COVER SHEET

TITLE: Functional Analysis of the Next Generation Common Operating Picture

TRACK: Track 4 – C2 Decision Making and Cognitive Analysis

AUTHOR: Dennis K. Leedom, Ph.D.
Evidence Based Research, Inc.
1595 Spring Hill Road Suite 250
Vienna, Virginia 22182
Leedom@ebrinc.com

FUNCTIONAL ANALYSIS OF THE NEXT GENERATION COMMON OPERATING PICTURE

Dennis K. Leedom, Ph.D.
Evidence Based Research, Inc.
1595 Spring Hill Road, Suite 250
Vienna, Virginia 22182

Abstract

The development of the current generation Common Operating Picture (COP) was motivated by the desire to improve situation awareness within a military command organization –thus leading to faster and better synchronized planning and execution decisions. Like many information management systems found in corporate industry, the COP was built on the same philosophy used for managing physical assets: capture information and put it in a place where it can easily accessed. As a result, the current generation COP has become an "information warehouse" for enormous amounts of information –much of which is poorly organized and validated, difficult to search and exploit, and often of marginal relevance to military decision makers. To overcome these deficiencies, the next generation COP must be built upon a clear understanding of the sociocognitive processes employed within a military command organization to translate available information into timely and focused action. These processes are variously identified in the research literature as information management, sensemaking, knowledge creation, and decision making. To this end, the present paper reviews recent research findings in each of these areas to (1) identify key concepts and models and (2) suggest from these concepts and models specific functional requirements for the next generation COP.

Introduction

During the past decade, the US military has exploited a number of information technology and networking concepts to provide battlefield commanders and their staffs with what has come to be called a "common operating picture," or COP. The COP, now manifested in the form of both geospatial displays of the battlespace and internal intranets that extend vertically through multiple layers of command, serves as a commonly-accessible repository of information for military decision makers. The development of the current generation COP was motivated largely by the desire to improve situation awareness within a military command structure –thus leading to faster and better synchronized planning and execution decisions. Evidence of success in this area is demonstrated by examples of operational and tactical decision making being displayed in Operation Iraqi Freedom, as compared with decision making just 12 years ago in Operation Desert Storm. These examples include the methodical and efficient destruction of elite Iraqi army divisions and the quick-responsive and precision attack of high-value targets by theater-level air and cruise missile assets.

However, experience with the current generation COP has highlighted a number of remaining challenges. Like many information management systems found in corporate industry, the COP was built on the same philosophy used for managing physical assets: capture the information and put it in a place where it can easily accessed. As a result, the current generation COP has become an "information warehouse" for enormous amounts of information, much of which is (1) poorly

organized and validated, (2) difficult to search, and (3) of marginal relevance to the military decision makers. Within corporate industry, Thomas Davenport (1999) has noted that many current generation information warehouses are overflowing with decision makers and their staffs having a difficult time finding what they need. He suggests that when companies realized they had too much of their physical asset inventory in the warehouse they began to think in terms of supply chain management processes and systems for more closely matching need with supply. By analogy, many companies are beginning to rethink their knowledge management strategies, tools, and methods and to look for more efficient ways of meeting the information demands of the decision makers.

A second challenge that has emerged from Operation Iraqi Freedom has been the increasing complexity of military decision making. One aspect of this complexity is seen in the desire to create "shock and awe" through the tailoring of effects-based operations –operations that combine various precision lethal and non-lethal effects to achieve the defeat of an adversary's will to fight, yet limit collateral damage to populations whose ultimate support we desire. A second aspect of this complexity is seen in the asymmetric nature of the conflict, itself –our desire to militarily defeat the Iraqi regime versus its desire to manipulate public opinion in the Arab world. A final aspect of decision making complexity is seen in the need to coordinate our military operations with those of our coalition partners, with the political and diplomatic initiatives of the US State Department and United Nations, and with the humanitarian and relief operations of numerous private and non-governmental organizations. Similar to a trend noted in corporate organizations (Malhotra, 1997), this increased complexity of decision making, in turn, generates profound implications for the military's supporting information systems. No longer can the COP be defined in terms of fixed, traditional models of combat at the tactical, operational, and strategic levels of warfare. Rather, the complexity of decision making now faced by the military demands greater flexibility and capability in its information systems to deal with (1) ambiguous operational problems and tasks; (2) new types of emergent threats and opportunities; and (3) a broad set of operational stakeholders and perspectives.

Given these challenges, it is useful to think about what the next generation COP will be expected to provide for military decision makers –that is, what types of functionality should be enabled or supported by emerging hardware and software technologies? To address this issue, however, requires better understanding of the sociocognitive processes at work within a military command organization.[1] No longer is it simply the case that we can build information systems and "they will come." The limitations of this approach have been amply demonstrated by our current generation COP systems. Rather, the next generation COP should be developed on a solid theoretical model of information management, sensemaking, knowledge creation, and decision making at the organizational level. This model, in turn, should be informed by relevant research in the social and behavioral sciences. The ultimate goal will be to transform these often ethereal bodies of research into (1) practical guidance for focusing technology development and (2) quantitative metrics for assessing return on investment in new technologies. To begin this thinking process, the present paper outlines an emerging model that is suggested by current research (published within the past five years) in the areas of organizational psychology,

[1] Following the vision originally introduced by General (retired) Paul Gorman (1980), a command organization is not necessarily defined here as a place (e.g., traditional command post), but as a cohesive decision making function that serves to focus and motivate a military force toward a desires set of objectives.

information science, knowledge management, and management science. From this model, one can begin to identify the types of functions and capabilities needed in the next generation COP.

Military Command Organization Process Model

Over the past decade or so, a number of fields of research have contributed to our understanding of how organizations and enterprises transform information into action. While much of this work has focused on the commercial sector, the resulting insights and theory are applicable to military command structures and organizations. What has emerged from this research is the basic model illustrated in Figure 1. This model, in turn, provides a framework for discussing and reconciling various bodies of research that can guide the development of the next generation COP. As seen in Figure 1, current research identifies four specific –yet, interrelated—functions that transform information into action: information management, sensemaking, knowledge creation, and decision making.

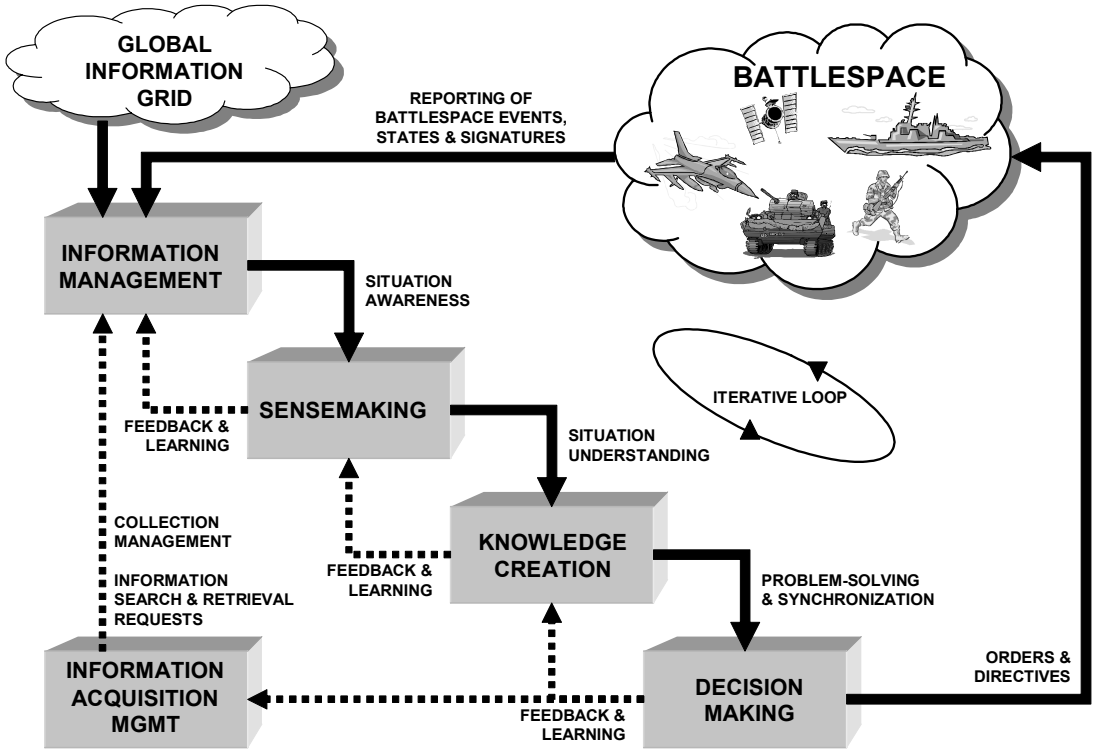


Figure 1 Military Command Organization Process Model

In the context of a military command organization, these functions are each seen to be (1) motivated, guided, and sanctioned by the commander; (2) implemented or supported through the collaborative actions of the battle staff; and (3) enabled by a combination of tacit expertise/experience and information technology. Each function highlights a different stage in the information transformation process; however, in actual practice, these functions often unfold in parallel, non-linear fashion as organization personnel move back and forth among hypothesis generation, information exploration, uncertainty resolution, problem framing, problem solving,

and decision making. The remainder of this paper briefly outlines each of these processes and discusses their relevance to the design of a next generation COP.

