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Paper 162

**DYNAMIC BATTLEFIELD VISUALIZATION: KNOWLEDGE MANAGEMENT IN A COMPLEX,
EMERGENT PMESII-PT BATTLEFIELD**

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DYNAMIC BATTLEFIELD VISUALIZATION: OPERATIONAL DESIGN AND PLANNING IN A COMPLEX, EMERGENT PMESII-PT BATTLEFIELD

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ABSTRACT

This paper provides an in-depth examination of battlefield visualization in a complex, emergent environment such as stability or counterinsurgency operations. This research integrates current theories of knowledge management with two sets of interviews conducted with military officers having recent command and staff experience in Afghanistan and Iraq. Phase I of this research identified seven specific socio-cognitive skill areas that contribute to command and staff performance in this area. In Phase II, the research revealed the importance of addressing three distinct processes—development of battlefield understanding, problem solving and operational design, and the planning and execution of specific operations—as interconnected aspects of battlefield visualization. At the same time, our research identified the specific classes of knowledge—artifact knowledge, cause-effect system knowledge, tactical episode knowledge, and strategic agenda knowledge—that are produced by these processes and woven into a complex and dynamic framework of awareness and understanding. Our emerging visualization model illustrates how these three processes, seven skill areas, and four classes of knowledge define command and staff operations in terms of two intertwined meta-activities: knowledge management and battle management. Knowledge management serves to construct and maintain a contextual framework of battlefield understanding that guides the second process, battle management.

INTRODUCTION

This paper summarizes the findings of a multiphase research program undertaken by Evidence Based Research, Incorporated (EBR) in support of the US Army Research Institute for the Behavioral and Social Sciences (USARI) to develop a more in-depth understanding of a military commander's battlefield visualization process. The initial phase of research included a cognitive task analysis and set of in-depth interviews conducted with brigade and battalion level commanders and staff officers recently returned from Iraq and Afghanistan. Findings from this initial research were translated by USARI into an advanced training package for improving the battlefield visualization skills of commanders and their support staff at battalion level. As part of a follow-on study, EBR was asked to further refine the visualization framework to better illustrate its integration with both planning and execution of operations. Findings from this subsequent phase of research offer new insights for linking products of the battlefield visualization process with the US Army's operational design framework.

THE VISUALIZATION CHALLENGE

Visualization can be generally defined as the art and science of developing situational understanding, determining a desired end state, and envisioning how to move the force from its current state to the desired end state. As such, it is a critical element of successful battle command. However, recent research on expertise indicates that experience alone, be it real or in simulated battle, is not adequate for ensuring high levels of visualization performance (Shadrick, Lussier, & Fultz, 2007). A review of current methods of training battle command in today's Army suggests the need for (1) an improved understanding of the cognitive skills involved in battlefield visualization, (2) improved training methods for enhancing these skills in commanders and the supporting staffs, and (3) improved military doctrine that specifies how these skills are to be applied to the operational design of military operations in a complex and emergent battlefield.

The complex and emergent nature of modern military operations are highlighted in the US Army's new doctrine on insurgency and counterinsurgency operations. As such, they serve as a benchmark for

constructing a more in-depth understanding of the cognitive skills comprising the process of battlefield visualization. As noted in this new doctrine, “...an insurgency is an organized, protracted politico-military struggle designed to weaken the control and legitimacy of an established government, occupying power, or other political authority while increasing insurgent control. ...Political power is the central issue in insurgencies and counterinsurgencies; each side aims to get the people to accept its governance or authority as legitimate. Insurgents use all available tools—political (including diplomatic), informational (including appeals to religious, ethnic, or ideological beliefs), military, and economic—to overthrow the existing authority. This authority may be an established government or an interim governing body. Counterinsurgents, in turn, use all instruments of national power to sustain the established or emerging government and reduce the likelihood of another crisis emerging.” (US Army, 2006) The ability to effectively visualize such a battlefield in terms of an interconnected set of endstates, centers of gravity, cause-effect relationships, and actors is a daunting challenge for military officers –especially those individuals whose previous training and experience is limited relative to the political, economic, and social aspects of the battlefield.

At the same time, much of the US Army’s past doctrinal writings have emphasized the process of planning over that of visualization. As noted in Field Manual 3-24, US Army doctrine draws a sharp distinction between planning and designing military operations –particularly in complex and emergent situations involving stability operations and counterinsurgency (US Army, 2008). While both activities seek to systematically envision ways to bring about a desired endstate within an area of operation, they are fundamentally different cognitive processes. Understanding these differences is critical for successfully applying the concept of battlefield visualization within a military unit’s battle rhythm –particularly in complex, emergent, and long-term operations such as those recently experienced in Afghanistan and Iraq.

PHASE I – INITIAL DEVELOPMENT OF VISUALIZATION SKILL TRAINING

To initially address these concerns, EBR undertook a cognitive task analysis in 2006 to develop a more in-depth model of the battalion level battlefield visualization process. This cognitive task analysis included (1) a review of current US Army doctrinal literature; (2) an assessment of battlefield visualization from a cognitive, social, and ecological perspective; and (3) a series of interviews with military officers having recent combat experience in either Iraq or Afghanistan. The goal of this analysis was to identify a set of underlying cognitive behaviors that contributed to effective visualization of a complex and emergent battlefield. Findings of this initial study were published in a formal technical publication (Leedom *et al*, 2007). In 2007, USARI translated the findings of this cognitive task analysis into a multimedia, interactive training support package. This cognitive task analysis and the development and assessment of the resulting training support package constituted Phase I of this research program.

A Doctrinal View of Battlefield Visualization

In order to lay a foundation for the cognitive task analysis, we examined various US Army doctrinal publications dealing with battle command. From this review, it was possible to identify several general characteristics of battlefield visualization:

Purposeful – Visualization purposefully frames actions and links them with understanding and intent –it serves to specifically frame and identify actions that can be taken to move the state of the battlefield toward a set of objectives, goals, or desired endstates.

Synchronized – Visualization is synchronized vertically across the commander and staff who each contribute to its construction and maintenance.

Balances Intuition with Deliberate Reasoning – Visualization balances intuition with deliberate reasoning according to the degree to which the current situation matches the experience of the commander.

Doctrinally Framed – Visualization is structurally framed by Army doctrine to provide a common ground of understanding—e.g., METT-TC, elements of operational design—that specify the common understood elements of knowledge that traditionally comprise an effective operational plan.

Matched to Situational Complexity – Visualization is matched to the dimensions of levels of operational complexity faced in modern military operations –e.g., short-term security operations (military) versus long-term nation-building and counterinsurgency operations (political, economic, social, information).

Socially Constructed – Visualization is collaborative constructed in order to achieve unity of effort across the multitude of units, teams, and agencies that can potentially impact the battlefield.

Continuously Adjusted – Visualization is continuously adjusted in response to both (1) problem elements within the battlefield revealed by a military unit's actions and (2) the often unpredictable nature of asymmetric adversaries and civilian populations.

Frames Planning and Execution – Visualization frames and guides a larger planning and execution process that combines visualization, description, and direction in order to translate understanding into action.

Doctrinally, these characteristics generally apply to visualization in any type of operational situation. Hence, they serve to frame any sort of analysis that might be undertaken to identify key training objectives. Examining battlefield visualization from the perspective of current stability operations added the following areas of emphasis: (1) the need to accommodate multiple stakeholders associated with leveraging interagency, joint, and multinational operations; (2) the need to enhance capabilities and legitimacy of the host nation; (3) the need to understand the potential for unintended consequences arising from current operations; (4) the need to use force in a non-threatening manner; (5) the need to act decisively while applying force selectively and discriminately; (6) the need to distinguish among different classes of stability spoilers; (7) the need to employ both lethal and non-lethal forms of influence; and (8) the need to organize missions along logical lines of operation. While many of these issues have traditionally been addressed only at higher (operational) levels of command, the nature of modern stability operations requires that they also be addressed at lower echelons of command.

A Cognitive, Social, and Ecological View of Battlefield Visualization

An analysis of battlefield visualization from a psychological perspective suggests that it must be approached as a holistic, continuous process involving three levels of system interaction: (1) the cognitive system of the individual, (2) the social system of the military command and control organization, and (3) the ecological system of the military force embedded within its operational environment. Each of these levels of system analysis allows identification of different training intervention points.

At an individual cognitive level, battlefield visualization reflects the mental process of linking intent with action through a hierarchy of different levels of thinking. These levels of thinking identify specific mental constructs—e.g., purpose, focus, system effects, objects, actions, resources, and timing—and link them to form the commander's assessment of how he will move from the current state of the battlefield through various lines of operation to a desired end state. From an ontological point of view, the different levels of thinking respond to the Commander's need to answer each of the following questions:

Purpose – What am I attempting to accomplish? How do I define my desired endstate?

Focus – Where can the enemy be most effectively influenced to achieve the desired endstate? How do I define the relevant centers of gravity?

System Effects – How do I achieve this specified influence? What systems, functions, and cause-effect relationships contribute to the identified centers of gravity? What effects do I need to produce?

Battlefield Artifacts – What specific objects, facilities, units, groups, events, and battlefield features do I need to target in order to defeat or manipulate the identified systems?

Actions – What actions (diplomatic, information, military, economic) do I need to initiate against these artifacts to produce the identified effects?

Resources – What resources (troops, Joint/Interagency support, Intergovernmental support) do I need to accomplish these actions?

Timing – What is the required timing (long term and short term) and synchronization of these resources and actions to produce an orchestrated set of effects?

The identification and linkage of these systems, artifacts, effects, actions, resources, and timing are based primarily upon the tacit experience and expertise of the battalion commander and his staff. Relevant cues from the unit's information environment serve to trigger or activate specific mental model fragments which are then instantiated by other available information and linked together to form complete associational pathways between intent and action. The overall process of constructing the visualization framework is dynamic in nature as the operational environment evolves, new information cues become available, and different mental models are refined and integrated into an overall hierarchical structure. While Army doctrine can guide this mental process through mnemonics such as METT-TC (*Mission, Enemy, Terrain and Weather, Troops Available, Time, Civilian Considerations*) and the elements of operational design, it involves using the relationships of these elements to develop a viable operational approach and course of action to

achieve a desired set of endstate conditions. It is the commander's tacit experience and level of expertise that help him mentally form the visualization along with the doctrinal processes. In known or familiar situations, the commander can rely upon traditional battle calculus to identify the various elements of the visualization space. However, in complex or chaotic operational environments (*e.g.*, stability operations), the identification and linkage of METT-TC and elements of operational design will be more creative in nature and rely on expertise outside of his personal area of experience.

While battlefield visualization is primarily addressed as a cognitive process occurring within the individual, there are important aspects of visualization that must be considered at a social level of analysis. Addressing this process at the social level is necessary because the knowledge required to link intent with action is typically distributed across an organization, rather than being concentrated in one mind. At a social level of analysis, the commander and his supporting staff are seen to play unique and complementary roles in the battlefield visualization process. The commander establishes the top-level framework for this process through the articulation of Commander's Intent, Commander's Planning Guidance, and the Commander's Critical Information Requirements (CCIR). The staff translates this vision into cause-effect mechanisms and pathways, battlefield objects, and actions through the MDMP process. This more detailed knowledge is developed through the collaboration of specific areas of staff expertise across the commander's personal staff, coordinating staff, and special staff that focus on specific aspects of the commander's visualization space. The effective working of these groups in creating shared understanding and unity of purpose requires the deliberate minimization of specific types of cognitive, social, organizational, and technical collaboration barriers. Finally, military units—particularly those engaged in stability operations—have the unique challenge of transferring locally developed tacit knowledge from one unit to another. Thus, for the purposes of visualization skill development, it is important to look beyond the individual and to address those types of management skills needed to organize and maintain this social process. Specifically, these skills relate to the ability of the commander—together with his personal, coordinating, and special staff officers to synchronize the elements and linkages of the visualization space in each of several ways: (1) vertically across the different levels of thinking and assessment conducted by the commander and his staff, (2) horizontally across the different METT-TC dimensions of the battlefield, (3) chronologically across both short-term actions and their long-term consequences for mission objectives, and (4) socially across the different stakeholders and functional experts relevant to the commander's area of operation.

