finally, the BCE serves to coordinate air operations with other forms of fire support—e.g. land force artillery—so as to avoid duplication of efforts. While the BCE does not generally have decisionmaking authority, it serves as a vital, collaborative participant in the Joint targeting process.

Externally, the Joint targeting process within the JAOC is collaboratively shared with the Joint Task Force Headquarters staff. As illustrated earlier in Figure 4-17, there does not exist a precise delineation of responsibilities and work threads between these two staffs. Rather, the collaborative sharing of sensemaking and knowledge management responsibilities is seen as a

dynamic function of both (1) the specific steps in the targeting process and (2) the exact nature, priority, and sensitivity of the targets. (JCS, 2002b) In terms of current doctrine and procedures, "*The recurring target nomination process supporting the ... joint targeting effort can be from 72 to 96 hours in duration (from target nomination to complete execution). Shorter durations of 48 hours or less are possible with proper coordination between the appropriate supporting and supported commanders.*" (JCS, 2002b) The length of this process is dictated by (1) a targeting process that must accommodate target nominations from each of the Component Service Commands, the Joint Task Force Headquarters staff, and National Command Authorities (NCA) and (2) the fact that target nominations will typically exceed the capabilities of the Joint forces to service. Hence, some level of adjudication and negotiation are required to establish the final prioritized list of targets that are published in the daily JIPTL.

While this type of deliberate planning process might be suitable for targeting fixed installations and facilities, a more immediate process is required for time sensitive targets. Accordingly, current doctrine outlines the need for close collaboration among the Component Service and Joint staffs in detecting, locating, identifying, nominating, tracking, allocating, and attacking time sensitive targets. Figure 4-24 illustrates the current process outlined in Joint doctrine for attacking time sensitive targets, including the need for real-time assessment and reattack. Such collaboration must be supported by preestablished staff drills, common information sharing technologies, and Joint—rather than individual Service—experimentation to explore and identify feasible working arrangements for this challenging task. (JCS, 2002b)

The major focus of attention within the JAOC is the development of the ATO, the daily operational plan that specifies which targets are to be attacked by which combat resources and platforms. Current doctrine specifies that the JAOC will be developing three different ATOs at any given time: the Joint ATO being executed in today's operations, the Joint ATO being produced for tomorrow's operational plan, and the ATO being developed for the following day's operational plan. (JCS, 1994) The full ATO planning cycle—from the time that the Joint Commander issues his intent and guidance until the time the ATO begins execution—is dependent upon Joint Task Force Headquarters and JAOC procedures. Nominally, the ATO planning cycle takes 30-72 hours and results in an operations order that spans a 24 hour period. Similar to the Joint Task Force Headquarters, sensemaking and knowledge management within

the JAOC is framed by a cyclical battle rhythm. A typical JAOC battle rhythm is illustrated in Figure 4-25.

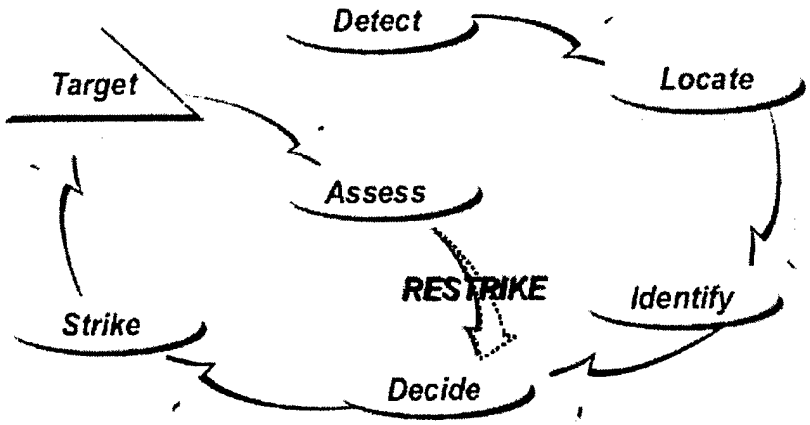

Figure 4-24. Joint Process for Time Sensitive Targets (JCS. 2002b)