Information Management

Information management comprises a collection of activities related to the collection, storage, organization, and retrieval of dynamic information available from battlespace sensors/reporting as well as both dynamic and reference information available through reach-back from the Global Information Grid (GIG). As such, information management provides the foundation for successive stages of the information transformation process. As currently implemented, the information management function is defined primarily in terms of technical issues such as network connectivity/reliability, network bandwidth, information storage capacity, and information search/retrieval. As such, past research has focused almost exclusively on the management of explicit/codified information –information that is largely structured by standardized rules, protocols, and procedures adopted by the organization. However, in the past few years, research efforts within the Defense Advanced Research Projects Agency (DARPA) and the Intelligence Community's Advanced Research Project Agency (ARDA) have begun to address the challenges of managing, searching, and correlating large (tetrabytes) databases of unstructured information that might yield useful intelligence and other operational insights.[2]

As pointed out by John Seely Brown and Paul Duguid (1998), the core competency of any decision making 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 COP, in the case of military organizations. By contrast, the organization's "know how" is embedded within work practice and is often difficult to track, retrieve, and apply in moment-to-moment decision making. Effective decision making requires management of both components.

Shown in Figure 2 is a conceptual depiction of the challenge. Within a command organization exist both the codified information assets and the tacit expertise assets needed for effective decision making. These assets must be brought together at the right time and right place to identify and respond to different emerging threats and opportunities within the battlespace. (Leedom, 2002) This can only be done if effective management systems exist for (1) identifying the relevant information sources and areas of expertise and (2) bringing these assets together in effective patterns of collaboration –e.g., formal technical networks and informal social networks. (Clippinger, 1999) To date, much of this management has been ad hoc and problematic – particularly in joint and coalition operations where staff personnel are unfamiliar with where critical information and expertise might reside.[3]

[2] Example programs include DARPA's Total Information Awareness Program and ARDA's Novel Intelligence from Massive Data Program.

[3] For example, as reported in the Washington Post on 5 February, 2003, an Air Force study indicated that personnel assigned to the Combined Air Operations Center at Prince Sultan Air Base, Saudi Arabia, were experiencing "significant confusion about roles, responsibilities and chain of command throughout key areas within the COAC."

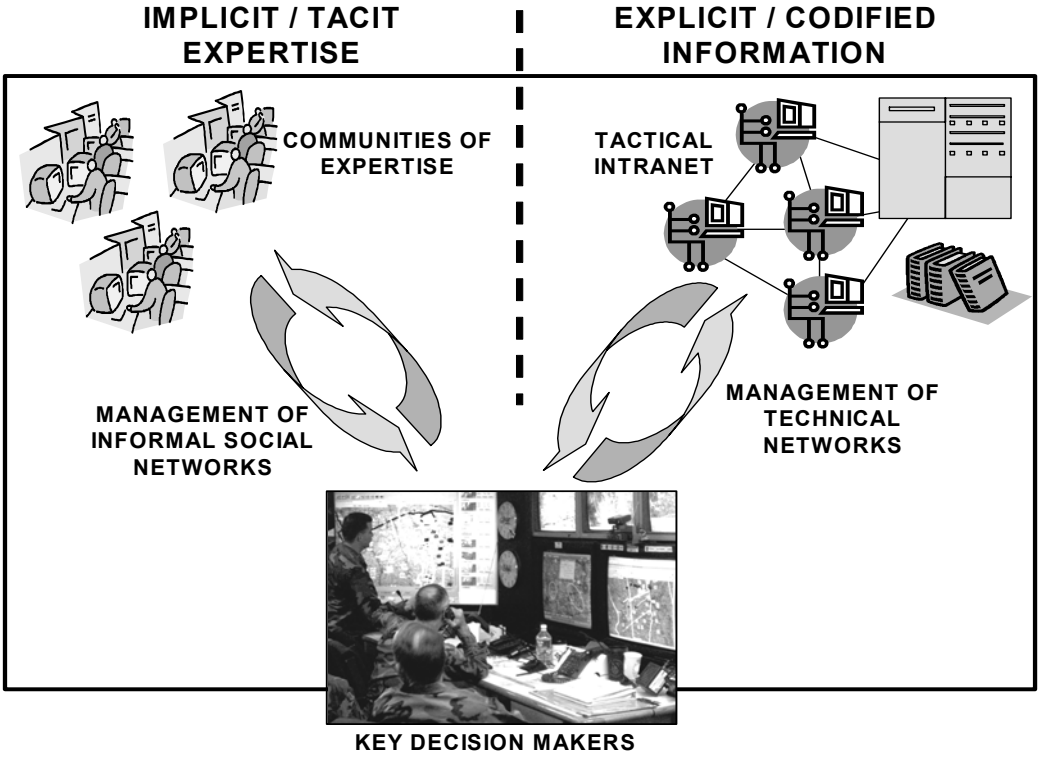


Figure 2 Information Management Challenges in a Military Command Organization

As a result, a number of recent research efforts have begun to address the benefits and challenges associated with the deliberate management of both codified and tacit knowledge that is essential to an organization's decision making effectiveness. (Cf. Seemann, 1997; Lutters et al, 2002; Horn, 2001; D'Amore et al, 2001; Ceruti & Bowman, 2001; Welch, 2002; Hutchins et al, 2002) This body of work –collectively referred to as "knowledge mapping" technologies—suggests a number of areas that should be explored in the next generation COP:

- Development of a knowledge mapping language that can be used to identify, organize, and retrieve relevant information and expertise within or available to a military command organization. Such a language must be capable of accounting for flexible meaning, open system definitions, and the variability of operational situations to which the information and knowledge might apply.
- Development of technologies for automatically tracking the acquisition and status of newly generated knowledge (e.g., key elements of decision briefings, wargaming analyses, effects-based target analyses). Specifically, such technology should provide the means for assessing knowledge validity, authority, and currency in the context of continuous staff operations where documents and analyses are frequently updated, adjudicated, and approved.
- Development of technologies for tracking key variables, events, and situations that alert staff members regarding overlapping stakeholder and functional interests. Such technology could potentially improve the efficiency and effectiveness of collaboration within a command organization by specifically identifying (1) which relevant

participants/experts should be collaborating and (2) what specific functional issues or emerging problems need to be addressed in each collaborative session.

- Development of templated knowledge structures for communicating the types of narrative knowledge that frequently characterize tacit expertise and experience –e.g., stories, means-ends models, goal structures, expectations. Part of this technology would reflect elicitation methods for rapidly and efficiently capturing relevant expertise and experience that might later be incorporated into wargaming analyses, command intent, etc.
- Development of personnel tracking systems that maintain a knowledge bank of the relevant expertise available to the command organization at any given point in time. Such technology would extend across functional and organizational boundaries and be useful for identifying, locating, and involving key experts relevant to the timely interpretation and assessment of emerging threats and opportunities.

Sensemaking

Sensemaking refers to a number of sociocognitive activities undertaken by an organization when it is faced with novelty or operational situations that do not conform to prior expectations. (Cf., Weick, 1995; McMaster, 1996; Leedom, 2001) This process is illustrated in more detail in Figure 3. As shown in this figure, military command organizations generate a set of expectations via the planning process. As originally theorized in the late 1970s by Beech & Mitchell (1990), these expectations are based on a hierarchy of mental images developed from past experience combined with on-going assessments of the battlespace. These images reflect beliefs and assumptions regarding the likely participants in a conflict and their values, the assigned goals and objectives for the operation, the desired course-of-action, and desired tactics. These images, in turn, produce a set of expectations regarding anticipated events and the flow and timing of the operation.