Battlefield visualization can also be addressed at an ecological level of analysis –*i.e.*, the manner in which the mental development of understanding is influenced by enactment of the battlefield operational environment. That is, visualization is not entirely a passive process of fitting available information into an experience-based framework of interpretation. Rather, there are times when military units actively engage their operational environment to both (1) shape real world events and states in conformance with the Commander's vision and (2) probe and reveal additional aspects of the operational environment that can be subsequently exploited for advantage. From a battlefield visualization perspective, shaping actions serve to mold the commander's operational environment in conformance to his envisioned problem space. These actions also serve to mitigate the number of unknowns and risks along key lines of operation. Probing actions serve to illuminate additional problem elements and cause-effect linkages within the visualization space that can be subsequently exploited for operational advantage. Probing actions are particularly useful in complex operational environments where the commander is unable to apply a known battle calculus to develop portions of the visualization space. However, for probing actions to be effective and productive, they must be combined with deliberate analysis to identify emerging trends and patterns.

From a training point of view, the ecological aspects of battlefield visualization require the commander to establish meaningful measures of effectiveness (MOE). MOE focus on the results and consequences of unit actions. They assist the commander in determining if these actions are appropriate, or if different or alternative actions are required. MOE flow directly from the structure and content of the visualization space and serve to visibly link the outcome of actions with the system effects, focus, and purpose established by the commander. At the same time, the commander must also key his CCIR and within adjust his Priority Intelligence Requirements (PIR) to areas of uncertainty, ambiguity, and equivocality reflected in the visualization space. Focused information collection and interpretation activities shaped by the CCIR and PIR will assist the commander in further refining the visualization space in an efficient and purposeful manner. During execution, effective battlefield visualization enables the commander to track key problem elements

and lines of operation over time to identify meaning patterns or trends and to maintain unity of purpose with respect to long-term mission objectives. This involves the development of a Running Estimate, the staff's continuous assessment of current and future operations, to determine if (1) the current operation is proceeding according to the Commander's Intent and (2) future operations are supportable. Good documentation of the visualization space allows the Commander to identify key variances with respect to forecasted events and states, and to appropriately adjust his operational actions to maintain unity of purpose. Without constant reference to the content and structure of the visualization space, the Commander is apt to become mentally absorbed in moment-to-moment operations and lose sight of the bigger picture reflected in the endstate of the overall mission. Maintenance of the visualization space is reflected in (1) the Commander's continual adjustment of his planning guidance and intent and (2) the staff's continual refinement of the Intelligence Preparation of the Battlefield (IPB) estimate, running estimate, synchronization matrix and target folders.

Insights Developed from the Initial Set of Officer Interviews

As part of the cognitive task analysis, a set of 25 interviews were conducted with military officers to investigate their real-world experiences with battlefield visualization. Each of these interviews lasted approximately two hours, was preceded by providing each subject with a read-ahead description of the potential skill areas involved in battlefield visualization. Each interview was recorded and subsequently analyzed in terms of key processes and mental structures involved in effective visualization. The initial set of subjects (Major through Colonel) was identified based on relevant command experience (Battalion) or recent staff experience (XO or S-3 within either a Battalion or Brigade staff) in either Afghanistan or Iraq. Following these interviews, additional interviews were conducted with Command and General Staff College (CGSC) instructors and Fellows from the US Army's School for Advanced Military Studies (SAMS) to validate the initial findings and to further explore specific issues. A final interview was conducted with a retired general office to validate the other interview findings and provide further depth of analysis.

Briefly, some of the initial findings developed during these officer interviews included the following:

Center of Gravity – The civilian population is the center of gravity in stability operations, with a key visualization challenge being the non-lethal lines of operation that serve to influence this center of gravity.

Multiple Operational Perspectives – The fluid nature of stability operations, coupled with the presence of multiple stakeholders within the battlefield, gives rise to the need for reconciling multiple operational perspectives. This requires the command group to visualize the interaction of the various Interagency and Intergovernmental elements with the different political, military, economic, social, information, infrastructure, physical, and time (PMESII-PT) dimensions of the battlefield.

Reconciliation of Long-Term and Short-Term Effects – Stability operations involve both immediate timelines (e.g., cordon and searches, raids, Quick Reaction Force actions) and long-term timelines (e.g., building and integrating Iraqi Army forces into security operation, restoring local infrastructure, establishing a legitimate governance process). Thus, another visualization challenge is the ability to mentally reconcile these often competing actions, and to identify and understand negative second-order consequences one set of actions might have on another.

Loss of Focus in Long-Term Operations – Given the steady-state nature of stability operations, command groups tend to sometimes lose focus on the need to do formal planning –opting instead to operate off of a series of fragmentary orders (FRAGO) and “templated” operations for cordon and searches, raids, etc. Thus, another visualization challenge is the need to maintain a running estimate of the overall situation, to maintain a focus on long-term endstate goals, and to keep track of progress being made by a unit as it completes its rotation.

Multiple Visualization Modalities – Only a small fraction of the required knowledge base is visualized in graphical form, with much of it occurring in the form of After-Action Review (AAR) summaries, link-node diagrams, prioritized lists, ancillary documents and notes on key individuals, statistical charts showing operational trends, timeline charts, etc. This codified knowledge is significantly supplemented by tacit knowledge gained from personal experience –most of which accumulates during the current rotation since prior combat experience is often not relevant.

Identified Skill Areas for Battlefield Visualization

A synthesis of the literature review findings and interview findings during the initial phase of this research resulted in the identification of eleven skill areas. These skill areas address various cognitive, social, and ecological aspects of developing, maintaining, and exploiting an actionable knowledge structure referred to in this project as the Commander's visualization space. These eleven skill areas were subsequently consolidated into a set of seven skill definitions (and associated performance criteria) that provided the foundation for USARI's development of a new training support package. The resulting visualization framework organized these skills into four basic areas that linked intent with action: (1) build the visualization framework, (2) synchronize the framework, (3) assess the framework, and (4) exploit the framework. A brief summary of these skill area definitions is provided as follows:

Build the Visualization Framework

Skill Area 1 – Identify Tactical Problems Employing the Factors of METT-TC and Elements of Operational Design: Addresses the ability of the Commander to develop a visualization of the operational environment by identifying tactical problems from triggers and cues in the environment, doctrinal elements of the METT-TC and Elements of Operational Design, and personal experience and training. Together, these elements and their interactions form the Commander's vision of the operational environment and provide a working mental model of how he can move the force from its current state toward a desired endstate.

Synchronize the Visualization Framework

Skill Area 2 – Synchronize the Visualization Internally across Commander and Staff: Involves the collaborative process between the Commander and staff to develop a shared understanding required to transform the visualization into a well formulated plan. The process is integrated with the planning steps that specify when the visualization is shaped, produced, shared, and updated—during the Military Decision Making Process—with relevant information from the Warfighting Functions. In each operation, the collaborative framework must be clearly understood by all staff members and be comprehensive in its coverage of the operational environment from the Commander's perspective.

Skill Area 3 – Synchronize the Visualization across Relevant External Players: Addresses the need to accommodate, within the Commander's visualization, the perspectives and interests of other military and non-military organizations and stakeholders potentially influencing the Area of Operation (AO). Military organizations include adjacent military units, other military units operating in a transient manner within the Commander's AO, and a military unit that is transferring authority for the same AO. For interagency and coalition operations, these organizations include US Government Agencies, nongovernmental organizations, international organizations, and coalition partner units. In stability operations, this need extends to local host-nation power brokers, to include village and city leaders, who play a role in the country's security and governance.

Assess the Visualization Framework

Skill Area 4 – Collect Information and Identify Patterns / Trends: Addresses the ability of the Commander and staff to efficiently organize and focus the unit's collection and interpretation of information about the operational environment in order to conduct immediate operations and to achieve long-term mission objectives. It includes the Commander's identification of CCIR to define the need for additional collection, the collection of information, and the analysis to reduce uncertainty (verify situational elements within a known battle calculus) and ambiguity (pattern/trend analysis to reveal operational variances or to discover influence mechanisms that can be subsequently exploited) from the start of an operation to the achievement of the desired endstate. This requires the Commander and staff to continually maintain, update, and refine the running estimate.

Skill Area 5 – Develop Measures of Effectiveness (MOE): Addresses the effective analysis of the visualization framework to identify meaningful measures to track mission progress along each line of operation. An MOE is a tool to assess changes in system behavior, force capability, or the operational environment in order to measure the attainment of an objective or end state. MOEs focus on the results or consequences of unit actions. The MOEs assist the Commander in determining if unit actions are appropriate or alternative actions

are required. If direct measurement is not possible, then appropriate indicators of achieving the objective, end state, or effect are provided by the MOEs.

Exploit the Visualization Framework

Skill Area 6 – Target Shaping and Intelligence, Surveillance, and Reconnaissance (ISR) Operations: Addresses the proactive use of shaping and ISR operations to reduce risk and uncertainty and/or discover enemy weaknesses or systems that can be subsequently exploited. Because shaping and ISR operations consume combat resources that would otherwise be employed for decisive operations, they must be carefully identified and focused by the Commander's visualization framework. Areas of identified risk and uncertainty provide a framework for determining where shaping and ISR operations are needed, how they should be performed, and what they should accomplish.

Skill Area 7 – Discover and Exploit Newly Revealed Problem Elements: Addresses the manner by which the Commander positions his force to rapidly discover and exploit newly revealed enemy weaknesses or systems within the operational environment that sustain an adversary or influence a civilian population or host nation. Opportunities for discovering these weaknesses or systems might come through the execution of deliberate planning or serendipitous discovery.

Training Support Package Development

Upon completion of the cognitive task analysis, the USARI research group collocated with the US Armor Center at Fort Knox translated the seven identified skill area definitions into a computer-based instructional package called END STATE. This multimedia, interactive training package was designed to improve the visualization performance of field grade officers, battalion commanders, and staff in the seven identified skill areas. Based on an Iraqi operations scenario, the training package included 14 scenario-based training and practice exercises in vignette form. Officers first observed and then subsequently applied various visualization skills across a spectrum of stability and counterinsurgency vignettes. Immediate performance feedback and evaluation was then provided by the interactive software. Formative assessment of the END STATE training package was conducted by USARI with a test group from the US Army's School of Command Preparation within the US Army Combined Arms Center (USACAC) at Fort Leavenworth. Results from a pre- and post-training administration of a Visualization Confidence Inventory indicated improvement across all four areas of visualization skills (Shadrack *et al*, 2008). This assessment suggests that the visualization framework reflected in END STATE can provide a solid foundation for improving individual and collective performance in these skill areas.

PHASE II – SUBSEQUENT REFINEMENT OF THE VISUALIZATION FRAMEWORK

During the assessment of the END STATE training package at the School for Command Preparation, it was noted by some officers that the instructional material was not consistent with current US Army doctrinal publications on command and control. At the urging of the US Armor Center at Fort Knox, USARI briefed the findings of the cognitive task analysis and subsequent training package to the Combined Arms Doctrine Directorate within USACAC. Based on these discussions, USARI was asked to explore further refine the visualization framework for potential inclusion in future US Army doctrinal publications. In response, EBR was asked to (1) take a second look at the theoretical concepts underlying the visualization process – specifically the content and structure of the knowledge produced by visualization, (2) conduct a second set of officer interviews to identify additional visualization challenges, and (3) develop a model of visualization that extends across a continuous planning and execution cycle.

Visualizing Different Levels of Complexity and Emergence within the Battlefield

Over the past several years, EBR has been engaged in the modeling and study of organizational sensemaking – specifically as this socio-cognitive process unfolds in a complex, emergent work environment. From this research has emerged a new paradigm for representing the construction and management of operational awareness and understanding (Leedom & Eggleston, in press). This work draws together findings from several bodies of literature and places them in the operational context of visualizing military operations in a complex, emergent battlefield. This work—which focuses on the product of visualization (an interconnected framework of knowledge elements representing the Commander's operational awareness and understanding) complements the previous research that focused on the process of visualization. As will be

seen, the knowledge framework that emerged from this research fits nicely with the US Army's doctrinal definition of operational design. Together with the process model discussed earlier in this paper, a more in-depth discussion of the knowledge framework produced by the Commander's visualization process will usefully augment future training in this area. To better understand this aspect of visualization, we briefly review selected findings of EBR's recent research.