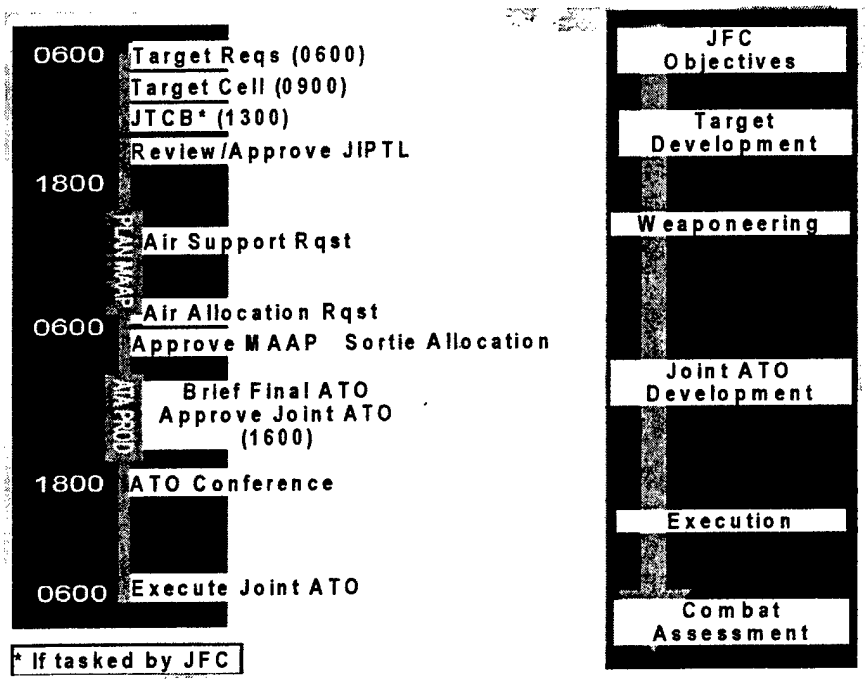

Figure 4-25. Notional 48 Hour Joint ATO Battle Rhythm (JCS. 1994)

Within the cycle illustrated in Figure 4-25, the JAOC staff carries out work tasks within a number of specific phases. These phases, shown on the right side of Figure 4-26, include

- *Joint Force Commander Objectives.* In this phase, the Joint Commander consults with his Component Service Commanders to assess operational progress and provide strategic guidance for future operational plans. This guidance will include targeting priorities for establishing the JIPTL, appropriate coordination measures for maneuver and Joint fire support, rules of engagement, and his air apportionment decision.
- *Target Development.* In this phase, the Joint Task Force and JAOC staff receive target nominations from various force elements and the NCA. These nominations are reviewed, sorted, and prioritized against received targeting guidance and available forces to produce an air operations plan and the JIPTL. This is the primary phase in which critical sensemaking and collaboration occur among the various participants and stakeholders in the targeting process to ensure proper linkage of effects and allocation of combat resources.
- *Weaponeering.* In the weaponeering phase, weaponeering analysts quantify the expected lethal and/or nonlethal effects to be achieved against each specific target aimpoint. From these analyses, the JAOC staff produces the Master Air Attack Plan (MAAP)—the plan of employment that forms the basis for the ATO. The development of the MAAP includes the review of command guidance, direct air support plans and support requests from each Component Service, updates to target requests, availability of capabilities/ forces, target selection from the JIPTL, and aircraft sortie allocation.
- *Joint ATO Development.* After approval of the MAAP by either the Joint Commander or JFACC (determined by the Joint Commander), the JAOC's Combat Plans Division continues development of the Joint ATO and two other products: Special Instructions (SPINS) and the Airspace Control Order (ACO). As part of this process, the JAOC reviews each Component Command's proposed sortie allocation and issues a final sortie allotment message that (1) revised, if necessary, a Component's sortie allocation to address unforeseen Joint requirements, (2) approves/disapproves Component sortie requests and proposed allocation of other Components' excess sorties, and (3) revises mission priorities and schedules as coordinated with the Joint Task Force Headquarters staff.

- *Execution.* During execution, the JAOC staff monitors air operations and redirects air missions as appropriate, based on emerging requirements. During this phase, the JAOC is the central agency for all redirection decisions, and is responsible for keeping each of the affected Component Service Commands informed of these decisions and their impact on planned operations. However, the actual decision to redirect missions is a shared responsibility between the JAOC and the Joint Task Force Headquarters. As dictated by circumstances, redirection decision authority for some mission—e.g., interdiction and close air support—can be delegated to ground or airborne C2 mission commanders within the structure illustrated in Figure 4-26.
- *Combat Assessment.* Combat assessment—also formerly referred to as battle damage assessment—is conducted at all levels of command. It typically employs a dynamic system that involves both operations and intelligence personnel. The focus of combat assessment is to provide the Joint Task Force Headquarters and JAOC staffs with situation awareness regarding the effectiveness of targeting operations vis-à-vis operational goals and strategy.