As any military commander knows, plans do not often survive contact with an adversary. Battlespace conditions change, adversary intentions and strategy are not always fully understood, and the fog and friction of war combine to produce both situational novelty and ambiguity. As noted in recent military operations, emergent threats and opportunities can often reflect a mixture of military, political, and diplomatic issues.[4] As a result, when a command organization begins to compare reports and indications of actual events within the battlespace to the prior held set of expectations, discontinuities emerge and give rise to the need for sensemaking. As depicted in Figure 3, sensemaking can be both a belief-driven process and an action-driven process. (Weick, 1995) It is a belief-driven process in the sense that the interpretation of current events is based on the past experience and accumulated expertise of the commander and his battle staff. This interpretation is also shaped by the context of assigned mission goals/objectives and the prior decisions and commitments that have already been made by the commander. It is an action-driven process in the sense that organizations often take actions to shape their operating

[4] For example, the refusal of Turkey to allow passage of the US Army's 4th Infantry Division has led to a rethinking of the role of this unit in Operation Iraqi Freedom and a rethinking of the Coalition strategy for closing on Baghdad. Similarly, the use of Fedayeen Saddam terrorists to stiffen the resistance of Iraqi regular army forces has provided Coalition forces with an unexpected set of military and political challenges in the opening days of Operation Iraqi Freedom.

environment and then later attach meaning to these actions to provide them with significance. Both processes operate simultaneously –and as a continuous stream of mental activities—as the commander and staff attempt to impose a mental framework on the chaos of the battlespace –a framework that both simplifies and systematizes their thinking about the unfolding operations. This framework attempts to answer those key questions shown in Figure 4, often by arranging known facts and held beliefs in story form. In fact, storytelling has become a commonly recognized method for communicating visions, strategies, structures, identities, goals, and values within both organizations and cultures. (Denning, 2001; Swap, Leonard, Shields & Abrams, 2001) Stories also represent a powerful mechanism for communicating themes and evoking visual images. (Morgan & Dennehy, 1997) Finally, there has been recognition of the benefit of accommodating storytelling features in the design of computer-supported cooperative work systems. (Gruen, 2000)

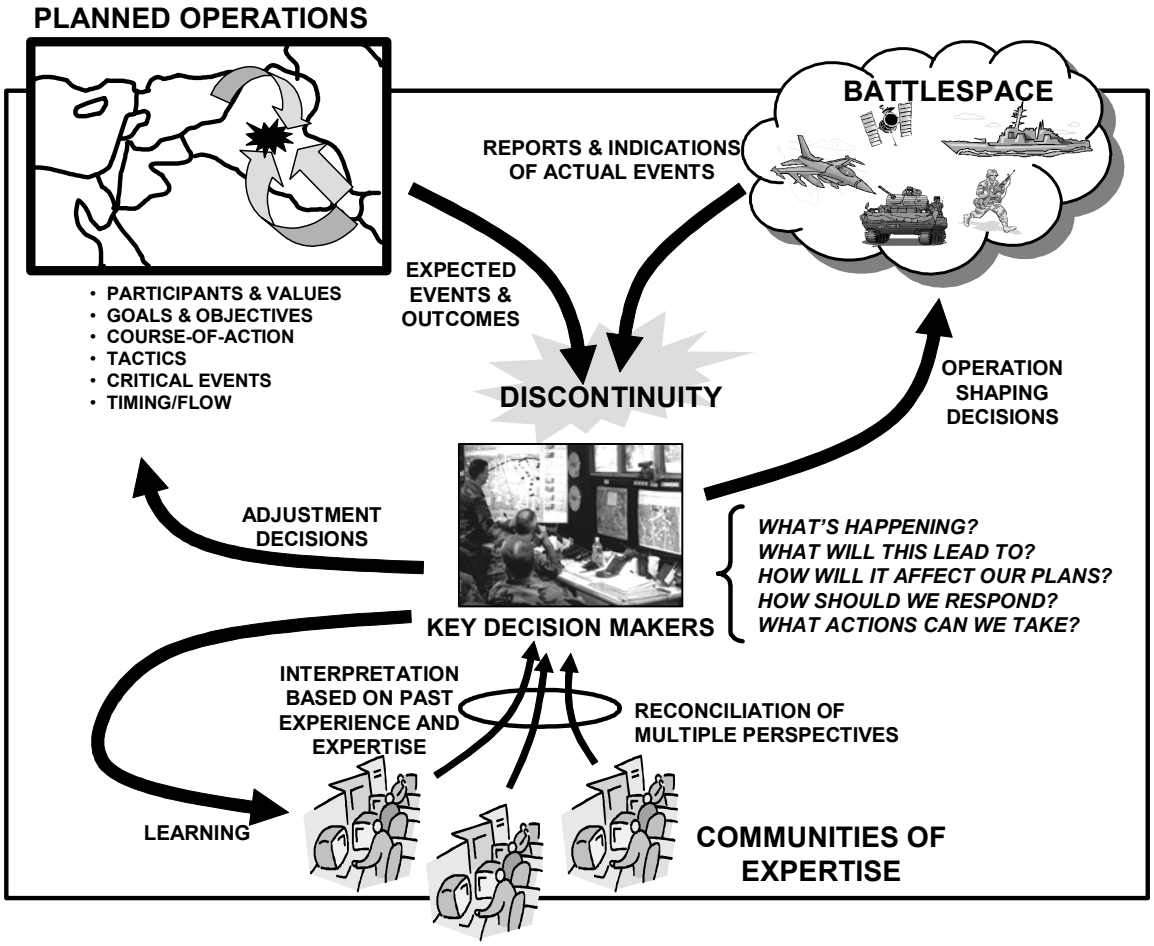


Figure 3 Organizational Sensemaking in a Military Command Organization

In attempting to understand an evolving situation, the decision makers also must cope appropriately with various types of organizational ignorance. (Zack, 1999) Expanding on the work of Zack, it can be seen that each of these types of ignorance involves a particular challenge regarding the transformation of information into knowledge:

- Lacking sufficient information or lacking confidence in the available information to adequately make sense of a situation (*situation uncertainty*)
- Being overwhelmed with too much irrelevant information that prevents focusing on the important elements of a situation (*information glut*)
- Lacking an appropriate, experience-based problem framework for interpreting the available information and associating it with action responses (*situation ambiguity*)
- Having multiple, competing problem frameworks for interpreting the available information (*explanatory equivocality*)
- Having an experience-based problem framework that yields only limited insight into an evolving or emergent situation (*situation emergence*)

Each of these dilemmas suggests a different coping strategy. In general, uncertainty is the only situation in which tasking subordinates to collect more information is a productive strategy. Of course, the proper identification of uncertainty requires that one recognize that one or more important pieces of information are missing vis-à-vis the problem solving framework selected for use in a given situation. Information glut and ambiguity both require intervention by either decision makers (with their tacit knowledge) or software (with predefined problem solving frameworks) to provide a meaningful context for focusing, filtering, and structuring available information. Equivocality involves the reconciliation of multiple viewpoints (a situation discussed in the next section on shared understanding). Finally, emergence requires one to look at situation understanding as an iterative process in which tentative actions might be taken as one refines their understanding of an operation and its environment.

At the same time, this framework serves to organize and focus the work activities of the command organization. As operations evolve within the battlespace, different communities of expertise (representing different functional areas or responsibility and different stakeholders) will perceive emerging threats and opportunities from different perspectives. Thus, it becomes necessary for the organization to adjudicate these various perspectives in different ways: (1) accommodate differences in a mutually supportive manner, (2) deliberately choose to adopt one perspective over another, and/or (3) deliberately choose to ignore differences that are deemed operationally insignificant. The adjudication of various competing perspectives –a process referred to as "collaborative debate"—represents a critical step in the decision framing process as key decision makers decide which emerging threats and opportunities reflect the highest level of urgency and operational significance.

Of particular research interest in the area of organizational sensemaking has been the study of how this process can catastrophically collapse under evolving or novel conditions. (Cf. Comfort, 2001; Weick & Sutcliffe, 2001) Based on studies of actual military, governmental, and corporate organizations, such research has begun to suggest a number of critical process dimensions and strategies for insuring that the sensemaking process remains robust:

- Focus decision maker attention on modes of failure, not just success
- Guard against over-simplified interpretations while being sensitive to non-linearity
- Remain sensitive to operational details that provide early indicators of change/novelty
- Maintain resilience by planning for improvisation
- Adjust patterns of collaboration to engage appropriate experts with relevant information

While some of these dimensions deal primarily with organizational culture and attitudes, other dimensions suggest that the next generation COP should be built on information technology that is flexible, auto-adapting, and self-organizing in terms of how it enables the right information to be combined with the right expertise at the right time. Challenges that should be addressed in the development of the next generation COP include the following:

- Development of technologies that allow depiction and mapping of held beliefs and assumptions onto the COP. Specifically, these technologies should enable the COP to be viewed in narrative or story form, where appropriate. In addition, these technologies should allow a command organization to organize and link its beliefs and assumptions in hierarchical fashion, beginning with participants/values and then extending downward through goals/objectives, course-of-action, tactics, critical events, and timing/flow. Such visualization functionality would assist the command organization in assessing the impact of emerging threats/opportunities and framing adjustment decisions at an appropriate level.
- Development of technologies that characterize the specific type of ignorance reflected in each part of the COP –e.g., situational uncertainty, information glut, situation ambiguity, explanatory equivocality, and situation emergence. Such functionality would assist decision makers in formulating the appropriate type(s) of response strategy for enhancing the validity and clarity of the COP.
- Development of technologies that permit "what if" wargaming projections to be organized and displayed in a multi-perspective context (e.g., military, political, diplomatic, humanitarian, legal) in order to highlight key variables, linkages, and assumptions. Such technology would facilitate collaborative debate among relevant functional perspectives and stakeholders.
- Development of methods for continuously comparing the COP against a framework of held expectations in order to identify potential indicators of change and novelty in the operational environment. Such tools –perhaps supported by agent technologies—would assist decision makers in monitoring on-going operations within the battlespace and determining when the nature of the problem framework has begun to shift or change in some critical manner.
- Development of information display architectures and protocols that facilitate the rapid incorporation of new problem dimensions and key variables. Enhanced display flexibility would assist the command organization in visualizing and framing problem spaces by highlighting emerging patterns across different dimensions –e.g., geospatial, temporal, political, ethnographic, and humanitarian. At the same time, such displays would contribute significantly to the organization's ability to plan and synchronize multi-dimensional effects-based operations that are focused against an adversary's centers of gravity.