Organizational sensemaking has emerged over the past 20 years as an analytical construct for understanding how organizations frame their understanding of a work environment in order to engage in the planning and execution of purposeful actions within that environment. Since the world does not naturally conform to the purposes of an organization, people within that organization act to impose order on the world by organizing their perceptions of it in certain ways. Thus, in a very basic way, humans have been engaging in sensemaking since the dawn of civilization. When situations and events do not make immediate sense, people and organizations can act in inefficient—even dysfunctional—ways relative to their perceived objectives. It can be said, therefore, that sensemaking provides the essential foundation for coherent behavior and purposeful accomplishment of work in the world.

A term that has arisen within the body of sensemaking literature is the notion of a *wicked problem environment*. Wicked problems always occur in a social context where the diversity of stakeholder perspectives reflects different interpretations of the situation and the elements of knowledge that comprise this understanding (Rittel & Webber, 1973). Wicked problems are typically ill-structured and involve an interlocking set of issues and constraints. Wicked problems are also dynamic in the sense that (1) the definition of a problem does not emerge until someone has developed a solution and (2) actions taken to solve a problem cause its definition to evolve. The concept of a wicked problem has been usefully applied to military operations. In a case study of stability and reconstruction operations in Afghanistan, Nancy Roberts (2001) characterized the challenge of developing shared understanding among a set of intergovernmental organizations as a combination of simple, complex, and wicked problems. Highlighted within this study was the idea that each of these problems requires a different strategy or approach to sensemaking. Whereas simple problems are best handled by an efficient, centralized decision authority, this same approach is counterproductive for wicked problems. Wicked problems are best framed and attacked through a distributed, collaborative effort involving multiple stakeholder perspectives.

More systematic insight is given by Cynthia Kurtz and David Snowden (2003). According to these researchers, creating workable order out of chaos is a primary driving force for human behavior at both the individual and organization level. They attempt to accomplish this by imposing rules and patterns on their operational environments, mechanisms that organize empirical or abstracted artifacts into a framework of work-related awareness and understanding. However, this process is mitigated by the ontological complexity of the operational environment and the contextual roles assumed by individuals and organizations over time and situation. These factors give rise to four general types of work environments and a corresponding set of sensemaking strategies. The following descriptions briefly paraphrase each of these environments and strategies:

Known Sensemaking Environment – This ordered work environment is characterized in terms of cause-effect relationships that are generally linear, empirically sensible, and expressible in terms of accepted engineering models. Attention is placed primarily on (1) categorizing received data in accordance with these models and (2) applying these models to achieve optimal work solutions.

Knowable Sensemaking Environment – This ordered work environment is characterized by stable cause-effect relationships that are only partially (or qualitatively) known and which must be abstractly inferred by functional area experts. Attention is placed primarily on (1) establishing the appropriate expertise with which to interpret work problems and (2) identifying observable metrics that yield insight into key features of these problems.

Complex Sensemaking Environment – This unordered work environment is characterized by an evolving set of cause-effect relationships that emerge in relative importance over time –i.e., they cannot be predicted, but rather are inferred retrospectively. Attention is placed primarily on (1) probing the work environment to stimulate orderly responses, (2) classifying emerging patterns, and (3) exploiting pattern-based opportunities while they are still relevant.

Chaotic Sensemaking Environment – This unordered work environment is characterized by turbulence and the lack of perceivable cause-effect relationships. Attention is placed primarily on (1) acting quickly and

deliberately to reduce turbulence (e.g., pre-defined crisis intervention actions) and (2) immediately sensing opportunities for creating known or knowable aspects of the environment.

The Different Forms of Knowledge Produced by Battlefield Visualization

Examining the nature of modern military operations, one concludes that the Commander's visualization process must be capable of incorporating all four types of sensemaking environments as they are defined by Kurtz and Snowden. While these various sensemaking environments imply the need for different sensemaking strategies, they also highlight the complex nature of knowledge that must be created and maintained in support of stability operations. At the heart of this issue is the question of what constitutes useful forms of knowledge in wicked problem environments. To address this question, we next turn to a discussion of two forms of knowledge required for creating and maintaining operational understanding in a complex and emergent operational environment.

Within the world of mathematics and computer science research, it is traditional to think of knowledge as being propositional in nature, empirically verified, and subject to the rules of formal logic. Familiar to many researchers, the so-called "scientific method" of accumulating knowledge enables us to amass bodies of knowledge that can be universally applied in various subject areas. However, those engaged in the study of organizational behavior recognize that another form of knowledge, narrative knowledge, is more commonly involved in every day work settings. For example, John Seely Brown and several other prominent organizational theorists note the essential nature of storytelling in organizational knowledge management (Brown, Denning, Groh & Prusak, 2005). Gary Klein (Klein *et al*, 2007), citing the work of earlier researchers (*cf.*, Schank & Abelson, 1977; Bartlett, 1932), notes the role of scripts and stories in providing a framework for sensemaking. Moreover, the words and concepts employed in storytelling do not typically represent a universally understood vocabulary or taxonomy. Rather, as pointed out by the mathematician Keith Devlin (2001), they emerged through a series of conversations in which a series of exchanges (called mini-negotiations) establish the meaning of the words spoken and the information they convey.

The idea that various forms of knowledge were relevant to the functioning of work system organizations was articulated over two decades ago by Jerome Bruner (1986). Specifically, he argued that humans employ two distinctive modes of thought for organizing their experience and constructing an understanding of their environments. These two modes of thought are formally defined by Bruner as (1) the *logico-scientific* (paradigmatic) and (2) *narrative* (story form). Although complementary in nature, they are irreducible to one another. According to Bruner, efforts to reduce one to the other, or efforts to ignore one at the expense of the other inevitably fail to capture the rich diversity of thought. In his outline of these two forms of knowledge, Bruner makes certain distinctions that are important to consider in the development of a geosocial knowledge system:

Objective of Knowledge – The objective of logico-scientific knowledge is the establishment of universal truth, whereas the objective of narrative knowledge is the endowment of meaning and intentionality to experience.

Nature of Knowledge – The nature of logico-scientific knowledge is empirically validated truth, whereas the nature of narrative knowledge is verisimilitude.

Method of Knowledge Construction – Logico-scientific knowledge is constructed through sound argument, formal logic, tight analysis, and proof, whereas narrative knowledge is constructed through association, storytelling, intuition, and inspiration.

Key Characteristics of Knowledge – Logico-scientific knowledge is theory-driven, abstract, context-free, ahistorical, objective, and coherent, whereas narrative knowledge is meaning-driven, context-sensitive, historical, intentional, and sometimes paradoxical.

Given the diversity of contextual dimensions and operational perspectives associated with modern military operations in a PMESII-PT battlefield, the Commander's visualization process must be capable of systematically and dynamically combining both logico-scientific and narrative knowledge into a coherent framework of understanding. This process must be systematic in the sense that it supports the matrixed analysis of the perceptual and systemic causes of regional friction and instability, the operational objectives of various regional actors, effect indicators, and monitoring methods. It must also be dynamic in the sense that the framing of wicked problem spaces involves the continual reinterpretation of artifacts and their contextual meaning.

An examination of current knowledge representation, machine learning and reasoning, geographic information systems, social networking service, semantic web, and collaboration technologies reveals their basic dependence upon a logico-scientific definition of knowledge. While this knowledge paradigm—and associated technologies—supports sensemaking in an ordered or known operational environment, it is considered too brittle to address the contextual richness and dynamism associated with knowable and complex operational environments. At the same time, much of the social science research underlying theories regarding the creation and use of narrative knowledge in real world settings is descriptive or qualitative in nature and lacks the analytical rigor needed for diagnostic and predictive analysis. Thus, to date, few—if any—of its findings have been applied to the development of knowledge management software. To redress this deficiency, research was undertaken by EBR in 2007-08 for the US Air Force Research Laboratory to explore the development of a knowledge representation language that could capture both logico-scientific and narrative knowledge in an analytically rigorous and quantitative manner. A unique aspect of this language (and resulting knowledge framework) is its ability to explicitly treat narrative knowledge as a part of the central foundation of contextual meaning, rather than as a cognitive bias or source of noise to be ignored or eliminated through training.

The motivation for the new knowledge system stems from a combination of operational and theoretical ideas. Operationally, the need for a knowledge system that can dynamically respond to the complex and emergent nature of modern military operations is motivated by recent military doctrinal writings –specifically, the US Army’s new doctrine for designing and conducting military operations (US Army, 2008). Here, awareness and understanding primarily come from a structural and transactional assessment of the organization’s (1) perceived centers of gravity, (2) envisioned endstates, (3) projected lines of effort, and (4) operational approach that attempts to influence specific cause-effect pathways in certain ways. From an ontological point of view, the notion of building a framework of operational understanding requires us to move beyond a traditional understanding of knowledge as being fixed and universal in nature. Specifically, the work is motivated by Bruner’s concept of combining logico-scientific and narrative forms of knowledge into a coherent whole. The evolving and emergent nature of today’s modern battlefield requires us to interpret artifacts, systems, and events in a more dynamic, contextual manner. Indeed, what has emerged from this research is the concept of a holistic, self-referent knowledge system that yields different forms or levels of operational understanding. No longer can we simply represent the battlefield in terms of a fixed, universal set of operational indicators. Rather, insight into the strategic agenda and tactics of each actor within the battlefield derives from our ability to dynamically place different classes of knowledge in contextual relationship with one another.

Central to this new knowledge management paradigm are four classes of knowledge that can be analytically expressed and placed in dynamic relationship to one another to enable analysts to engage in just-in-time contextual framing and reasoning (Leedom & Eggleston, in press). These classes of knowledge include

Artifact Knowledge – This form of knowledge represents the fundamental definition of concrete objects and abstract constructs (e.g., intentionality) that are used by an organization to describe a work environment. Artifact knowledge tends to be atomistic and universal or context-free in nature, although it might reflect the particular vernacular of a given perspective or domain of expertise. Artifacts can be assigned state variables to quantitatively represent and measure their state of existence within the work environment. Artifact knowledge represents the building blocks from which the other three forms of knowledge are constructed.

System Knowledge – This form of knowledge represents the functional definition of important cause-effect relationships within the work environment. They are described in terms of a structurally and functionally linked framework of artifacts and their associated state variables. These relationships define the potential for work (state change) relevant to a given perspective or domain of expertise. Systems are also defined in terms of constituent boundaries and the extension of cause-effect across these boundaries –i.e., the interaction and nesting of systems.

Tactical Episode Knowledge – This form of knowledge represents the instantiation of actions and effects within the work environment. Tactical episodes link cause-effect frameworks (e.g., system knowledge) and consequences (e.g., state variable changes) with specific actions, events, or emergent conditions within the work environment. Episodic knowledge is narrative in nature and links Bruner’s dual levels of actions and meaning/significance to provide a plausible explanation for why and how the state of a work

environment evolves over time. Episodic knowledge is considered tactical in nature because it deals expressly with specific actions, events, or emergent conditions.

Strategic Agenda Knowledge – This form of knowledge ties together a sequence of tactical episodes to form a meaningful story. Agendas place system knowledge and episodic knowledge within an intentional framework that provides a plausible explanation of how actions, events, and emergent conditions either support or contradict the achievement of specific work goals. Like episodic knowledge, agenda knowledge is narrative in nature; however, it represents a higher or more strategic level of narrative.