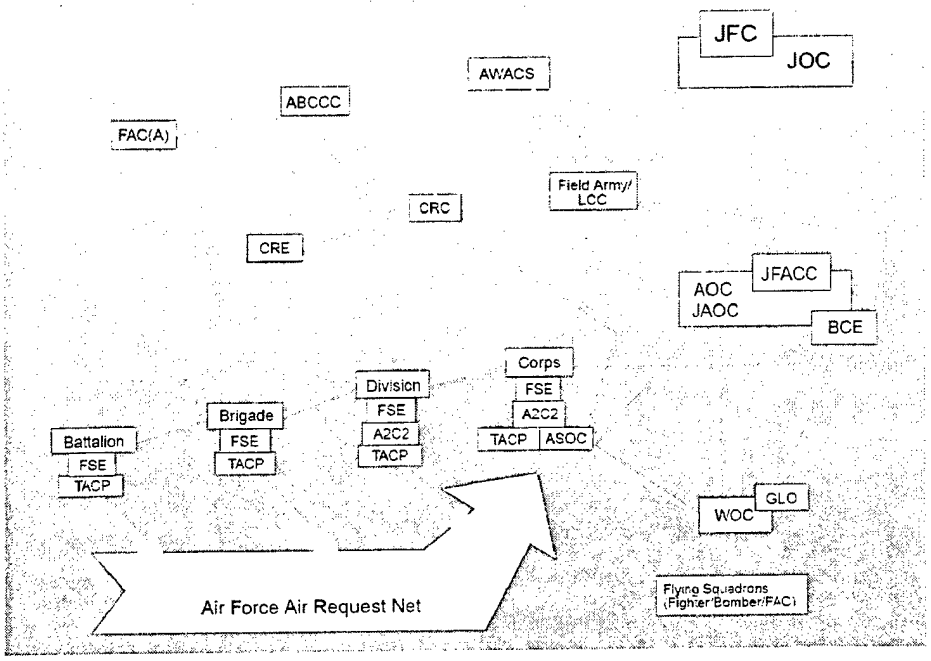

Figure 4-26. Ground and Airborne C2 Elements for Joint Targeting Missions (Joint Pub 3-09.3. 1995)

Targeting Activities Within Other Component Command Headquarters

Targeting activities and responsibilities reside within each of the other Component Service Command headquarters, dependent upon their resources for engaging potential targets. In this final section, the discussion focuses on those targeting activities conducted within the JFLCC headquarters. According to current doctrine, The JFLCC staff conducts operational planning using the same processes of the command that formed the core of the headquarters. (Dept of Army, 2001) Typically, the forming command will be an Army Corps headquarters. As specified in the *JFLCC Handbook*, a notional JFLCC headquarters staff will be formed using the structures illustrated in Figure 4-27.

As depicted in Figure 4-27, targeting activities are focused in both (1) the Targeting Cell located within the J-2 Intelligence Directorate and (2) the Target Development Team that forms part of the Deep Operations Coordination Cell (DOCC) (or, alternatively, the Force Fires Coordination Cell) located within the J-3 Operations Directorate. The DOCC responsibilities include

- Advising the JFLCC on operational fires an effects
- Identifying fires and effects requirements from other Component Service Commands

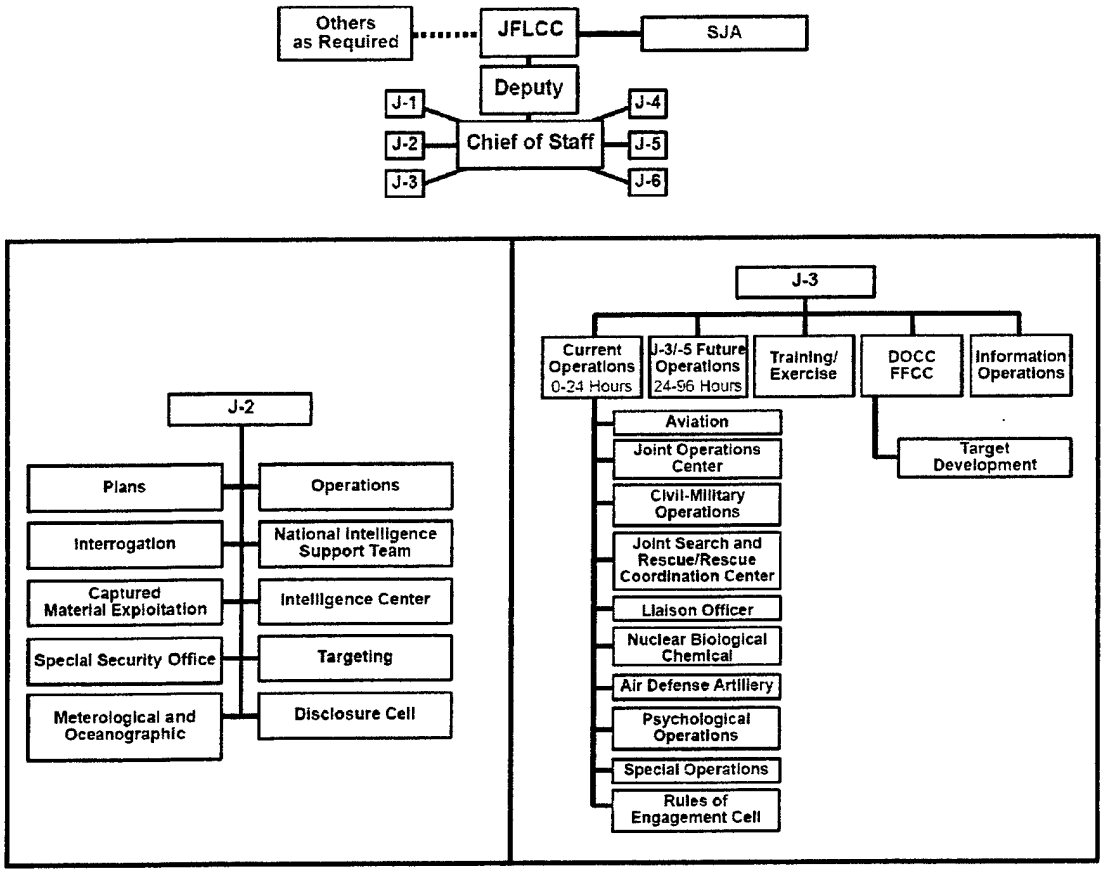

Figure 4-27. Notional JFLCC Headquarters (Dept of Army, 2001)