Knowledge Creation

Whereas sensemaking is primarily a backward-looking process of understanding events that have already happened, knowledge creation is viewed in current research as a forward-looking process that focuses on problem-framing and problem-solving. This process is perhaps best described by

examining two views –eastern and western—developed by those who have studied how corporations transform existing knowledge into new knowledge in order to remain competitive. While these lessons have been primarily developed in the context of industrial organizations, they nevertheless apply to military command organizations. A western view of knowledge creation is best illustrated by the work of Thomas Davenport and Lawrence Prusak (1998). This view tends to focus on the accumulation, management, and use of explicit (codified) knowledge within an organization. In this regard, knowledge is differentiated little from information inasmuch as it is considered to have relatively static value –i.e., its utility to the organization is not dependent upon situational context. Organizations are seen primarily as knowledge marketplaces that support transactions among *sellers* (experts, knowledge bases), *buyers* (problem-solvers, decision makers), and *brokers* (gatekeepers, boundary spanners). Key processes include the generation, codification, and transfer of knowledge among the sellers, buyers, and brokers. Davenport and Prusak also highlight a number of sociocognitive barriers to effective knowledge transfer and use within an organization –e.g., trust, culture/vocabulary/frames of reference, time/resource limitations, status/social capital, absorptive capacity, knowledge ownership, intolerance for error. Of interest here is the task of identifying how information technology developments can serve to (1) facilitate transactions within the information marketplace and (2) overcome specific barriers to knowledge transfer and use within the organization. Effective matching of information technology to the sociocognitive dynamics of this marketplace will help the military to avoid the types of unsuccessful/irrelevant technology applications that characterized many of the "dot com" failures during the past few years.

Marketplace issues are reflected in the reluctance of organizations (or elements within an organization) to share information and knowledge with others –despite the technical means to do so. Part of this reluctance stems from (1) a concern that information/knowledge will be used by others in a manner that is inconsistent with the original context and (2) the time/resource cost of generalizing information in a form that makes it available for other purposes. While these issues are partly influenced by a number of sociocultural factors, they can also be mitigated through better design of the COP. For example, the use of "information tagging" –e.g., attaching contextual references to each information entity posted within the COP—provides one strategy for increasing the likelihood that information/knowledge generated by one organizational component will be correctly interpreted and used by another component. Thus, it can serve an important enabling role in the aggregation of information and the creation of new knowledge within a command organization. (Clippinger, 1999)

In contrast to the research on Davenport and Prusak, the eastern view of knowledge management is seen in the work of Ikujiro Nonaka and Hirotaka Takeuchi (1995). This view focuses more on the creation of knowledge (as distinct from information) and the important role played by tacit knowledge (internalized experience and expertise) possessed by key individuals within the organization. In contrast to the western static view of knowledge, Nonaka and Takeuchi emphasize the situational value of knowledge that has been organized and interpreted to meet the specific decision needs of the moment. The eastern view of knowledge creation and management portrays organizations as being comprised of three essential layers: a knowledge base consisting of explicit and tacit knowledge resources, a business system for formalizing plans and enacting decisions, and tailored project teams that engage in adaptive collaboration to produce actionable knowledge for specific situations.

As with the western view of knowledge management, the work of Nonaka & Takeuchi is directly applicable to the discussion of a next generation COP. To understand how their work applies, it is first instructive to note that a command organization functions in both linear and non-linear fashion. As depicted in Figure 4, military command organizations traditionally impose a cyclical battle rhythm framework on the decision making process. This process is considered to be somewhat linear in nature as the staff organizes its activities around a specific briefing and decision cycle –with the length of this cycle varying according to level of command. While some have argued for replacing the traditional decision cycle with a more continuous decision process, a cyclical battle rhythm traditionally provides certain advantages for structuring the work schedule of the staff. At the same time, however, this linear briefing and decision cycle is supported by a host of knowledge creation activities that unfold in a more nonlinear fashion. The nonlinearity of the knowledge creation activities comes about as various patterns of formal and informal collaboration form over time to address specific types of problems. What can be concluded from this is that the next generation COP should be capable of supporting a linear briefing and decision making cycle as well as the nonlinear knowledge creation activities that support it.

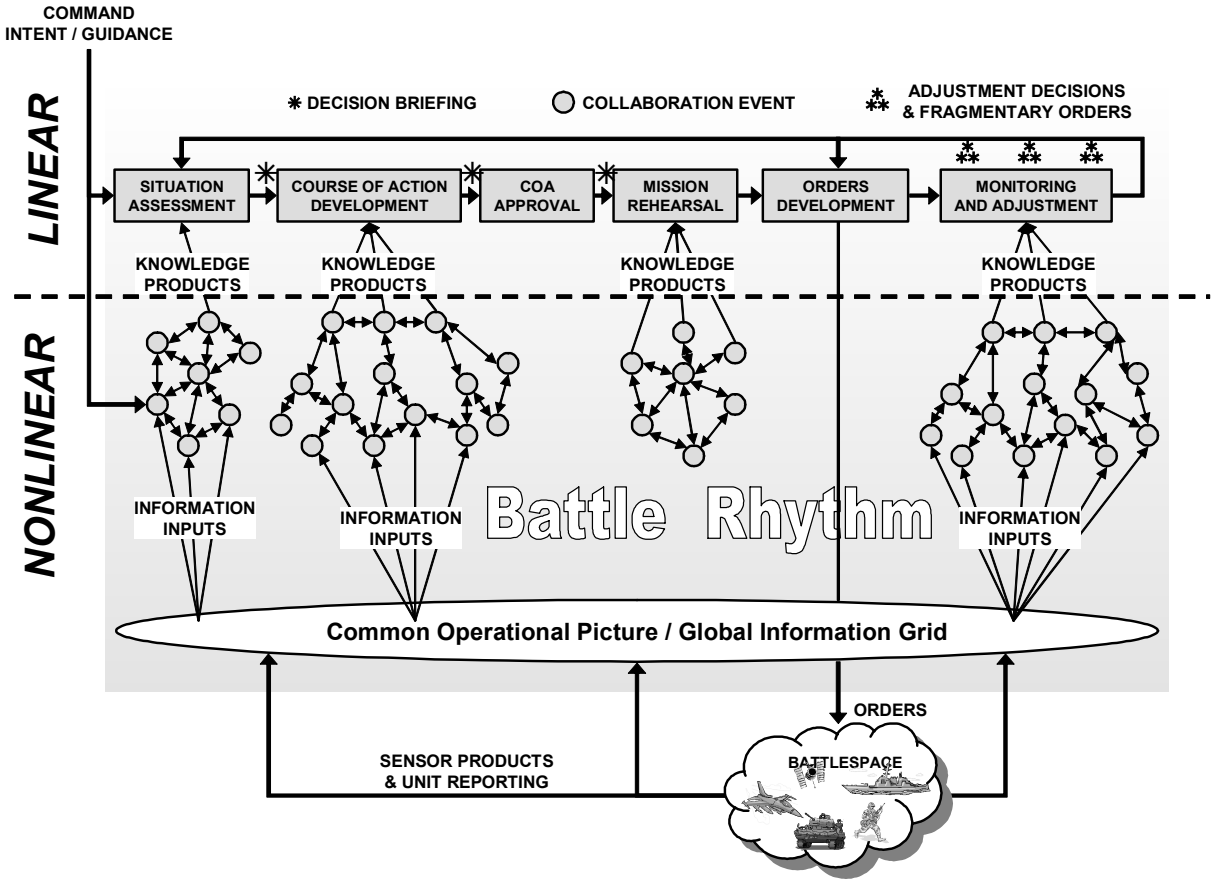


Figure 4 Linear and Nonlinear Aspects of a Military Command Battle Rhythm

Considering both the linear and nonlinear aspects of the battle rhythm, it is possible to conceptualize a command organization in terms of knowledge creation three layers defined by

Nonaka & Takeuchi (1995). As depicted in Figure 5, the knowledge base is reflected in the cultures and values of the military, the expertise of the staff, and the common operating picture provided by advanced information technology. The business system of a military command organization is reflected in the procedures and battle rhythm that organizes the decision making process. Nonaka and Takeuchi's concept of the project team is seen to be reflected in the formal and informal collaboration that occurs within and between staff elements for a specific problem-solving purpose (defined in other literature as "communities of interest"). Knowledge creation and management is enabled by certain factors and elements such as intention (command intent), self-organizing teams, knowledge creation induced by crisis (role of commander), information redundancy (access to a common operational picture), and requisite variety of expertise to match the complexity of the situation. Finally, the key elements seen to contribute to decision making effectiveness and agility include knowledge repositories, knowledge access and transfer mechanisms, and knowledge environment management (referred to earlier in this paper as organizational knowledge mapping).