A key idea represented in the work of Leedom and Eggleston is that these four forms of knowledge are used by the Commander to form a coherent, holistic, and self-referent framework of battlefield awareness and understanding. That is, the contextual meaning of any given element of knowledge flows naturally from its dynamic association with other structural or functional elements within a holistic framework of awareness and understanding. By representing knowledge in this manner, Leedom and Eggleston conform to Michael Polanyi's (Polanyi & Prosch, 1975) view that knowledge is best represented as an individual's instantaneous state of awareness and understanding –not an external commodity that can be managed like data or information. At the same time, it captures Gary Klein's notion that sensemaking involves the continuous fitting of data (artifacts and artifact states) with plausible frames of understanding (systems, episodes, and agendas). It also acknowledges the importance of narrative knowledge underscored by the writings of Jerome Bruner, Karl Weick, Laurence Prusak, and John Seely Brown. Finally, it consistently supports the US Army's framework of operational design, as illustrated in Figure 1.

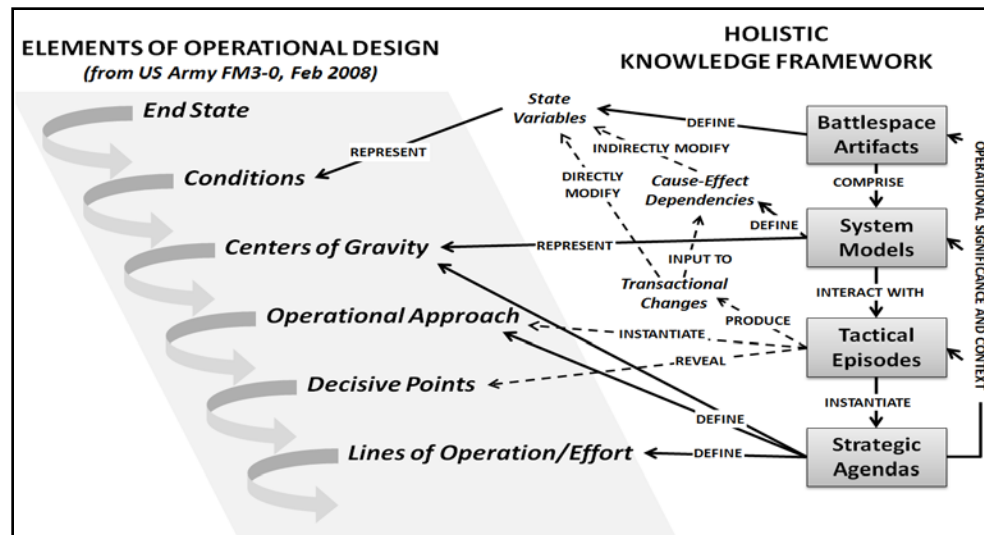


Figure 1 Mapping of Knowledge Elements into the US Army's Framework of Operational Design

Second Set of Officer Interviews

As part of this follow-on research effort, a second series of interviews was conducted with 18 military officers attending the School for Advanced Military Studies. These interviews were designed to provide an updated understanding of battlefield visualization as it was practiced at the brigade/battalion level in Afghanistan and Iraq. These interviews revealed a number of interconnected issues regarding battlefield visualization as it is currently practiced in the field. The first issue deals with the trend over the past several years for commanders to substitute intuitive decision making for analytic decision making when the former is not supported with relevant operational experience. The second issue deals with the disruptive impact of unit rotations on battlefield visualization and operational design. The final issue deals with the failure of higher level commanders to effectively articulate the essence of their operational design in terms of meaningful measures of operational progress. Each of these issues is briefly taken up in the following paragraphs.

Misuse of Intuitive Reasoning When It Is Not Supported by Relevant Expertise

Over the years, US Army doctrine has emphasized the combined use of both analytic and intuitive forms of reasoning within the military decision making process (MDMP). As described in Field Manuals 3-0 and 6-0, analytic reasoning reflects a systematic approach to decision making that decomposes a problem framework into its constituent elements, examines alternative pathways to resolving each part of the problem, and arrives at an optimal solution space. By contrast, intuitive reasoning is defined in this same document as a holistic mental process that emphasizes a pattern recognition form of decision making. It is considered to be based on the ability of the commander to recognize familiar battlefield conditions and operational patterns, and to instinctively use this experience to mentally formulate a relevant course of action (US Army, 2008). The manner in which analytic and intuitive forms of reasoning are discussed in existing doctrine leads the reader to adopt an interesting—but inaccurate—paradigm. In these publications, analytic reasoning is interpreted as a staff-centered activity associated primarily with the deliberate execution of the 7-step MDMP. By contrast, intuitive reasoning is interpreted as a commander-centered activity that is employed under conditions of high time stress to short-circuit a lengthier staff planning cycle. Over the years, many US Army officers have come to apply this paradigm in rote fashion: commanders intuitively visualize—*i.e.*, mentally construct—the battlefield problem framework while staffs analytically develop this visualization into a detailed set of tasks and resource assignments.

The concept of intuitive—or pattern recognition-based—reasoning was popularized by Gary Klein’s research in the 1990s and his publication of a book entitled *Sources of Power* (Klein, 1999). This work, based on the study of expert decision makers operating under conditions of high time stress, established scientific credibility for an intuitive form of reasoning in real life situations. Its popularity arose, in part, because it challenged the industrial age model of decision making based on the systematic analysis of problem frameworks and the formal evaluation of proposed solution spaces. Commanders who were frustrated with doctrine that required the formal development and assessment of three alternative courses of action saw this new model of intuitive reasoning as a means for shortening the MDMP cycle. As this practice has evolved, units have become less and less motivated to conduct a formal MDMP, instead relying more heavily on the commander’s ability to intuitively shape and reshape the problem framework. At the same time, staffs engage in the mechanical aspects of the MDMP (*e.g.*, preparing staff estimates, responding to published CCIRs, wargaming, target development, and orders production) without analytically maintaining a deep understanding of the problem framework that drives these steps. For example, many brigade combat teams report that a formal MDMP is conducted only at the beginning and end of a rotation to plan their entry and exit from a theater of operation. During the remainder of their 15 months in theater, these units rely upon a continuous process of intuitive reasoning that frames operations in terms of an ongoing sequence of fragmentary orders (FRAGOs). As a consequence, a type of “Groundhog Day” syndrome arises in which every day of deployment appears to be a rote continuation of the same mission, with little awareness that meaningful operational progress is being made.

The problem with this simplified view of analytic versus intuitive reasoning is that it fails to consider the complex and emergent nature of today’s battlefield. Commanders and staff officers, once trained in applying a familiar battle calculus to traditional force-on-force combat operations, presume that the same reasoning strategies can be applied to stability and counterinsurgency operations. But with little actual experience or expertise in the non-military aspects of PMESII-PT, they have little basis for recognizing meaningful patterns and developments within this complex and emergent environment. In short, intuitive reasoning cannot be substituted for systematic analysis of the battlefield in situations where the decision makers lack relevant experience and expertise! While there is evidence that some units have attempted to engage in systematic analysis of their operational environment during rotations in Iraq and Afghanistan, the majority of unit have simply struggled to develop a cohesive and purposeful framework for action. This issue is illustrated by a number of reported error patterns observed in staff operations in Iraq and Afghanistan:

- Staffs simply assess operational progress in terms of what can be quantified (*e.g.*, IED incidents, terrorists killed) rather than in terms of what is operationally relevant to understanding the PMESII-PT dimensions of the battlefield,

- Staffs mechanically engage in familiar battle rhythm routines (*e.g.*, producing PowerPoint™ briefings) rather than understanding the need to support the commander’s continuous process of adapting and refining the problem framework to the evolving state of the battlefield,

Staffs repeatedly plan familiar types of kinetic and nonkinetic operations with little or no understanding of how these operations contribute to desired endstates within the area of operation, and Staff initiative and creativity is stifled because the unit's battle rhythm or leadership atmosphere is not geared to accommodate analysis of the overarching problem framework, thus leading to a situation in which low risk operations that avoid casualties or criticism are preferred over operations geared to achieve momentum over an adaptive adversary.

The effective abandonment of the MDMP process by many units would appear to be a case of throwing the baby out with the bath water. The failure of commanders and staffs to recognize the need for systematic analysis of the PMESII-PT battlefield has led to a dichotomous pattern of behavior. On the one hand, many units have relegated the use of the MDMP to known types of phased missions such as ingress and egress from a theater of operation. On the other hand, these same units have approached the task of understanding long-term operations within the PMESII-PT battlefield in an ad hoc manner—with less than effective results. Plans are developed in an intuitive manner, but they lack the depth of relevant PMESII-PT experience to justify this approach. At the heart of this issue is a failure to recognize that the design of operations in a dynamic and emergent battlefield is a collaborative activity that requires the unit to analytically engage relevant perspectives and sources of information in the systematic analysis of key battlefield artifacts, systems, cause-effect relationships, constraints, and defeat/stability mechanisms that are deemed relevant to a unit's assigned mission.

Failure to Adequately Transfer Awareness and Understanding between Rotating Units

As brigade combat teams and regiments replace other units in theater, there is generally an observed pattern of discovery learning that takes place during the first several months of their operations. This cycle of learning does not go unnoticed by an astute adversary who will often revert back to earlier tactics and exploit these cycles for operational gain. Over time, the new unit will develop an understanding of its operational environment and begin to engage both adversaries and the civilian population in a more purposeful manner. Unfortunately, as this unit is replaced with another unit, the cycle of learning is repeated—thus creating another opportunity for adversaries to regroup and regain momentum.

At the same time, unit rotations have been accompanied by an abrupt shift in operational strategy for achieving security in an area. Whereas one unit might have relied heavily upon non-kinetic tactics to gain the cooperation of local tribes and neighborhoods, the next unit will shift to a more kinetic approach of intimidation and coercion. The resulting discontinuity in operational strategy can have a devastating impact on the level of trust and cooperation given by local leaders and civilian populations. This is especially critical in stability and counterinsurgency operations that extend over long periods of time. In short, local leaders and indigenous civilian populations are less likely to cooperate with US military forces over time if these forces exhibit inconsistent behavior.

While the reasons for maintaining unit rotations are many and varied, there seems to be little appreciation of the disruptive impact they have on the design of military operations. Again, it is recalled from Field Manual 3-24 that units engage in design activities in order to establish a workable framework of key battlefield artifacts, systems, cause-effect relationships, constraints, and defeat/stability mechanisms that are deemed relevant to a unit's assigned mission. It would seem logical—especially in stability and counterinsurgency operations—that this framework be maintained as one brigade or regiment assumes mission responsibility from another for a given area of operation. Yet, it is reported that little understanding of this framework is effectively passed from one unit to another at the time of unit rotation. The reasons for this discontinuity appear to be twofold. On the one hand, many commanders appear to exhibit an attitude of “the last unit messed up—our unit can do it better.” Despite the US Army's practice of briefly overlapping command teams during RIPTOA, there seems to be a built-in resistance to understanding the framework of operational design created by the last unit. At the same time, many elements of this framework—including its key assumptions about the nature of the operational environment—might have been poorly documented, and so they are difficult to communicate to the in-coming command team. While a few units have attempted to maintain some knowledge of the problem framework in the form of a battle briefing book, other units have little to offer to an in-coming unit.

Compounding this lack of continuity associated with unit rotations is the fact that mission handoffs do not involve the overlap of staff elements. While it might seem unimportant to include staff-to-staff interaction

during a rotation handoff, they nevertheless play a critical role in communicating an understanding of key battlefield artifacts, systems, cause-effect relationships, constraints, and defeat/stability mechanisms within a given area of operation. Staff elements contribute to the ongoing framework of design through their respective staff estimates, with each individual having the potential to add a unique perspective. Since they are excluded from the interaction that takes place between units during a rotation handoff, in-coming staff elements essentially start with a blank sheet of paper regarding an in-depth understanding of the PMESII-PT battlefield.

The combination of resistant attitudes and poor documentation of the operational design result in the lack of operational continuity between rotating units. Since it is unlikely that the US Army will change its policies regarding unit rotations, commanders and their staffs must develop better procedures for communicating their frameworks of operational design during rotation handoff. Such improvements would not only deny adversaries a potential window of exploitation opportunity, but also serve to maintain the essential cooperation of local leaders and civilian populations.