- Reviewing the JFACC's apportionment recommendation
- Recommending JFLCC attack resources for apportionment by the Joint Force Commander (e.g., ATACMS, attack helicopters)
- Develop JFLCC targeting guidance and priorities for both ground fires and air interdiction
- Develop the JFLCC command target lists and fire support coordination measures
- Integrate and synchronize lethal and nonlethal fires
- Plan, coordinate, and supervise the execution of JFLCC deep operations
- Coordinate all planned airspace requirements

Typically, the JFLCC will also organize a *Target Coordination Board* (TCB) to function as an integrating center for targeting oversight and review. The TCB is a Joint activity with participants representing the JFLCC staff, the different Component Commands, and subordinate units. (Dept of Army, 2001) The role of the TCB is to (1) provide the JFLCC with clear

guidance, objectives, and rules of engagement for operational planning and targeting; (2) update mission planning guidance, intent, and priority intelligence requirements throughout the targeting process; (3) provide a forum for reviewing Joint targeting guidance and apportionment; (4) to review major JFLCC operational plans several days in advance to anticipate future targeting requirements, priorities, and restricted/no-strike target lists.

While target planning typically operates on a time horizon of several days, time sensitive targets are coordinated on an immediate basis by the *Fire Support Element* (FSE) through a quick-fire information network. According to current doctrine, "*This may be by radio, phone conference call, or computer chatter link. As a minimum, this net links the DOCC/FFCC, collection management, and the battlefield coordination detachment (BCD). Additional nodes may be a major subordinate command (MSC) FSE, Army Air Missile Defense Command (AAMDC), special staff, J-3 current operations, and others as the situation dictates.*" (Dept of Army, 2001) Time sensitive targeting requests may be submitted by any subordinate command. The request is evaluated on the basis of need, criticality, and comparison with other requests. If the request cannot be serviced in a timely manner or is denied, the request is adjudicated by the DOCC Chief.

Within the J-2 Intelligence Directorate, targeting-related responsibilities include support to target development; the coordination of intelligence, surveillance, and reconnaissance resources and operations; the development of collection requirements for theater and national tasking; and the assessment of non-lethal effect operations.

CURRENT ISSUES AND OBSTACLES

It was noted in the introduction section of this chapter that the Air Force initiated a number of changes in its targeting philosophy after Operation Desert Storm. Accompanying these changes were a number of technological initiatives to improve operations within the JAOC. However, it was concluded that development of an effective EBO-based targeting process must address a number of relevant dimensions, including information technology, leadership and training, personnel management, staff process and battle rhythm, and organizational structure. In this regard, the discussion now turns to lessons learned during the most recent Operation Iraqi Freedom. These lessons learned are primarily developed from after action reviews or papers

prepared by the U.S. Army's 3rd Infantry Division (3IF, 2003), the U.S. Marine Corps' 1st Marine Division (1MD, 2003), and personnel who served in the Army's 1st Battlefield Coordination Detachment that was collocated with the Coalition Air Operations Center (CAOC) at Prince Sultan Air Base, Saudi Arabia. (Kelly & Andreasen, 2003; Kelly, 2003) The issues identified in these lessons focus on three aspects of the targeting process:

- The inability of the current targeting process to support fast-moving ground operations
- The lack of information system compatibility between air and ground forces
- The lack of effective staffing and management of personnel

Inability of Current Targeting Process to Support Fast-Moving Ground Operations

Operation Iraqi Freedom (OIF), like the previous war in Iraq a decade earlier, reflected a fast-moving ground operations campaign as coalition forces moved from their initial entry points to the final objective areas at Baghdad and other key cities. Yet, during operations up through D+3, the Army's 3rd Infantry Division and the 1st Marine Division advanced up to 350 kilometers, fighting through heavy resistance at several points, with few CAS sorties being flown in support of these operations. (Biddle *et al*, 2003) To discover why this occurred, one must look closer at the systems and procedures used for targeting air operations in support of the JFLCC during OIF.

Despite many of the successes reflected during OIF, this operation provided many examples of poor communication and joint system integration—obstacles that would prove more disastrous against a more capable enemy in the future. As noted by personnel operating the BCE within the CAOC, "*Many of the processes and systems designed to support joint targeting and operational fires interfaces between the land and air components proved unwieldy, ineffective and inefficient.*" (Kelly & Andreasen, 2003) The targeting process required CFLCC planners to submit detailed Air Support Requests (ASR) against mobile targets three days in advance of execution—with little or no knowledge regarding the status of ASRs submitted on the previous two days. During the initial days of the operation, the CAOC staff struggled to maintain an awareness of which missions had been flown and where. When ground operations again picked up after the operational consolidation south of Karbala, the CFLCC lacked adequate knowledge of adversary forces and their operational status. As a result of this knowledge gap, ground forces were required to conduct a movement-to-contact instead of a deliberate attack.