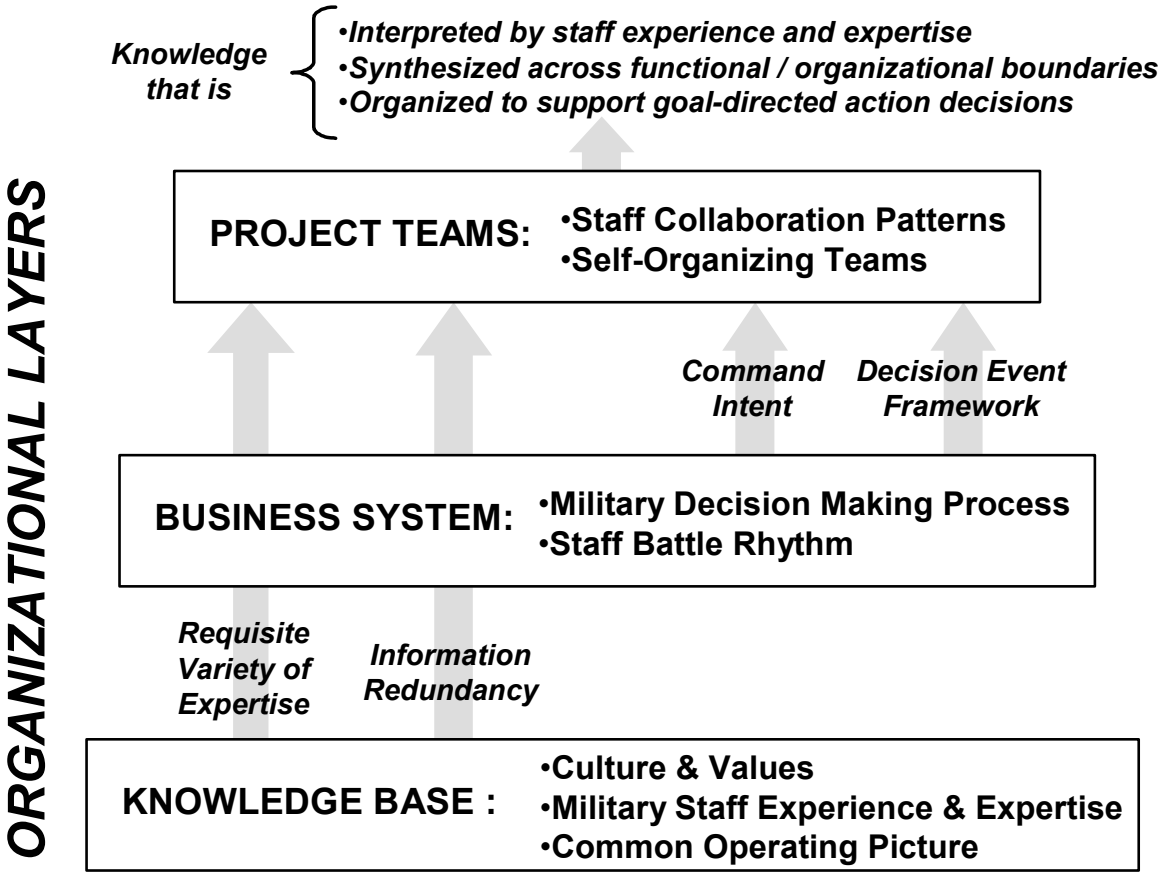


Figure 5 Knowledge Creation Layers within a Military Command Organization

An essential idea that flows through much of the research on knowledge creation is the distinction held between information and knowledge. Building on the concepts eloquently expressed in mathematical form by Keith Devlin (2001), information is simply *data* (e.g., sensor reports) that have been interpreted in terms of *technical meaning* (e.g., T-55 tank) and *operational meaning* (e.g., the T-55 tank is a weapon system that poses a threat to advancing

forces). Much of what is represented by mere information tends to be static and ubiquitous in nature –it potentially means the same thing to different individuals at different times. Knowledge, on the other hand, is defined as information *organized and available* to a decision maker in a manner that *supports goal-directed actions* (e.g., the T-55 tank is blocking a key avenue of approach that must be cleared before 0900). Such a distinction is often lost by members of a battle staff who overload the commander with information briefings that have little or no relevance to key decisions that the commander is attempting to shape and execute.[5] As seen in Figure 5, the effectiveness of a command organization ultimately depends upon the ability of the supporting staff (working as a collaborative pattern of self-organized project teams) to retrieve, sort, filter, interpret, organize, and present available information in a way that defines and illuminates the key decisions to be made by the commander.

A final area of interest within the field of knowledge creation is the process of collaboration. That is, collaboration occurs when representatives from different communities of expertise form a community of interest to bring different perspectives and areas of experience to bear on a specific operational problem. Increasingly, attention has been given to improving the ability of geographically-dispersed participants to collaborate electronically. To this end, various types of hardware/software systems have been developed to assist participants in developing a common framework of understanding for exchanging ideas and information and for engaging in collaborative problem solving. Current generation tools for electronic collaboration include traditional e-mail systems, instant messaging systems, shared whiteboards, chat rooms, multimedia auditoriums, and shared workspaces. While such tools provide the technical means for collaboration, they do not address a fundamental sociocognitive issue: when is it appropriate and necessary for a specific set of experts to engage in collaboration? This issue was highlighted in a recent joint exercise in which battle staff personnel were provided a number of tools for enabling electronic collaboration across the entire command organization.[6] Encouraged by their senior officers to fully exploit and demonstrate the value of these collaboration tools, staff personnel used the tools to conduct a variety of working group meetings, command briefings, and sidebar chat sessions throughout the exercise. While the overall impact of these tools on staff effectiveness was positive, many personnel complained that the process of collaboration often resulted in an inefficient use of time and staff resources. Specific reasons cited for this inefficiency included (1) lack of clarity as to the specific issues being addressed in a given collaboration meeting, (2) uncertainty as to which participants were essential for each meeting, (3) simultaneous scheduling of meetings that required the same individuals, and (4) the amount of time collaboration took personnel away from individual staff duties. Each of these problems points to the need for the next generation COP to assist the battle staff in the management of the collaboration process.

To better understand what might be done in this arena, it is useful to first examine the basic need for collaboration within a command organization. In this regard, Nancy Roberts (2001) provides some interesting insight. Specifically, Roberts studied (1) the types of problems that emerged from conducting multi-agency relief operations in Afghanistan and (2) the types of management

[5] A conclusion reached by the author after witnessing countless "decision briefings" given to commanders that reflected little more than an information dump.

[6] This anecdote is based on the author's personal observations during Millennium Challenge 02, a joint military exercise conducted by Joint Forces Command during the summer of 2002.

approaches that effectively dealt with these problems. From this research, Roberts identified three classes of problems and their associated management strategies:

- Simple Problems: problems in which there is clear agreement on the nature/scope of the problem and the preferred/accepted method of solution. In such cases, the preferred management strategy is for a centralized authority to direct implementation of the solution path. Collaboration in such cases is unnecessary and wasteful of staff time and resources.
- Complex Problems: problems in which there is clear agreement on the nature/scope of the problem, but in which various stakeholders or functional areas argue for different solution paths. While it is possible that collaboration among stakeholders and functional areas might identify a compromise solution path, it is more likely that a central authority will be required to adjudicate among the competing proposals.
- Wicked Problems: problems in which there is neither agreement on the nature/scope of the problem nor clear understanding of what type of solution might be appropriate. It is in this third class of problem where collaboration among stakeholders and functional areas is both necessary and useful for arriving at an organizational solution.