Continuous Operations Require Careful Articulation of Operational Objectives

The elements of operational design in traditional force-on-force combat operations can be developed in a relatively straightforward manner, based on the commander's experience, intellect, creativity, intuition, and education. Historically, commanders have dominated the design process because they represent the greatest body of experience within a military unit. Once this design has been formulated in the commander's mind, the staff planning process unfolds in a linear manner to translate this design into a detailed, synchronized sequence of specific tasks and resource assignments.

In traditional force-on-force combat operations, the linear sequencing of these design and planning activities and the commander's dominant—if not unilateral—role in visualizing the operational design are specifically justified because of the familiar and structured nature of these types of military operation. However, the complex and emergent nature of stability and counterinsurgency operations presents a unit with an entirely different situation. This is true in two respects. First, when faced with a complex set of PMESII-PT dimensions, the commander will often lack a precise vocabulary with which to express certain concepts. This is particularly true with regard to the political, economic, social, information, and infrastructure dimensions of the battlefield. Second, many of the key factors involved with each PMESII-PT dimension might not become known except through an iterative cycle of probing actions, pattern analysis, and collaboration with other elements of national security. Both of these issues affect the manner by which a unit develops and maintains its framework of understanding and operational design.

The lack of a precise vocabulary for expressing certain PMESII-PT concepts requires the commander to take extra care in both (1) fully articulating the elements of operational design in terms of observable phenomena and (2) insuring that staff officers and subordinate commanders correctly interpret these elements through positive feedback. A common issue reported by many staff officers at brigade and below level is the often ambiguous or equivocal nature of command intent received from higher headquarters. For example, endstates such as "stabilized region" or "achieve security" can be interpreted in a variety of ways that emphasize either kinetic or non-kinetic strategies. Different interpretations of endstate conditions, in turn, can give rise to the identification of different centers of gravity, different operational approaches, different decisive points, different lines of effort, and so forth. Another result of ambiguous design guidance is the tendency of staffs to focus on immediate and familiar tasks, conditions, and standards without understanding how these tasks contribute to the underlying endstate purpose. Staff briefings and orders give pro forma attention to certain words and phrases extracted from command intent, but provide little real understanding of (1) what is expected to be achieved along each PMESII-PT dimension and (2) how these different achievements connect with one another. Such a situation, if left unchecked, leads units to simply react to events on the battlefield, rather than proactively maintain initiative and momentum against and adaptive adversary. To paraphrase Field Manual 3-0, ambiguous or equivocal statements of operational design tend to result in a series of disconnected engagements, with relative attrition the only measure of success. Because this problem has been cited by many staff officers returning from Iraq and Afghanistan, it would appear that senior officers need to exercise more care in practicing mission command.

LINKING VISUALIZATION PROCESS WITH VISUALIZATION PRODUCTS IN A CONTINUOUS CYCLE

Based upon the review of recent knowledge management research and the insights obtained from the second set of interviews, EBR developed a refined model of battlefield visualization that addresses both process and product. Specifically, it describes battlefield visualization as it impacts three interconnected processes: (1) the Commander's development of battlefield awareness and understanding; (2) the Commander's development of problem solutions and an operational design for his assigned mission; and (3) the unit's planning, refinement, synchronization, and execution of the mission. The final section of this paper describes this model in more detail.

A Cyclical Nature of Battlefield Visualization

The cyclical nature of battlefield visualization is illustrated in Figure 2. This diagram consists of three concentric circles that illustrate the processes, skills, and knowledge classes associated with battlefield visualization. Depicted within the outer circle are the specific tasks associated with the three interconnected processes described above. The development of battlefield awareness and understanding involves (1) the identification of key battlefield artifacts, (2) the organization of these artifacts into cause-effect system models, (3) the connection of these systems into meaningful pathways of influence via a series of tactical episodes, (4) the organization of systems and episodes into meaningful strategic agendas, (5) the development of appropriate MOEs for assessing operational progress, (6) the synchronization of this framework of understanding across different operational perspectives, and (7) the assessment of the current state of the battlefield. The development of problem solutions and an operation design involves (1) the definition of a desired endstate and relevant PMESII-PT conditions, (2) the identification of one or more centers of gravity, (3) the design of an operational approach in terms of effects and decisive points, (4) the orchestration of the operational approach into specific lines of operation or lines of effort, and (5) the refinement of the operational design in terms of the remaining mission variables. The unit's planning, refinement, synchronization, and execution of the mission is illustrated in terms of the US Army's traditional MDMP.

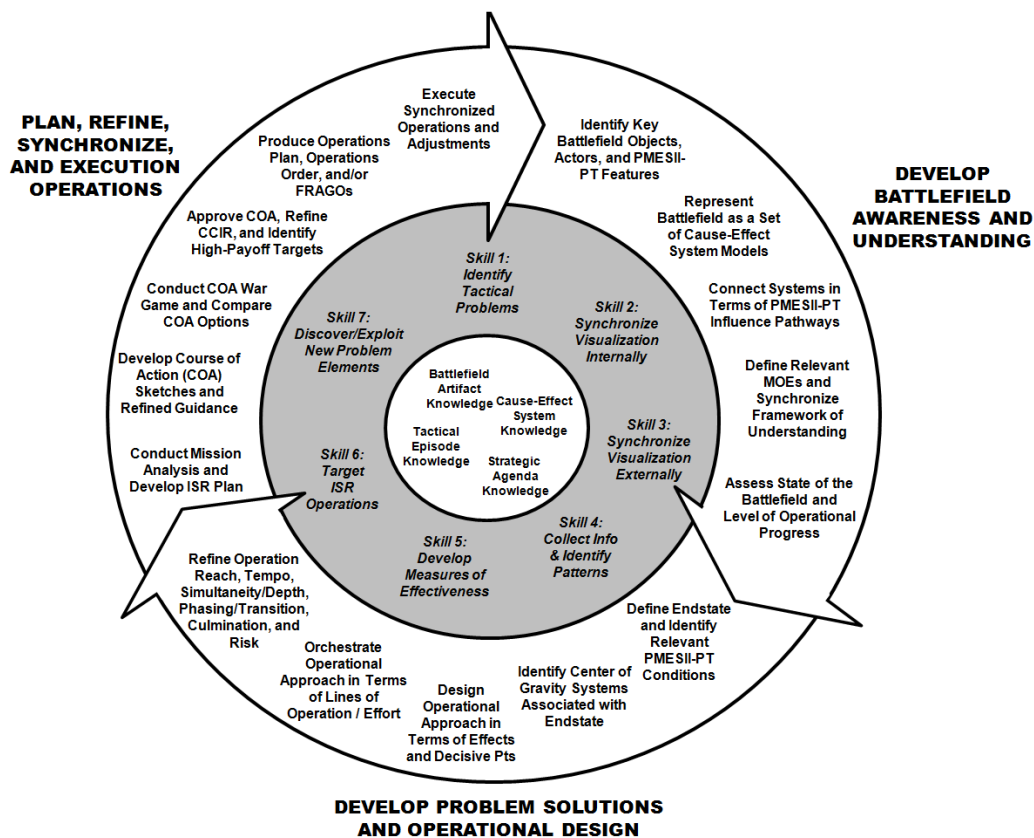


Figure 2 Battlefield Visualization within a Continuous Battle Command Cycle

Depicted in the middle circle are the visualization skills that support the various processes outlined in the outer circle. These skills include the seven skill areas defined earlier in Phase I of this research effort. Finally, the inner circle depicts the four classes of knowledge produced by the different visualization skills as they are applied to the tasks in the outer circle. The cyclical arrows in this diagram illustrate the continuous nature of this task cycle in a long-term stability or counterinsurgency operation. At the same time, it illustrates the interconnected nature of knowledge management and battle management. Knowledge management occurs in each phase of this cycle –i.e., the management of battlefield understanding, the management of operational design knowledge, and the management of detailed planning knowledge. Battle management also occurs in each phase of this cycle –i.e., management of operational attention and focus, management of problem framing, and management of battle execution.

Specific Flow of Knowledge Products

The flow of knowledge products within this cyclical model is illustrated in Figure 3. This figure includes the same set of battle command task sequences depicted concurrently in linear form. Arrows illustrate the flow of specific knowledge products between each of the task sequences. Of particular note is the fact that product flows run in both directions, with some tasks providing the elements of knowledge needed to initiate subsequent tasks and other tasks providing the operational context necessary for constructing meaning in antecedent tasks.

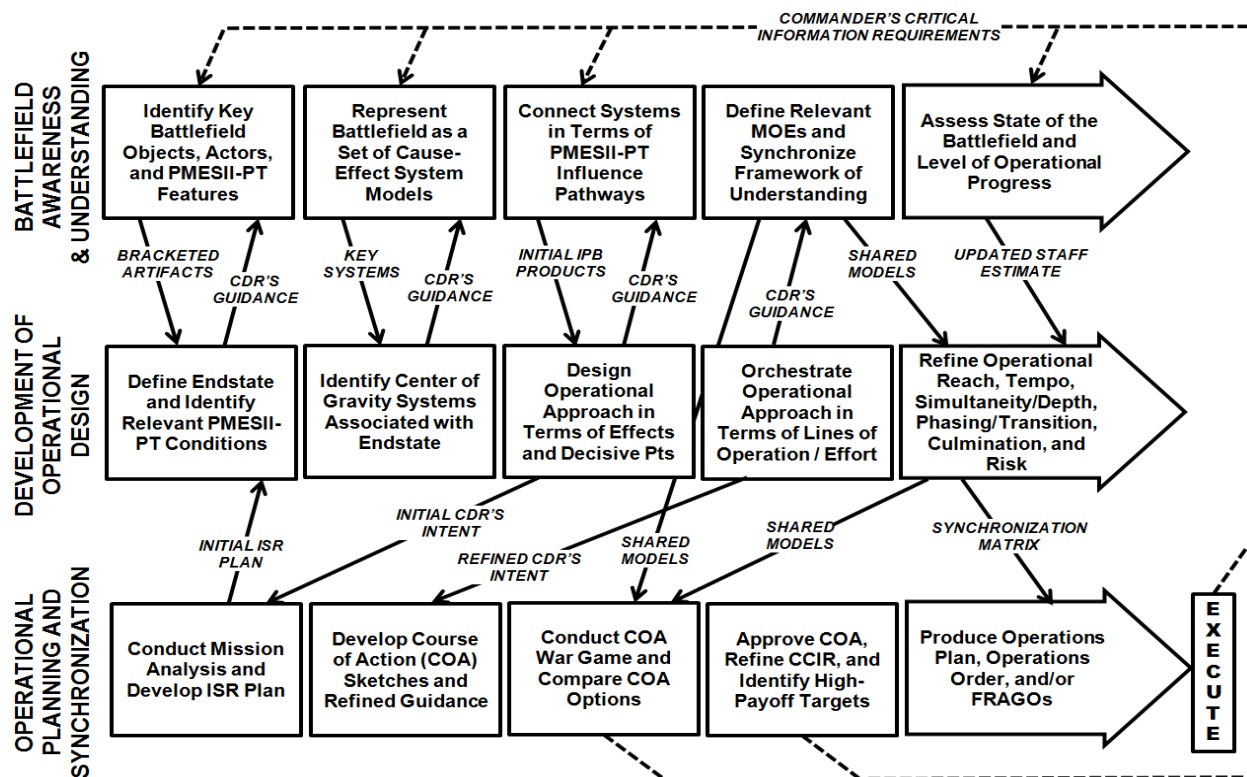


Figure 3 Flow of Knowledge Products within a Continuous Battle Command Cycle

The Management of Battlefield Visualization over Time

Of particular note in Figure 3 is the feedback loop indicated by the dashed arrows leading back to the set of battlefield understanding development tasks. Given the emergent nature of stability and counterinsurgency operations, it is likely that the Commander's framework of awareness and understanding will evolve over time as new artifacts and influence relationships are discovered. Such discoveries can occur during COA analysis and review, as well as during the execution of the operational mission. This is especially true for

complex sensemaking environments described earlier in this paper. It is important, therefore, that the Commander and his supporting staff remain sensitive to the need to continually assess and refine the elements of knowledge that comprise his understanding of the battlefield. For this reason, the three battle command processes (development of understanding, operational design, and planning/execution) should be viewed as three simultaneous or concurrent command and staff activities during a unit's rotation period.