Within the 1st Marine Division, division staff noted that the 72-hour deliberate targeting cycle was unable to keep up with the dynamics of the battlefield. (1MD, 2003) As a result, the air interdiction shaping effort often did not focus on the enemy forces the division would actually fight in 48 hours. Here, the speed of execution was never fully appreciated by the division's future planners. As a result, the maneuver briefings provided to targeting boards and other forums typically lagged by 24-48 hours in terms of situation awareness. Additionally, the division's *Synchronization Working Group* did not sufficiently address changes in the scheme of maneuver as it attempted to validate the Prioritized Target List.

As reported by the 3rd Infantry Division, air interdiction target requests were submitted for four ATO cycles during the initial days of OIF. To offset the lack of continuous communications capability as the division was on the move, the Division's Fire and Effects Coordination Cell (FECC) liaison officer deployed with the Field Artillery Intelligence Officer (FAIO) to a Deployable Intelligence Support Element (DISE) to analyze, refine, and update target nominations. (3IF, 2003) The integration of the DISE into the normal targeting process was an invaluable work around and paid major dividends in the defeat of the Iraqi 11th Infantry Division during 19-24 March, 2003. After 25 March, the division reverted to the normal targeting process, with one major exception: the targeting process focused only 24 hours out, rather than 72 hours. This was due to the effectiveness of Corps-level shaping operations and the dynamic pace of the battlefield. As a result, the 3rd Infantry Division recommended that this targeting methodology—with its 24-hour time horizon and integration of the DISE—be continued for future operations. In addition, recommendations were included for improving the long-range communications capability required for linking the division's targeting process with Corps and the JFACC.

A related doctrinal issue noted by the 3rd Infantry Division focused on the definition and placement of the Fire Support Coordination Line (FSCL)—a doctrinal control measure for coordinating air and land targeting operations. (3ID, 2003) Normally, the FSCL is placed 30-40 kilometers out, a distance that corresponds to the maximum range of the division's indirect fire assets. However, for OIF, the FSCL was placed approximately 140 kilometers in front of the division—primarily because the division was flanked by the 1st Marine Division that has organic air assets that can reach out that far. This left a gap of about 100 kilometers between the 3rd Division's area of influence and the area shaped by the CFACC. This created an issue regarding

which organization was responsible for shaping deep operations in this area—the JFACC or the Corps? The JFACC is doctrinally responsible for deep shaping, relying upon its available intelligence, reconnaissance, and surveillance assets to develop viable targets in this area. However, as noted in the 3rd Division's report, the JFACC's lengthy targeting process was often ineffective because (1) there was no process to update the CAOC's target awareness and (2) mobile targets had moved by the time of sortie execution. Consequently, the inability to pass current situation awareness from the division back to the CAOC resulted in a number of wasted interdiction sorties. Also noted in the 3rd Division's report, "*The placement of the FSCL was so far in front of the forward edge of the battlefield (FEBA) that neither divisional or corps assets could effectively manage the battlespace... Link this with the limited ability of corps to conduct target development within their battlespace, and the inefficient use of CFACC assets becomes apparent.*" (3ID, 2003)

A related problem was the movement of the FSCL. When the FSCL was moved according to a maneuver trigger—i.e., ground forces had advanced beyond a certain line—the likelihood existed that JFACC air interdiction missions planned on the basis of the original FSCL would now be executed within the corps or division operational area. (3ID, 2003) For the future, the 3rd Infantry Division recommended better doctrinal integration of this process. Specifically, there needs to be a system for dynamically redirecting air interdiction missions either into (1) CAS missions that could controlled through the ASOC in support of ground forces or (2) alternate interdiction missions that could be controlled through the JFACC's Airborne Warning and Control System (AWACS). Additionally, this interdiction process could be improved by (1) placing Army liaison officers onboard AWACS and (2) placing the Army's Forward Battle Command Brigade and Below (FBCB2) system onboard AWACS.

During OIF, the Army's 5th Corps employed allocated CAS sorties to strike targets within the 3rd Division's operational area, short of the FSCL. An imaginary line was placed about 30 kilometers out to delineate between divisional CAS responsibility and the Corps' use of fixed wing aircraft to engage targets. However, the parameters of this concept were never clearly defined beyond a PowerPoint slide. As a result, 5th Corps continually engaged targets inside of division area without proper coordination and deconfliction. Likewise, there was no positive clearance of fires.

Finally, it was noted in several reports that land forces were unable to obtain timely and useful BDA information during OIF. This problem was due to a number of reasons, including (1) the failure of pilots to report damage assessments in-flight, the lack of precise procedures for developing and reporting BDA at each level of command, and (3) communication blockages, particularly at the lower tactical echelons.