This framework of problem classes and associated management strategies can now be used to define a potential approach to managing the collaboration process. Specifically, the concept is proposed in which advanced agent-based software is employed to track the emergence of specific threats, opportunities, and other operational issues within each stakeholder and functional area. These agents would be trained to conduct keyword searches, parse e-mail traffic, monitor information search activities, track key variables, and assess information pedigrees in order to provide indications as to what operational issues are being worked in each part of the command organization. These agents would also cross-monitor each other in order to identify potentially over-lapping areas of interest –e.g., areas involving a common set of keywords or key variables, areas with known functional linkages and dependencies, areas of information pedigree conflict, and areas of overlapping authority or responsibility. In such cases, the agent-based software would alert relevant participants in each functional or stakeholder area to the fact that other parts of the command organization were actively engaged in sensemaking, knowledge creation, and/or decision making in an area of mutual interest. Based on these alerts, the participants would then engage in a collaborative session to specifically address the area of overlapping interest, adjudicate potential conflicts, develop mutual understanding, and synchronize planning and execution decisions. In short, such a system uses computational power to relieve humans of the burden of monitoring and identifying the requirement for collaboration. At the same time, human experts retain responsibility for engaging in the more subtle/complex areas of collaborative problem solving.

Taken together, these concepts suggest a number of challenges that should be addressed in the development of the next generation COP:

- Development of technologies that facilitate the brokering of available information together with the specific needs of different information consumers within the command organization. Specifically, tools and methods should be developed for negotiating the

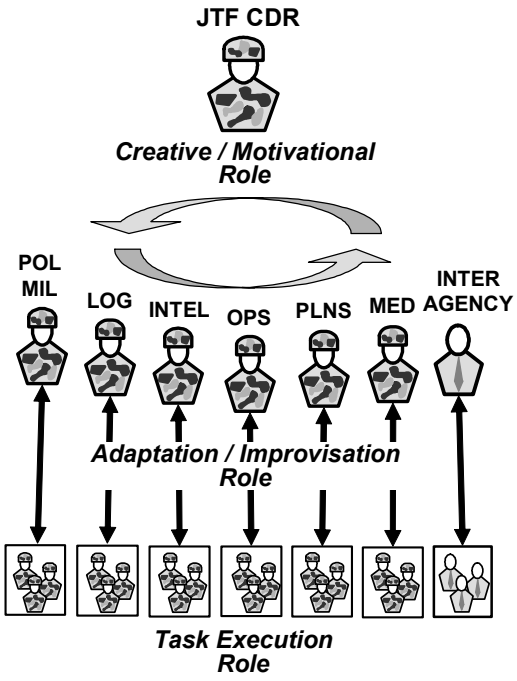
manner in which information is posted to the COP so that it can serve multiple consumers –each with different intended uses of the information.

- In a related manner, the next generation COP should provide the means for "information tagging" so that the original context of information/knowledge posted to the COP is retained and available to multiple users of that information/knowledge. Information tagging is thought to be a critical enabler for information aggregation and knowledge creation within an organization.
- Development of technologies that enable the dynamic creation of ad hoc "project teams" or communities of interest that respond to the emergence of specific operational problems that must be framed, addressed, and resolved in an on-going operation. Such technology might employ agent-based software systems to monitor different stakeholder and functional areas and to alert participants to the potential requirement for collaboration. This implies a certain degree of agility is required within the COP to allow for the dynamic entry of new participants, the posting and sharing of new forms of knowledge, and the support of collaborative problem framing and problem solving.
- Development of technologies that facilitate the appropriate filtering, interpretation, and organization of information into actionable knowledge that supports goal-directed actions and decision making. Development of such technologies, however, requires a clear understanding of the distinction between information and knowledge. Specifically, such expert tools (e.g., "wizards") would assist the staff in structuring available information, linking it with the decision making focus of the commander, and tailoring it in the form of actionable knowledge that can lead to swift and decisive operations.

Decision Making

The final function to be supported by the next generation COP is that of decision making. In one sense, decision making cannot be separated from the activities of sensemaking and knowledge creation. In fact, much of the research literature prior to the 1990s subsumed sensemaking and knowledge creation under the broad heading of decision making. Yet, at the same time, it is useful to distinguish decision making from these other two steps. The reason for this making this distinction is twofold: (1) to focus on the differences in decision making responsibility across each level within a command organization and (2) to highlight different approaches to decision making that arise under varying circumstances of situation ambiguity and time stress.

Traditional models of military command and control have often reflected decision making as a activity that is focused in the personage of the commander. While it is true that decision making responsibility and authority ultimately reside with the commander, other individuals within a command organization contribute to various levels of the decision making process. In this regard, the next generation COP should be developed in a way that supports each of these levels. As shown in Figure 6, the decision making process within a command organization can be generally partitioned into three levels: (1) the commander, (2) the commander's principal advisors from each functional area, and (3) the technical staffs that support each of these functional advisors. Each of these levels is unique in terms of cognitive focus and responsibility.



COMMAND	• Create vision and set goals to shape ill-defined problem space • Focus and motivate the staff • Scan for decision opportunities • Adjudicate conflicting perspectives • Approve courses of action and operational adjustments
PRINCIPAL ADVISORS	• Monitor functional areas to identify emerging threats / opportunities • Develop common understanding • Assist commander with shaping of decision opportunities • Adjust / improvise / synchronize plans in each functional area
SUPPORT STAFF	• Build COP within specific areas of responsibility • Track operations / conduct specific analyses as directed by advisors • Develop detailed courses of action • Build / transmit plans, orders, and directives for subordinate units

Figure 6 Decision Making Levels within a Military Command Organization

At the top level, the commander plays a role that is both creative and motivational in nature. Consistent with research findings from the corporate world (Kotter, 1999), the commander spends much of his personal time developing and maintaining (1) a flexible agenda for the operation and (2) a broad network of relationships. From a decision making perspective, the commander crafts the operational vision for the organization and sets specific goals in order to impose order on what is often an ill-defined problem space. This vision and goal set, in turn, provides the decision making framework for focusing and motivating the battle command staff. Throughout the operation, the commander continuously scans across different functional areas in order to identify emerging decision opportunities. The commander also serves as the final authority for adjudicating conflicting perspectives that might arise among different functional areas and stakeholders. Finally, the commander represents the final approval authority for courses of action and operational adjustments that are developed and recommended by the staff.

At the next level, the commander's principal advisors –typically the head of each major staff section—operate within the commander's decision making framework to keep him informed of emerging threats and opportunities that can potentially influence the planned operations. As part of this process, the principal advisors also maintain a common awareness and understanding across multiple functional areas in order to identify linkages and interactions. In contrast to the creative and motivational role played by the commander, the principal staff advisors serve in an adaptation and improvisation role wherein they attempt to reconcile the commander's vision with the hard realities of real-world time and resource constraints. Working upward, the principal advisors often play a key role in shaping and framing the decision opportunities that will eventually bubble up to the commander for action. Working downward, the principal advisors

often oversee the adjustment, improvisation, and synchronization of planned operations by the remaining staff organization.

At the final level, supporting personnel within each functional staff element serve in a task execution role by carrying out the various information management and analytical activities needed to build and maintain the COP, track specific aspects of the operation, and conduct specific analyses as directed by the principal advisors. Chief among the products of the supporting staff are the detailed course of action wargaming analyses, plus the development and publication (or posting) of specific operational plans, orders, targeting directives, etc. for subordinate units.

These various levels within the command organization operate in a synergistic manner to produce command decisions; yet, they each operate in a different cognitive fashion and they each demand different support from the next generation COP. For the commander, the COP should serve as a canvas for painting his vision for the operation and a storybook for articulating his goals and expectations to the remainder of the command organization. To this end, the COP should help the commander to focus and structure the information management, sensemaking, and knowledge creation activities carried out by the command organization. For the commander's principal advisors, the COP should serve as a flexible framework for collaborative problem framing and problem solving as they attempt to implement this vision and story in terms of available time and resources. To this end, the COP should provide appropriate tools and methods for bringing together relevant and appropriate information and knowledge resources and focusing their activities on specific operational problems. At the same time, the COP should facilitate the packaging of available information and analyses into actionable knowledge that directly supports the commander's decision making process. Finally, for the supporting staff, the COP should serve as the common repository of explicit information/knowledge products and a common map of implicit information/knowledge sources that are needed in the execution of specific support tasks. To this end, the COP should be structured in ways that (1) make information available to multiple users for multiple purposes and (2) provide a valid and consistent foundation for conducting specific analysis and planning activities across different functional areas.

It is also noted that different approaches to decision making can arise under varying circumstances of situation ambiguity and time stress. Shown in Figure 7 is a depiction of three primary modes of decision making that are typically observed within a military command organization: deliberate decision making, recognition-primed decision making, and incremental decision making. (Leedom et al, 1998) Deliberate decision making embodies the traditional Military Decision Making Process (MDMP) in which the staff engages in the systematic identification, analysis, and assessment of several course of action responses to an adversary. This process is characterized by a formally communicated commander's assessment, the systematic wargaming of alternative courses of action (for both friendly and adversary forces), and the identification of a preferred course of action that balances expected outcome against risks and resource costs. Deliberate decision making is engaged in when time stress is relatively low (e.g., pre-hostilities phase of an operation), where the operational situation is understood with some degree of clarity, and where the problem framework is relatively defined in terms of objectives, key variables, and constraints.