At the same time, it is of equal importance to consider the effectiveness with which visualization products are transferred from one unit to another at the point of mission handoff. This challenge is illustrated in Figure 4. As noted earlier from the second set of officer interviews, the transfer of a battlefield visualization framework from one unit to another has been problematic. Incoming units typically begin the process of battlefield visualization afresh upon their arrival within the area of operation. As a result, considerable time might elapse before they construct an effective understanding of their operational environment –i.e., knowledge of the key battlefield artifacts, the cause-effect system models, the influence pathways, the operationally relevant MOEs, and so forth. In turn, the incoming unit's ability to develop an effective operational design will be hindered by its poor understanding of the battlefield.

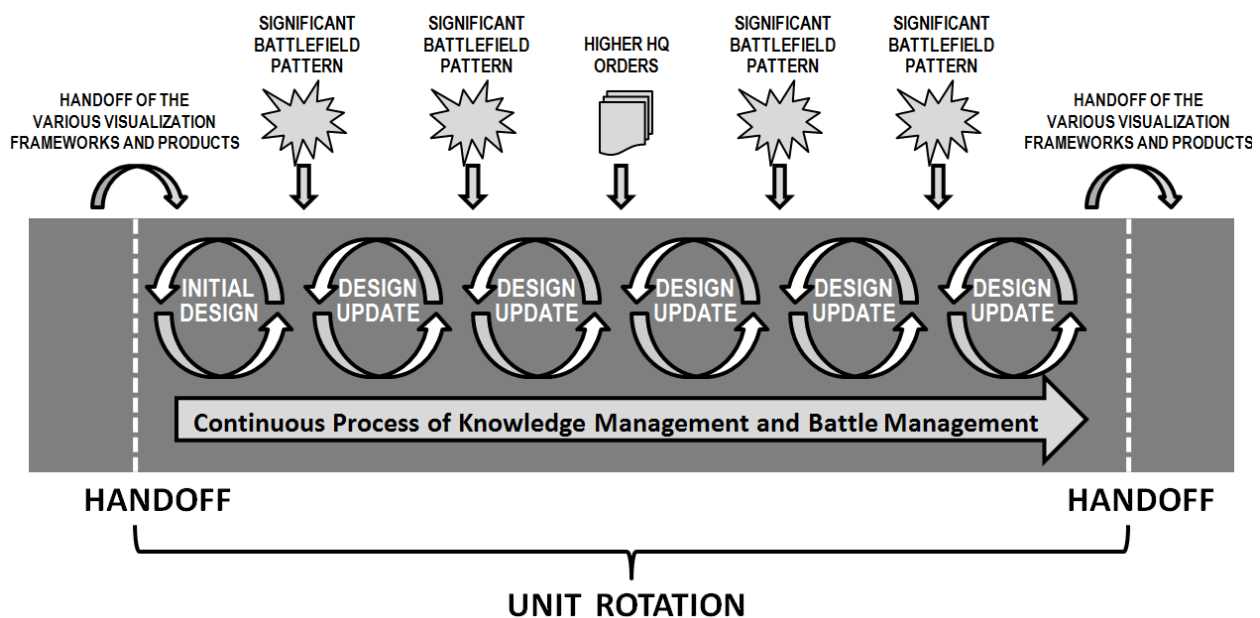


Figure 4 Transfer of Battlefield Visualization at Mission Handoff

To overcome the current pattern of operation, outgoing and incoming units must deliberately engage in a collaborative process of transferring a contextual framework for decision making. Using the model of battlefield visualization described above, commanders and staff officers should systematically work together to transfer their understanding of key battlefield artifacts, the manner in which these artifacts are linked into meaningful cause-effect systems, the history of operationally significant episodes, and the relationship of these forms of knowledge to the strategic agenda implied by mission orders received from higher headquarters. At the same time, commanders and staffs should evaluate the operational design emplaced by the outgoing unit to determine if it needs to be adjusted on the basis of (1) a change in mission orders, (2) a shift in the operational state of the battlefield, and/or (3) important differences reflected in the personnel and equipment available to the incoming unit. This knowledge then provides an informed context for planning and executing operations by the incoming unit.

SUMMARY

This paper has provided an in-depth examination of battlefield visualization as it is undertaken in a complex, emergent environment such as stability or counterinsurgency operations. This research integrates current theories of knowledge management with two sets of interviews conducted with military officers having

recent command and staff experience in Afghanistan and Iraq. Phase I of this research identified seven specific socio-cognitive skill areas that contribute to command and staff performance in this area. In Phase II, the research revealed the importance of addressing three distinct processes—development of battlefield understanding, problem solving and operational design, and the planning and execution of specific operations—as interconnected aspects of battlefield visualization. At the same time, our research identified the specific classes of knowledge—artifact knowledge, cause-effect system knowledge, tactical episode knowledge, and strategic agenda knowledge—that are produced by these processes and woven into a complex and dynamic framework of awareness and understanding. Our emerging visualization model illustrates how these three processes, seven skill areas, and four classes of knowledge define command and staff operations in terms of two intertwined meta-activities: knowledge management and battle management. Knowledge management serves to construct and maintain a contextual framework of battlefield understanding that guides the second process, battle management. It is hoped that this model will serve as a foundation for improving both future doctrine and training.

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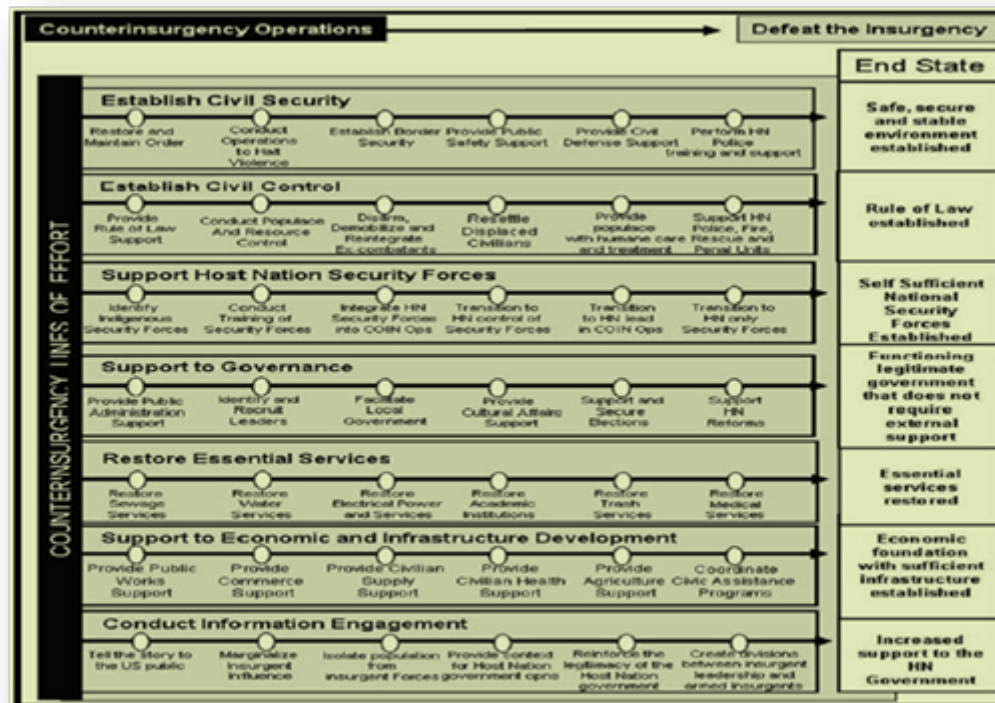
**Dynamic Battlefield Visualization: Knowledge Management in a
Complex, Emergent PMESII-PT Battlefield**
Paper 162

Dennis K. Leedom, Ph.D., Evidence Based Research, Incorporated
Scott B. Shadrick, Ph.D., U.S. Army Research Institute

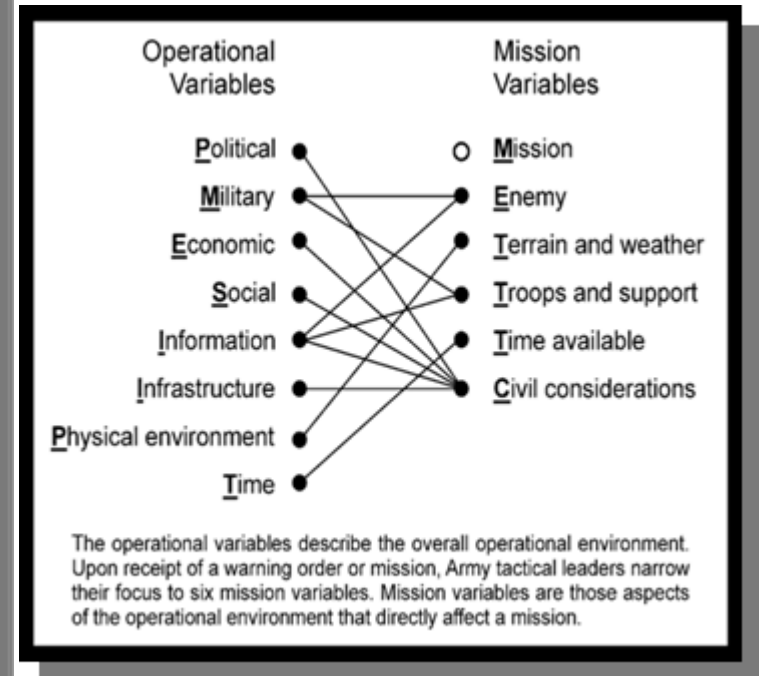
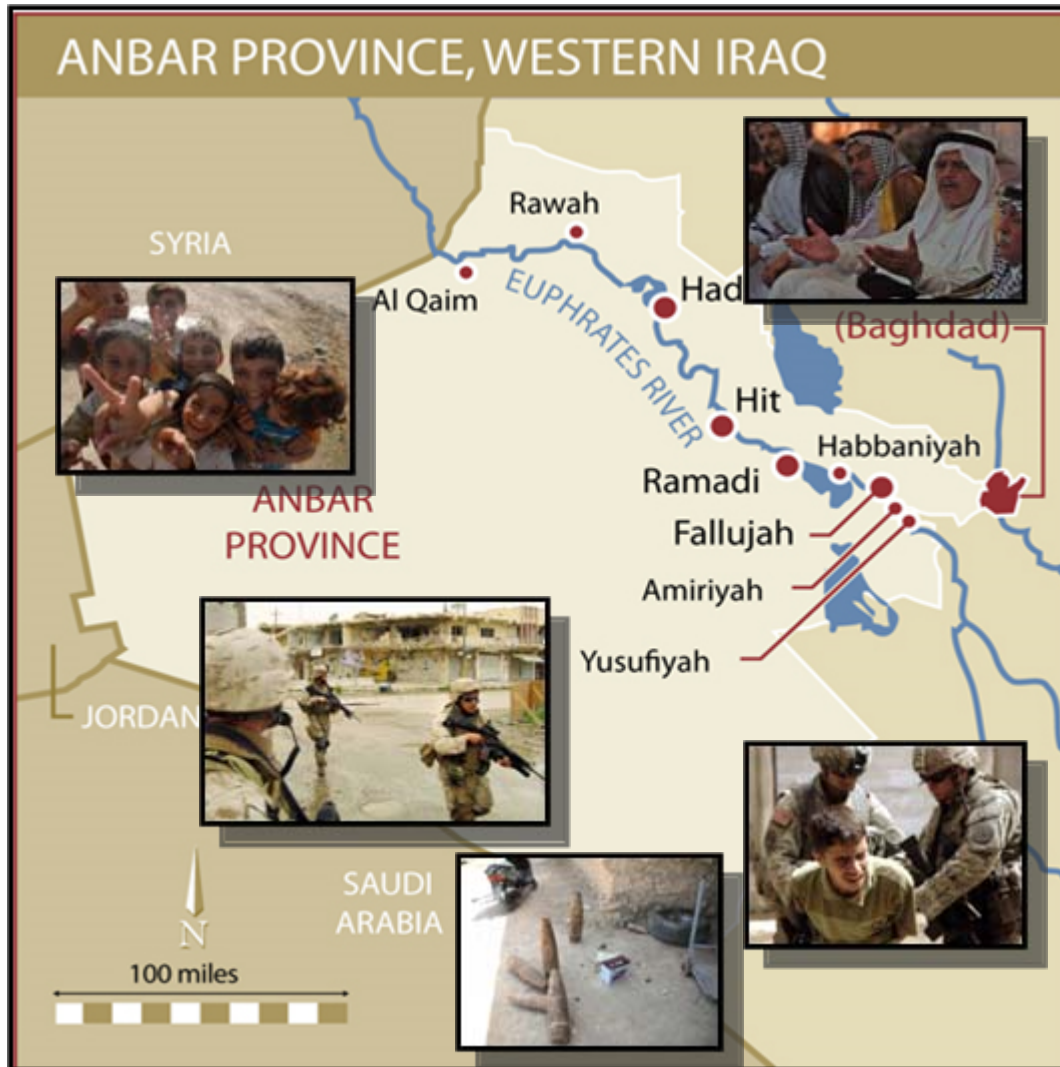
14th ICCRTS “C² and Agility”
Washington, DC, 15-17 June, 2009