Lack of Information System Compatibility between Air and Ground Forces

For effective collaboration to be achieved among component forces, there need to exist both common—or interoperable—information systems and common experience among the staffs. Regarding information systems, personnel within the BCE noted that a proliferation of partially redundant software systems exist within the CAOC and BCE. The inability of these systems to link together or share all types of target-related information presented various obstacles to the effective and dynamic coordination of targeting operations. For example, within the BCE there existed 43 computer systems, four different and incompatible "chat" networks, and four different Common Operating Pictures (COP)—thus, requiring the staff to (1) monitor four separate chat networks simultaneously and (2) rely upon PowerPoint and Excel to pass much of the relevant and timely targeting information. (Kelly, 2003)

Of particular concern were incompatibilities that existed between the Air Force's Theater Battle Management Core System (TBMCS) and the Army's Advanced Field Artillery Tactical Data System (AFATDS)—the two primary systems for passing ASRs, sharing interdiction target data, and coordinating joint fires. Specifically, these systems were designed to pass target information only for air interdiction missions—not CAS missions. Thus, the CFLCC staff had no means for coordinating shaping attacks against those mobile targets that fell short of the FSCL. Eventually, the CFLCC and CFACC staffs developed a manual work around procedure that artificially treated all ASRs as air interdiction missions; however, this procedure relied upon a confusing system of target numbering that was not understood by all staff members. In a related area, TBMCS and AFATDS could not effectively exchange target weaponeering data or kill box information. As a result, the CFLCC staff—which was also responsible for coordinating Corps indirect fire support—did not know which targets within a given kill box were actually being serviced by CFACC air missions. (Kelly & Andreasen, 2003)

An additional problem arose regarding the management of the Modern Integrated Database (MIDB), an integrated collection of several targeting databases within the Department of Defense (DOD). The MIDB includes several legacy systems:

- Electronic Order of Battle Services
- Expeditionary Warfare
- Military Facilities File
- PORTS
- Target Material Management
- CENTCOM/SOCOM Integrated Data System
- Force Trends Database
- Force Tracking Information System
- Space Database

During OIF, the MIDB—using a target reference system based on Basic Encyclopedia (BE) numbers and Unit Identification Codes (UIC)—was unable to effectively support the targeting of mobile targets. (Kelly and Andreasen, 2003) Additionally, TBMCS could not accept BE numbers for multiple strikes against the same target. Finally, CENTCOM and the national intelligence agencies wanted to centrally control the MIDB, while CFACC and CFLCC desired an ability to modify the targeting data within MIDB to match the dynamics of the operation While CFACC and CFLCC staffs were eventually allowed to modify the targeting database, this issue raised a concern for the future. While there is some merit is centrally managing a single targeting database across all of DOD, there is a risk that target analysts in different theaters or operations will misuse this database because either (1) the data has not been appropriately tailored to the local situation or (2) the target analysts do not understand the weaponeering assumptions embedded within the national targeting data. As future EBO-based targeting operations consider a wider variety of operational effects, this issue will become more significant.

Next, it was noted during OIF that there was often a disconnect between the actual ASRs passed from the CFLCC to the CFACC and (1) CFLCC guidance and (2) the capacity of the coalition air forces to service targets. (Kelly & Andreasen, 2003) The CFLCC's *Daily Effects Board*—the

name given to TCB during OIF—produced clear PowerPoint products that articulated the CFLCC's desired effects and priorities over time. However, the current system of developing ASRs is a bottom-up, rather than a top-down process within the land forces. This target nomination procedure is based on the traditional assumption that the lower tactical echelons of command have the best operational understanding of what needs to be attacked or influenced. However, these lower echelons of command did not always possess an accurate understanding of either operational level thinking or the capabilities of the coalition's air forces. As a result, the DOCC was flooded with target nominations that (1) did not match CFLCC guidance and (2) greatly exceeded the servicing capacity of the CFACC. While the DOCC attempted to reconcile, filter, and organize the various requests consistent with guidance and capacity, problems remained with this system.

Finally, problems existed with supporting CENTCOM's kill box concept with the current ASR system. Specifically, the kill box concept is based on the notion of directing air mission to a geographical area. Once the aircraft arrive at that area, they are then provided updated intelligence, reconnaissance and surveillance information that enable them to identify specific targets for attack. By contrast, the current ASR system requires land forces to specify <u>in detail</u> each specific target to be attacked. Such a system wastes staff time and resources since the location and detail of most mobile targets will have long since changed by the time actual missions are flown against a specific ASR. As summarized in a lessons learned paper, "*Current C4I systems drive users to focus on unneeded detail. Instead of nominating 180 to 250 unit type targets in painful detail, the CFLCC needed to focus on fewer effects-based targets. This might have accomplished what the CFLCC wanted better while reducing the amount of effort put into handjamming UIC-based target information into Army and joint systems.*" (Kelly & Andreasen, 2003) In a related area, it was noted by the 1st Marine Division that the current targeting system provided no means for the land force commanders to track the status of their ASRs. Specifically, there existed no means for CFLCC units to either (1) track the pairing of target reference numbers with CFACC mission numbers or (2) determine the status of whether a specific target nomination had been serviced by the CFACC. (1MD, 2003) Here, a recommendation has been developed for future operations to follow the more dynamic system that has been instituted within the CAOC for attacking time sensitive targets. That is, the CFACC operates a TST cell within its Operations Division that can exploit the advantages of current intelligence,