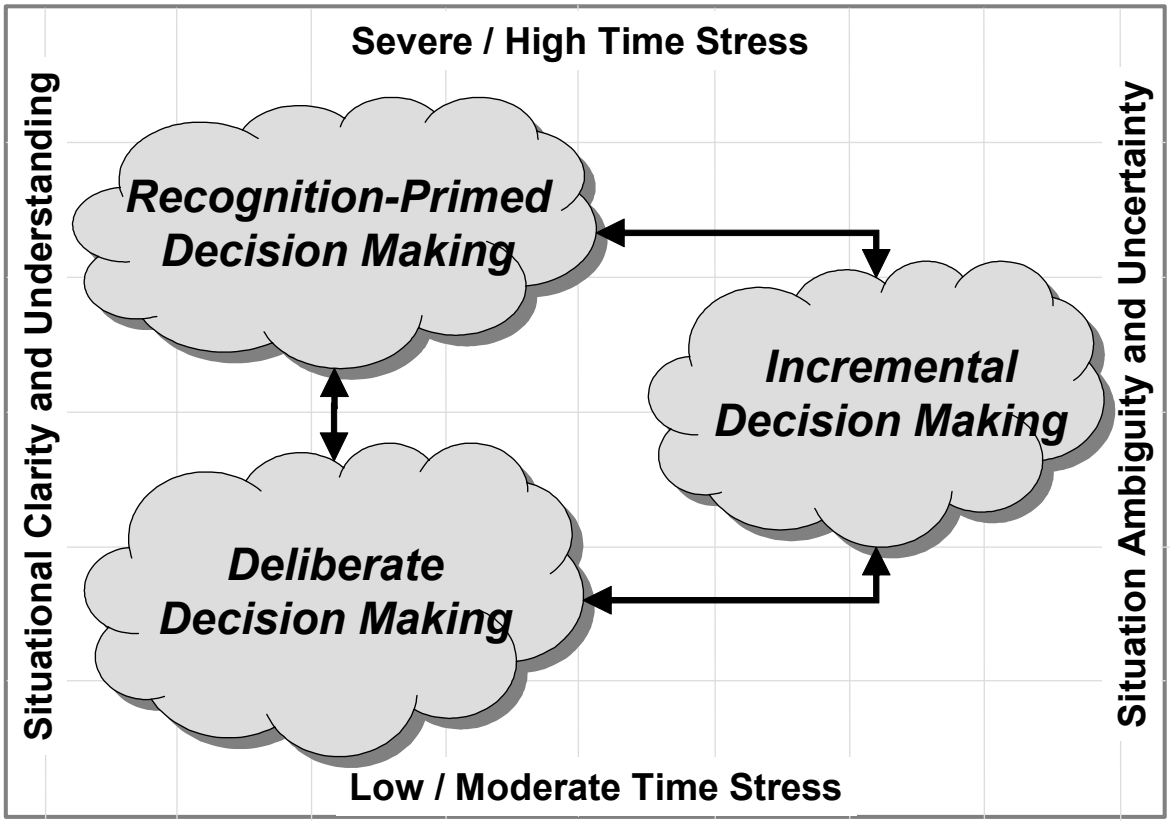


Figure 7 Modes of Decision Making Exhibited by Military Command Organizations

Recognition-primed decision making (also referred to in research literature as "naturalistic decision making") is a mode of decision making preferred by experts in high time stress environments. (Klein, 1998) Based on studies of highly stressed decision making environments (e.g., fire fighting teams, nuclear power plan control rooms, emergency medical teams), recognition-primed decision making is defined as a process by which experts (1) employ their past experience to recognize familiar tactical situations, (2) invoke familiar responses to these situations with minimal formal analysis, and (3) continually monitor the operational situation to test the validity of their assumptions and mental models. As compared with deliberate decision making, recognition-primed decision making offers the advantage of being both (1) action-oriented (the decision maker always has response options available for execution) and (2) rapid (minimal time is consumed between recognition and response). The recognition-primed model also conforms to the personality of many military leaders since it provides them the opportunity to remain actively involved in the operational situation and requires minimal contemplative thought. (Kotter, 1999)

Over the past few years, the recognition-primed model of decision making has gained popularity within military circles. There is a danger, however, in assuming that all military decision making can be characterized by this model. There is growing evidence that organizations cannot simply employ a naturalistic decision making process in the same way as individuals. Individuals –those acting somewhat autonomously from others—make sense of the world largely through the use of internal mental models. This natural human process largely reflects the recognition-primed

model just discussed. When functioning in this manner, there is often little or no need for the individual to "externalize" their knowledge and communicate it with others. In fact, most individuals would find this task to be extremely difficult since much of their expertise exists subconsciously in the form of intuition or tacit (hidden) knowledge. However, such is not the case in an organization where decisions and actions must be synchronized across participants toward a common goal and common understanding of the operational environment –a fact that is beginning to be recognized in some military quarters. (Hall, 2000) In order for such synchronization to take place, individuals must "externalize" what they know and understand to the degree that it can be shared and reconciled with others. This process of sharing and reconciling knowledge is exactly what makes cohesive sensemaking difficult to achieve at the organizational level.

A related issue that arises at the collective level of decision making is that of knowledge authority. (Muller & Millen, 2000) For example, the commander represents a formal authority in a military command organization –i.e., his vision or command intent is accepted by the rest of the organization as a framework for organizing the collective sensemaking process. However, other knowledge authorities might also exist informally –e.g., recognized technical experts, operators who possess first-hand knowledge of a situation. Ultimately, organizations have to deal with authority conflicts that arise across functional or organizational boundaries when two or more participants hold different (but equally valid) perspectives on an operational situation. Weick (1995) refers to this reconciliation process as "collaborative debate." As a result, organizations often rely upon a formal set of planning procedures that have built-in knowledge approval steps in the sensemaking process. In a military command organization, examples of these knowledge approval steps include "commander's assessment," "commander's guidance," "course of action selection," and "mission approval."

A final issue associated with decision making at the collective level deals with how teams and organizations are often able to compensate for the mental limitations and biases of individuals. (Heath, Larrick & Klayman, 1998) That is, individuals are limited in terms of both attentional capacity and the mental models they bring to an operational setting. It is in these two areas where other participants –acting collaboratively as part of a team or organization—can provide "cognitive repairs" to overcome these limitations and maintain the overall robustness of the sensemaking process. As noted earlier, the need to maintain multiple perspectives on a given operational situation is often cited in the literature as an essential component of organizational agility. (Cf., Comfort, 1994; Heath, Larrick & Klayman, 1998; Choo, 2001; Comfort, 1999; Weick & Sutcliffe, 2001)

Thus, the advantages of recognition-primed decision making must be balanced against its limitations. This is particularly true for coalition and joint operations in operations where the degree of situational ambiguity is high and various parts of the command organization see the operational situation from different perspectives. The need to cope with situational ambiguity gives rise to the third mode of decision making depicted in Figure 8. This mode is defined as incremental decision making –a process by which a command organization directs its forces to take incremental steps to contain an adversary's operational advantages while continuing to clarify the overall operational situation. (Lipshitz & Strauss, 1997) The notion of incremental decision making is consistent with current research literature on organizational sensemaking

inasmuch as it acknowledges the need to combine mental analysis with action-taking in order to develop an understanding of the operational situation while –at the same time—shape the operational situation to conform with expectations and desired objectives. This model of decision making is also consistent with research on corporate strategies for dealing with ambiguity – sometimes referred to as "hedge-clipping" decisions. (Connolly, 1986)

At any given time, a command organization is likely to be engaged in all three modes of decision making, depending upon the nature of the emerging threats and opportunities. Thus, it is important that the next generation COP provide effective support for each of these decision making modes. Considering these modes of decision making and the various levels of decision making discussed earlier, it is now possible to identify a number of challenges that should be addressed in the development of the next generation COP:

- Development of technologies that provide information management support to different levels of decision making within a command organization. Specifically, the next generation COP should support (1) the commander's role of creating and communicating an operational vision to the remainder of the organization, (2) the principal advisors' role of reconciling this operational vision to the realities of time and resource constraints, and (3) the supporting staff's role of carrying specific information management and analytical tasks.
- Development of technologies that (1) make information available to multiple users for multiple purposes and (2) provide a valid and consistent foundation for conducting specific analysis and planning activities across different functional areas. As noted earlier, the next generation COP should provide the means for tagging posted information and knowledge with contextual information that enables understanding and use by multiple consumers.
- Development of technologies that support the simultaneous employment of different decision making modes within a command organization. Specifically, the next generation should provide specific tools and methods for (1) structuring the formal assessment of alternative courses of action under deliberate decision making, (2) articulating the tacit models and operational cues relevant to recognition-primed decision making, and (3) correlating probing and/or hedge-clipping actions with emerging hypotheses under incremental decision making.
- Development of technologies that facilitate the rapid transition from one mode of decision making to another as the command organization gains clarity of an operational situation and/or needs to respond to events that unfold under different time scales. Specifically, the next generation COP should enable the staff to rapidly reorganize and revisualize available information and knowledge as decision makers transition from one mode of decision making to another.