Visualization Defined

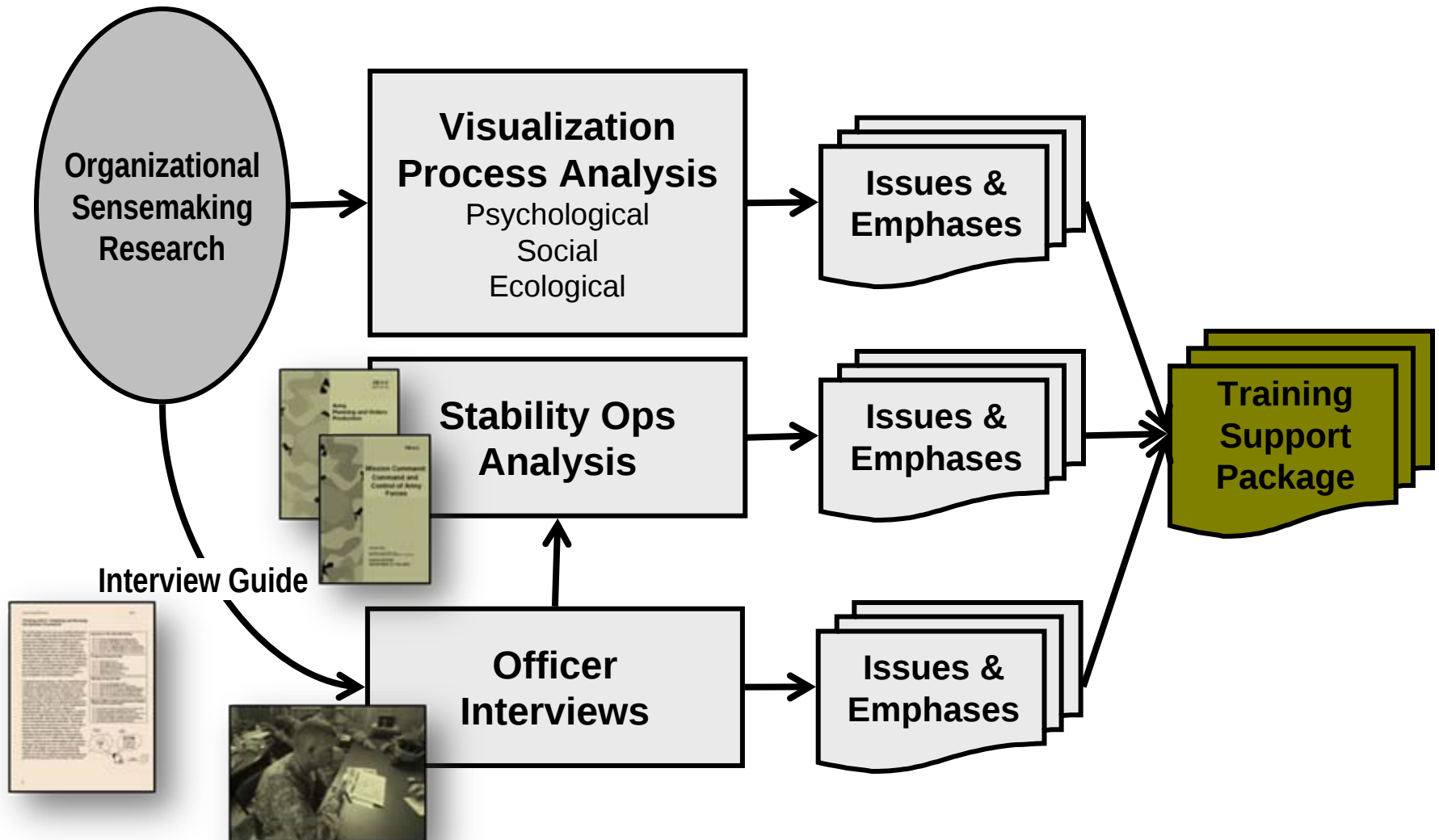
Visualization can be generally defined as the art and science of developing situational understanding, determining a desired end state, and envisioning how to move the force from its current state to the desired end state.



Visualization Challenge



Phase 1: Task Requirements Analysis



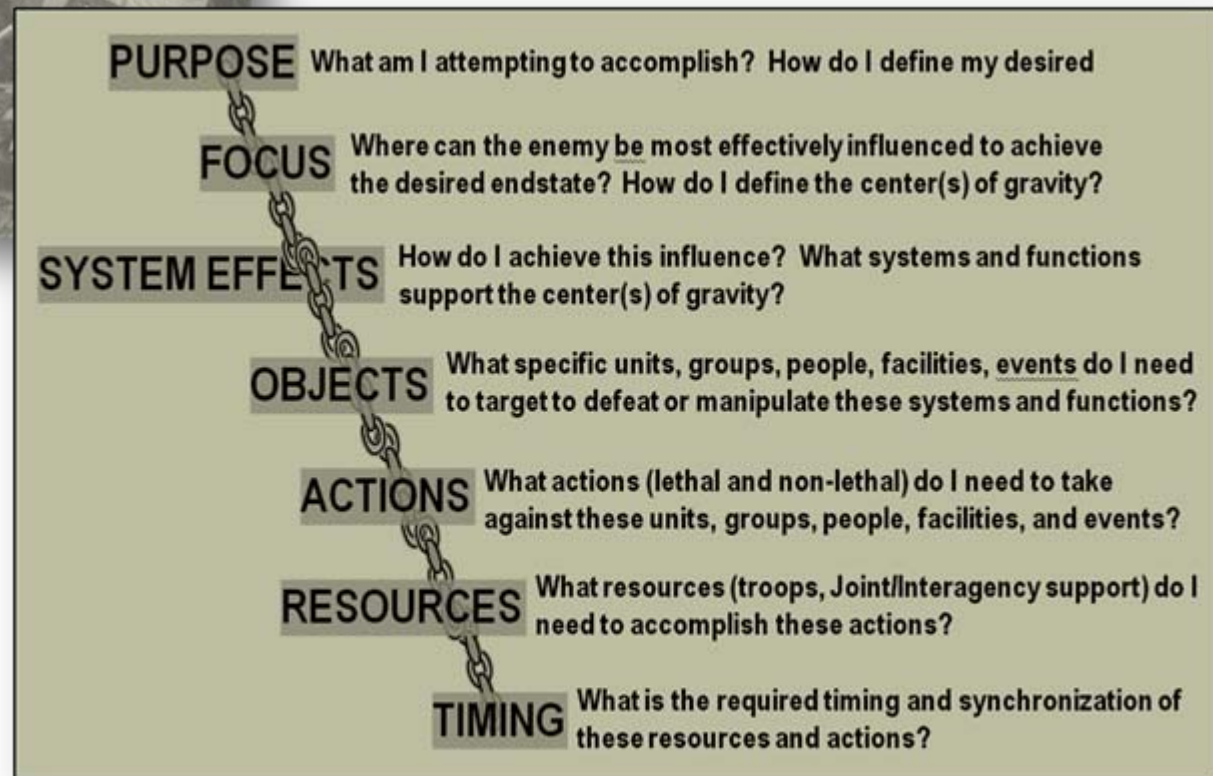
Visualization Characteristics



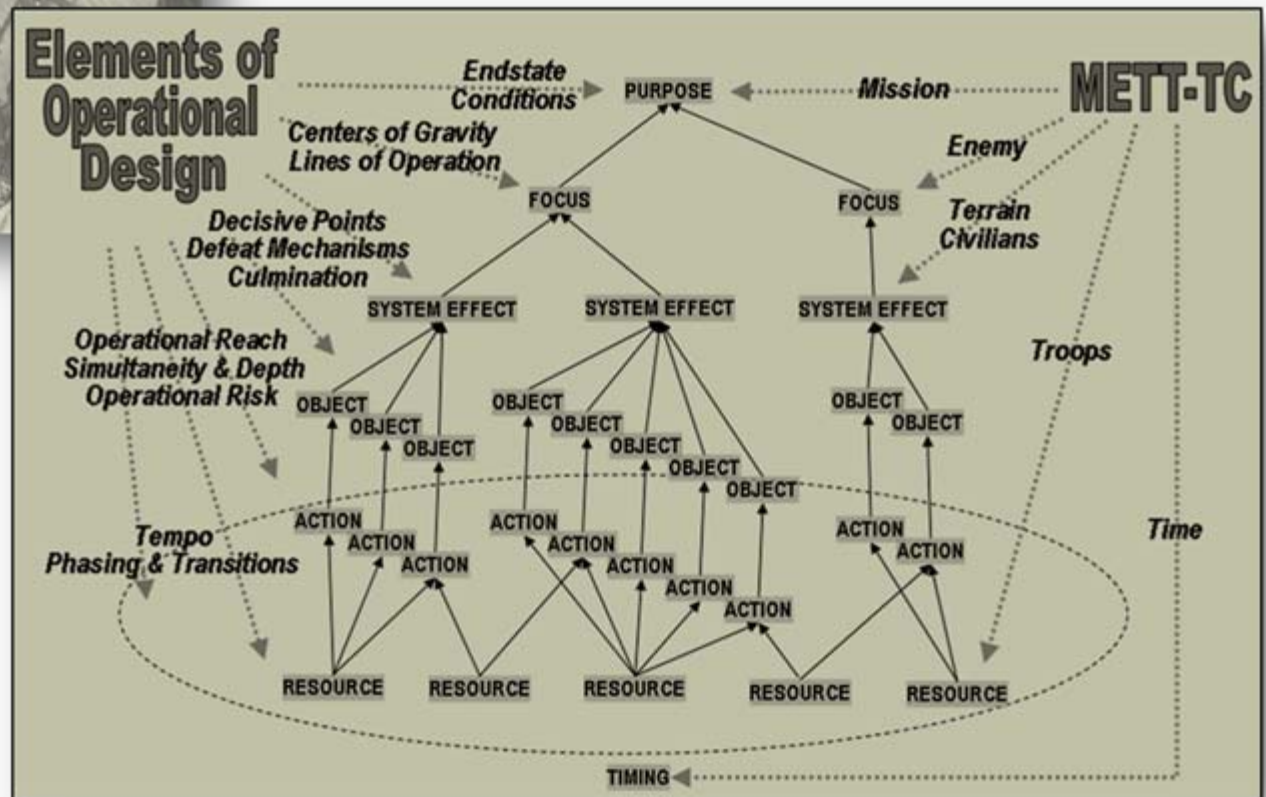
Battlespace Visualization

- Purposefully frames actions and links them with understanding and intent
- Is synchronized vertically across the commander and staff
- Balances intuition with deliberate reasoning according to past experience
- Structurally framed by doctrine to provide common ground of understanding
- Matched to the dimensions and levels of operational complexity
- Collaboratively constructed to achieve unity of purpose
- Continuously adjusted to revealed aspects and unpredictable adversary
- Supports and guides a larger planning and execution process