reconnaissance, and surveillance systems to continuously identify, track, and match dynamic targets with an appropriate weapon system. As such identification and tracking capabilities improve within each of the Component Services, this same concept could be expanded to address a broader range of mobile targets that fall within the scope of traditional interdiction and CAS missions. (Kelly & Andreasen, 2003)

Lack of Adequate Personnel Staffing and Management

The third aspect of targeting operations addressed in the lessons learned papers focused on personnel staffing and management. Personnel staffing issues affecting EBO-based targeting operations focused primarily on the lack of adequate HUMINT resources. Personnel management issues focused on the building of effective social networks across the various staffs.

Regarding the first issue, the asymmetric nature of operations during OIF pointed out the increasing need for HUMINT collection and analysis resources to support both operational maneuver and targeting. As noted by the 3rd Infantry,

> *Once the division reached the outskirts of Baghdad, the main effort eventually became SASO. The division's intelligence effort had to transition, with basic intelligence requirements identified and resources prepared to shift. ... The complexity of the operational environment requires sharing intelligence from the national level to the tactical level and among headquarters at each level. Our doctrine acknowledges the demands on our intelligence system in full spectrum operations. A division must be able to collect against a commander's priority intelligence requirements (PIR) throughout the full spectrum operations, including the intelligence dimension of SASO. As an example, it must be able to quickly integrate additional human intelligence (HUMINT) assets with corresponding demands for linguist support, operational direction, and analytical support. (3ID, 2003)*

In response to this need, the division received a Military Intelligence (MI) Battalion that brought *Tactical HUMINT Intelligence Teams* (THT) that were assigned to the each of the three direct support companies. Once the main effort became SASO, this capability was augmented with several dedicated SIGINT systems and 24 Arabic speakers to augment the THTs in their

interrogation of prisoners of war. Likewise, these operations validated the need for a G2X function—a permanent part of the division G2 staff dedicated to the collection and analysis of HUMINT. But, as the division reported,

> *However at that time, the divisional MI battalion did not have the senior, experienced leadership to provide a G2X. As war in Iraq loomed, the G2 took an officer out of hide to create a G2X. The position proved critical throughout the fight, not just as the division transitioned to SASO. The overall campaign had a number of agencies and special operations forces (SOF) working in the division's area of operations, and the G2X served as a focal point for deconflicting and synchronizing their operations. (3ID, 2003)*

A similar situation existed in the 1st Marine Division. The asymmetric nature of operations in OIF created significant uncertainty in the minds of planners and targeting analysts whose thinking was conditioned by more conventional combat operations. Quite simply, there was inadequate HUMINT expertise within the staff to accomplish planning in support of the division's mission. As reported by the 1st Marine Division,

> *We had an unprecedented level of resolution on the disposition of enemy equipment and near instant warning of activation of electronic systems or artillery fires. In many cases we maintained virtual surveillance of selected enemy forces. But, in spite of these capabilities we remained largely ignorant of the intentions of enemy commanders. While we were able to point with some certainty where their armor and artillery were deployed, we were largely in the dark as to what they meant to do with it. This shortcoming was especially critical as much of the war plan was either based on or keyed to specific enemy responses. When the enemy "failed" to act in accordance with common military practice, we were caught flat-footed because we failed to accurately anticipate the unconventional response. This was primarily due to a dearth of HUMINT on the enemy leadership. (1MD, 2003)*

With regard to personnel management, it was noted that the knowledge and experience required for an effective targeting process is very demanding and not something normally acquired

elsewhere in a military career. Hence, the learning curve for personnel assigned within a Corps targeting function, a BCE, or a CAOC is very steep. (Kelly & Andreasen, 2003) Once the skills and knowledge are acquired, however, two factors contribute to the challenge of maintaining them over time: personnel shortages and the lack of Joint training opportunities. As noted in the introduction section of this chapter, personnel shortages within the Air Force resulted in that Component Service rotating new staff members into the CAOC every 90 days. (PSAB CAOC Tiger Team, 2002) A similar situation is faced by the Army in its limited capacity to field and staff the collocated BCE:

> *By design, the BCD [BCE] is 'a mile wide and an inch deep' to cover the broad range of areas of coordination between the land and air component. Working in the BCD demands knowledge of operational and joint warfare not learned in the normal course of a soldier's career and, as a result, the learning curve for new BCD personnel is unusually steep. It is not enough for the BCD to simply have all its authorized personnel—the BCD needs the right people with the right backgrounds and the right training. (Kelly & Andreasen, 2003)*

This situation was exacerbated in recent operations by the need for the Air Force to split its CAOC operations between two locations—Qatar and Saudi Arabia—to cover operations in both Afghanistan and Iraq. Hence, at the beginning of OIF, the Army's BCE was only staffed at a 65 percent level. While personnel were eventually added to bring the staffing level up to 100 percent of the authorization, initial operations suffered from the lack of staff experience and the development of effective social networks. This situation, in turn, affected the effectiveness and efficiency of staff collaboration—both within a given functional area or cell, and across organizational boundaries.