Summary

Recent experience in Operation Iraqi Freedom has validated the underlying principles of network centric warfare and has demonstrated the worth of current generation technology for providing military decision makers with a common operating picture. Yet, it is also clear from a review of recent research in the fields of information management, sensemaking, knowledge creation, and

decision making that the state-of-art of this technology can be much improved. Specifically, this paper has identified a number of challenge areas in which a next generation COP –if properly developed—could make significant contributions to the functioning of joint and coalition command organizations in a complex, and often asymmetric battlespace. Research cited within this paper provides a glimpse at the state of maturity of our understanding of the sociocognitive processes at work within a command organization that transform information into actionable knowledge. In this regard, our current level of theoretical and empirical understanding of these processes is such that it is now possible to move beyond current generation "information warehousing" paradigms to the effective support of sensemaking and knowledge creation in an evolving operational environment.

References

Beach, L.R. & Mitchell, T.R. (1990). Image theory: A behavioral theory of decision making in organizations. In B.M. Staw & L.L. Cummings (Eds.), *Research in Organizational Behavior*. Greenwich, CT: JAI Press, Volume 12, 1-41.

Brown, J.S. & Duguid, P. (1998). *Organizing knowledge*. California Management Review. Spring 1998, Vol. 40, No. 3; pp. 90-111.

Ceruti, M.G. & Bowman, M. (2001). Expertise, pattern management, and decision making: Challenges in human informatics. Presented at *5th World Multiconference on Systemics, Cybernetics and Informatics (SCI 2001) and 7th International Conference on Information Systems Analysis and Synthesis (ISAS 2001)*, 22-25 July, 2001, Orlando FL, USA.

Choo, C.W. (2001). Sensemaking, knowledge creation, and decision making: Organizational knowing as emergent strategy. *Strategic Management of Intellectual Capital and Organizational Knowledge*, C.W. Choo & N. Bontis (Eds.). Oxford, England: Oxford University Press.

Clippinger, J.H., Ed. (1999). *The biology of business: Decoding the natural laws of enterprise*. San Francisco: Jossey-Bass.

Comfort, L.K. (1994). Interorganization learning following the Northridge earthquake of January 17, 1994. *Journal of Contingencies and Crisis Management*, 2(3), 174-188.

Comfort, L.K. (1999). *Shared risk: Complex systems in seismic response*. New York: Elsevier Science (Pergamon Press).

Comfort, L.K. (2001). Governance under fire: Organizational fragility in complex systems. Paper delivered at *Symposium on Governance and Public Security*, Campbell Public Affairs Institute, Maxwell School of Public Affairs and Administration, Syracuse University. January 18, 2001.

Connolly, T. (1986). Hedge-clipping, tree-felling, and the management of ambiguity. *In Managing the Challenge of Ambiguity and Change* (MB. McCaskey, L.R. Pondy & H. Thomas, Eds.) New York: John Wiley.

D'Amore, R.; Konchady, M. & Obrst, L. (2000). Knowledge mapping aids discovery of organizational information. *The Edge: The Mitre Advanced Technology Newsletter*, 4(1), April, 2000.

Davenport, T.H. & Prusak, L. (1998). *Working Knowledge: How Organizations Manage What They Know*. Cambridge, MA: Harvard Business School Press.

Davenport, T. (1999). Knowledge management round two: Making the most of an information rich-environment. *CIO Magazine*, Nov 1, 1999. [Retrieved 1 April 03 from http://www.cio.com/archive/ 110199/think.html]

Denning, S. (2001) *The springboard: How storytelling ignites action in knowledge-era organizations*. Woburn, MA: Butterworth-Heinemann.

Devlin, K. (2001). *Infosense: Turning information into knowledge*. New York: W.H. Freeman.

Gorman, P. (1980). *A command post is not a place*. Original unpublished manuscript. [Retrieved 15 Sept 2002, from http://www.ida.org/DIVISIONS/sctr/cpof/CPnotPlace.pdf].

Gruen, D. (2000). *Beyond scenarios: The role of storytelling in CSCW design*. Technical Report 00-02, IBM Watson Research Center. [Retrieved 5 Sep 02 from http://domino.watson.ibm.com/ cambridge/research.nsf/pages/index.html].

Hall, J.D. (2000). Decision making in the information age: Moving beyond the MDMP. *Field Artillery*, Sept-Oct, 28-32.

Heath, C.; Larrick, R.P.; & Klayman, J. (1998). Cognitive repairs: How organizational practices can compensate for individual shortcomings. *Research in Organizational Behavior*, (20), 1-37.

Horn, R.E. (2001). Knowledge mapping for complex social messes. Presented at *Foundations in a Knowledge Economy*, David & Lucille Packard Foundation, July 16. [Retrieved 5 Sep 02 from http://www.stanford.edu/~rhorn/].

Hutchins, S.G.; Kemple, W.G.; Adamo, R. & Boger, D. (2002). Knowledge management and collaboration in an effects-based operations environment. *2002 Command and Control Research and Technology Symposium*, Monterey, CA, 11-13 June. [Retrieved 5 Sep 02 from http://www.dodccrp.org/Activities/Symposia/2002CCRTS].

Klein, G. (1998). *Sources of power: How people make decisions*. Cambridge, MA: The MIT Press.

Kotter, J.P. (1999). What effective general managers really do. *Harvard Business Review*, Vol 77, Number 2, pp 145-159.

Leedom, D.K. (2001). *Final Report: Sensemaking Symposium*. (Technical Report prepared under contract for Office of Assistant Secretary of Defense for Command, Control, Communications & Intelligence). Vienna, VA: Evidence Based Research. Inc.

Leedom, D.K. (2002). *The joint task force headquarters: Challenges of building a sensemaking organization* (Contract No. N00140-01-D-H030). Suffolk, VA: US Joint Forces Command.

Leedom, D.K.; Murphy, J.; Killam, B. & Adelman, L. (1998). *Cognitive engineering of the human-computer interface for ABCS*. Technical Report E-4419U, Andover, MA: Dynamics Research Corporation.

Lipshitz, R. & Strauss, O. (1997). Coping with uncertainty: A naturalistic decision-making analysis. *Organizational Behavior and Human Decision Processes*, 69(2), 149-163.

Lutters, W.G.; Ackerman, M.S.; Boster, J. & McDonald, D.W. (2002). Mapping knowledge networks in organizations: Creating a knowledge mapping instrument. *Proceedings of the Americas Conference on Information Systems* (AMCIS),. 2014-2018.

Malhotra, Y. (1997). Knowledge management in inquiring organizations. *Proceedings of the 3rd Americas Conference on Information Processing (Philosophy of Information Systems Mini-Track)*, Indianapolis, IN, August 15-17, 1997, 293-295.

McMaster, M.D. (1996). *The intelligence advantage: Organizing for complexity*. Boston, MA: Butterworth-Hienemann

Morgan, S. & Dennehy, R.F. (1997). The power of organizational storytelling: a management development perspective. *Journal of Management Development*, 16(7), pp 494-501.

Muller, M.J. & Millen, D.R. (2000). *Social construction of knowedge and authority in business communities and organizations*. (Technical Report 01-03) Lotus Research. [Retrieved 5 Nov 2001 from http://www.lotus.com/lotus/research.nsf/]

Nonaka, I.; Takeuchi, H. & Takeuchi, H. (1995). *The knowledge-creating company: How Japanese companies create the dynamics of innovation*. New York: Oxford University Press.

Seemann, P. (1997). A prescription for knowledge management: What Hoffmann-LaRoche's case can teach others. *Perspectives on Business Innovation, Issue 1 (Managing Organizational Knowledge)*. [Retrieved 20 Aug 02 from http://www.cbi.cgey.com/journal/issue1/index.html].

Welch, S.C. (2002). Warrior development and the human side of knowledge management. Presented to *Army Knowledge Symposium 2002*, April 1-4, 2002.

Swap, W.; Leonard, D.; Shields, M. & Abrams, L. (2001). Using mentoring and storytelling to transfer knowledge in the workplace. *Journal of Management Information Systems*, 18(1), 95-114.

Weick, K.E. (1995). *Sensemaking in organizations*. Thousand Oaks, CA: Sage Publications.

Weick, K.E. & Sutcliffe, K.M. (2001). *Managing the unexpected: Assuring high performance in an age of complexity*. San Francisco: Jossey-Bass.

Zack, M.H. (1999). Managing organizational ignorance. *Knowledge Directions*, 1(Summer), 36-49.