With regard to Joint training opportunities, BCE personnel noted that "One key to BCD [BCE] success in OIF was the good working relationships and shared experiences built between the 1st BCD and the CAOC personnel before OIF as a result of Operation Enduring Freedom (OEF). A lesson for the Army is that time may not be available in future conflicts to build this trust before the fight." (Kelly & Andreasen, 2003) In short, air and land force staffs must be given the opportunity to train and work together prior to the initiation of combat operations. This will help

ensure that essential social networks are in place and that the staffs have learned to collaborate in both an effective and efficient manner. As part of this Joint training requirement, BCE personnel discovered that CENTCOM and EUCOM use different procedures and equipment for planning and coordinating operational fires. As a result, the recommendation was made to standardize these operations across all the combatant commands so as to allow for a cross-leveling of qualified personnel.

SUMMARY—IMPLICATIONS FOR FUTURE MODELING

As reflected in the introductory discussion of this chapter, future EBO-based targeting operations represent a level of complexity that is well beyond the planning and coordination of Joint fires in a traditional combat setting. The asymmetric nature of combat demonstrated in recent operations in both Afghanistan and Iraq present a more complex, a more dynamic, and an increasingly wicked problem environment for target planners. From the discussion of actionable knowledge in the EBO problem domain, we see that planners must be capable of (1) identifying critical centers of gravity with respect to both adversary capabilities and BLUE force command intent and (2) skillfully decomposing these centers of gravity into meaningful functions and objects that become the specific focus of attacks and effects. The process of target development can be compared to the task of finding a needle under a haystack—that is, there exist a large number of objects within the battlespace that could be attacked in comparison with the relative smaller number of validated EBO targets. At the same time, planners must be careful to consider a broad set of linkages and constraints—technical, geographic, infrastructure, organizational, sociopolitical, psychological, and operational dynamics—so as to not produce unintended consequences.

Doctrinally, the Joint targeting process spans across a number of command echelons and Component Service organizations, in addition to the functions and activities carried out within a Joint Task Force headquarters. From the review of these organizations presented earlier in this chapter, we see that current targeting operations follow a deliberate, multi-day cycle. While this deliberate planning cycle might have been once suitable for planning and executing traditional air operations against an adversary's fixed resources and infrastructure, more recent operations in Afghanistan and Iraq have shown this cycle to be inadequate during a fast-moving ground campaign. At the same time, many of the information systems and staff procedures used to plan

and coordinate targeting operations within and across Component Service and Joint boundaries do not effectively support newer targeting concepts such as CENTCOM's use of kill boxes. Traditional definitions given to air interdiction, CAS, the FSCL, and time sensitive targets have become blurred or obsolete as air and land force staffs have struggled to improvise the targeting process and develop expedient work arounds.

Recent operations in Afghanistan and Iraq have also demonstrated the vital importance of each dimension of the targeting process:

- The role, design, and functioning of information technology in support of the targeting process;
- The critical knowledge, skills, and experience provided by leadership and training;
- The impact of personnel management on maintaining the needed skill sets and social networks within the targeting process;
- The design and flow of the staff procedures, staff collaboration, and battle rhythm that define the targeting process; and
- The division and sharing of task responsibilities, key staff elements, decision authorities, and informal social networks that comprise the network of organizations contributing to the Joint targeting process.

Advanced technology—either in the form of battlefield sensors or precision weapons—does not, by itself, constitute an EBO-based targeting process. Careful attention must also be given to the other dimensions just listed. Here, many of the issues and improvisations associated with targeting operations in OIF provide a roadmap for future modeling and experimentation. Indeed, the dynamic systems, processes, and procedures used currently for engaging time sensitive targets in OIF might very well become the model for all Joint targeting operations in the future.

Clearly, then, the analytical and modeling community faces a significant challenge if it is to contribute to future deliberations and force planning regarding EBO-based targeting operations. As suggested in the earlier chapters of this report, the analytic modeling of EBO-based targeting operations must address each of the problem dimensions listed above. This will require both (1) the explicit representation of the EBO problem domain in terms of how informational cues from the battlespace are filtered, interpreted and organized relative to command guidance and

constraints into actionable knowledge and (2) the explicit representation of the sociocognitive staff elements, processes, systems, and obstacles that define the Joint targeting process. In this regard, it is hoped that the present report provides both motivation and insight regarding the next step in responding to this challenge.

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