Levels of Visualization Thinking



Commander's Visualization Space



Issues Highlighted in Interviews

- 25 interviews with officers possessing relevant BCT/BTF command and staff experience
- Read-ahead survey form based on initial task model
- 2 hour interviews recorded for post-analysis

- Visualizing effects of non-lethal actions on civilian population (center of gravity) / lack of doctrinal concepts and MOEs
- Reconciling multiple operational perspectives of military forces, interagency organizations, and intergovernmental elements in a common PMESII-PT battlespace
- Reconciliation of short-term operational objectives against short-term tactical actions
- Loss of operational focus during unit rotation / discontinuity of operations during unit handovers
- Managing multiple forms of verbal, written, graphic, and tacit knowledge

Visualization Task Areas

- **Build the Visualization Framework**

1. Identify tactical problems employing METT-TC and Operational Design frameworks

- **Synchronize the Visualization Framework**

2. Synchronize the visualization internally across Commander and staff to develop shared understanding
3. Synchronize the visualization across relevant external players to accommodate multiple stakeholder perspectives

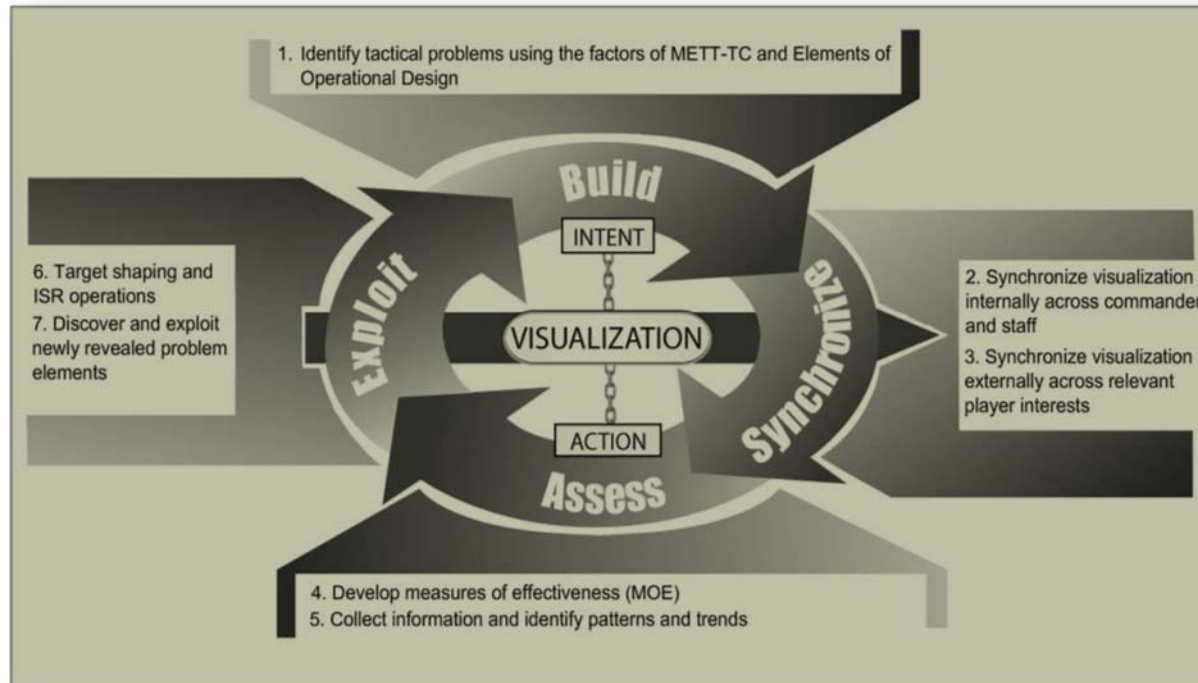
- **Assess the Visualization Framework**

4. Focus collection of information and identify patterns / trends to discover operational variances and maintain a running estimate
5. Develop meaningful measures of effectiveness (MOE) based on endstate objectives and 2nd-order consequences

- **Exploit the Visualization Framework**

6. Target shaping and ISR operations to reduce risk/uncertainty and discover adversary weaknesses
7. Exploit newly revealed problem elements to seize and maintain operational initiative

Training Development and Testing



- ✓ Deliberate practice of expert cognitive behaviors
- ✓ Multiple, realistic COE scenarios
- ✓ Built-in cues or triggers: ambiguous, critical, useful, irrelevant, and misleading
- ✓ Built-in performance measurement supports feedback
- ✓ Coaching/feedback via video or avatars of authentic mentors, instructors, and Soldier role models

PC-Based Tutorial Lessons

The screenshot shows a software interface for a military training module. At the top, a dark banner contains the text "END STATE" in large yellow letters and "COMMANDER VISUALIZATION AT THE BATTALION LEVEL" in smaller yellow letters. To the left of the banner is a circular logo with a shield and a cross. Below the banner, a navigation bar includes a "Course Map" button and four menu items: "INTRODUCTION", "ROAD TO WAR", "RULES OF ENGAGEMENT", and "BATTALION UPDATE BRIEF". The main content area has a dark background with the title "Introduction to Visualization Training" in white. Below the title, a paragraph in yellow text states: "In this module you will be introduced to the visualization skill, identify tactical problems using the factors of METT-TC & integrating the Elements of Operational Design." Below this, a section titled "In this module, you will see:" lists three items: a. A description of the visualization process for Build 1, with an example, which demonstrates how the trainee uses the Target Performance Criteria as the means to build the visualization. b. The background situation, with relevant maps, staff updates and situation update. c. A practical exercise of the Build 1, visualization process with assessment and feedback. To the right of the text is a video frame showing two soldiers in desert combat gear; one is pointing towards the camera. At the bottom of the interface, there is a control bar with a volume icon, a close button (X), a play/pause button, a "SCENES:" label with a small orange icon, a "Maps" button, and "BACK" and "NEXT" navigation buttons.

END STATE **COMMANDER VISUALIZATION AT THE BATTALION LEVEL**

Course Map INTRODUCTION ROAD TO WAR RULES OF ENGAGEMENT BATTALION UPDATE BRIEF

Introduction to Visualization Training

In this module you will be introduced to the visualization skill, identify tactical problems using the factors of METT-TC & integrating the Elements of Operational Design.

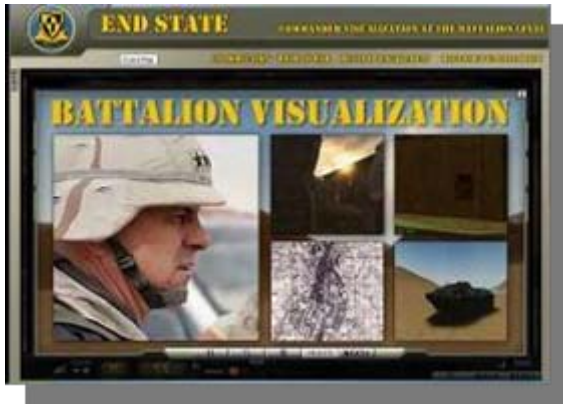
In this module, you will see:

- A description of the visualization process for Build 1, with an example, which demonstrates how the trainee uses the Target Performance Criteria as the means to build the visualization.
- The background situation, with relevant maps, staff updates and situation update.
- A practical exercise of the Build 1, visualization process with assessment and feedback.

VOLUME - + X >>> SCENES: Maps <BACK NEXT>

Introductory Materials

Visualization Introduction



Road-to-War Briefing



Battlefield Update Briefing



Training Vignette Features

Video from Iraq



Realistic Animations



UAS Video



C2 Information Displays



Pre- and Post-Training Assessment

Students review situation



Students perform task skills



Students receive feedback



Training Effectiveness Evaluation

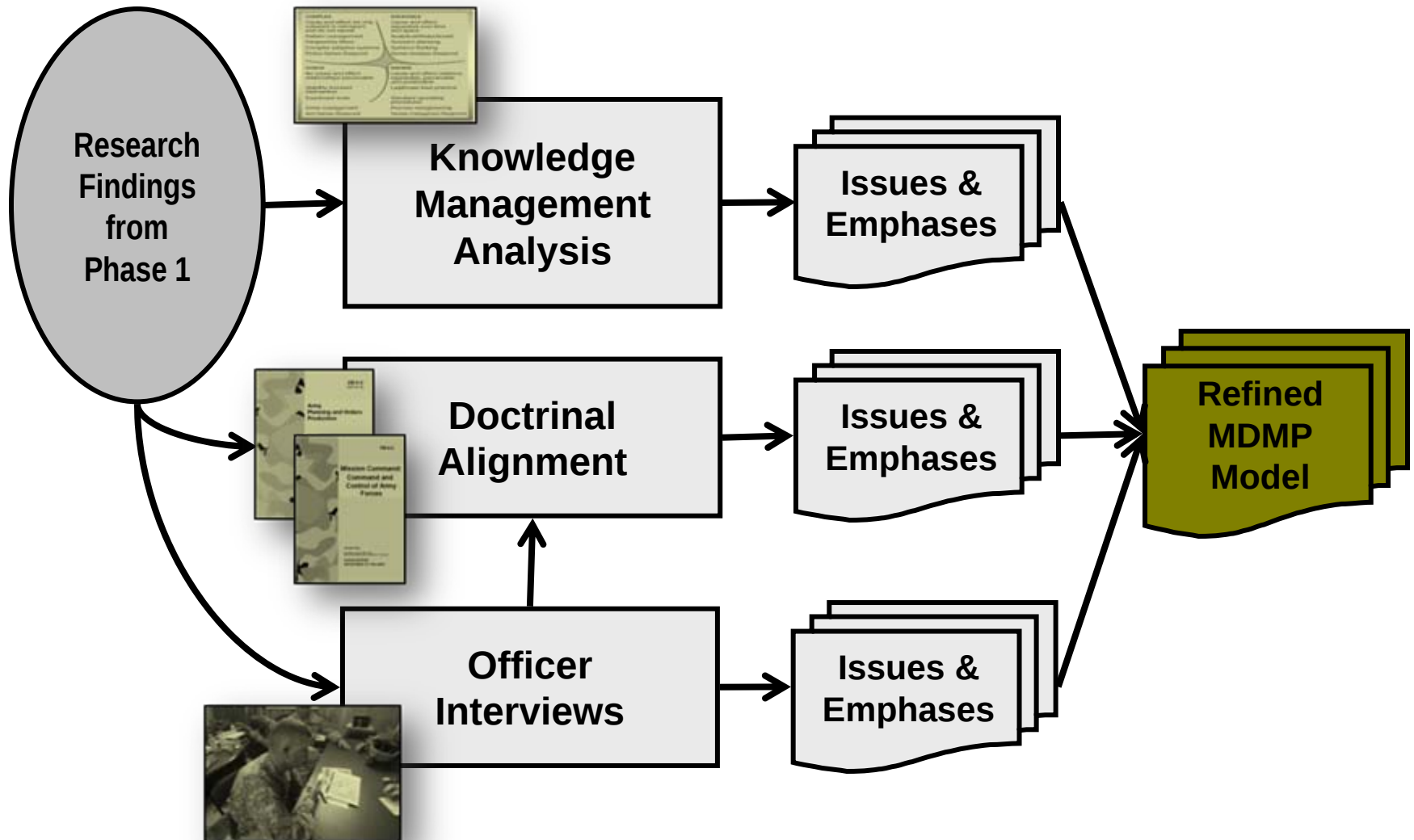
CONFIDENCE RATINGS

Visualization Skill Domain	Mean Rating	
	Pre-Training	Post-Training
Build	3.89	3.92
Synchronize	3.96	4.05
Assess	3.37	3.76
Exploit	3.04	3.71

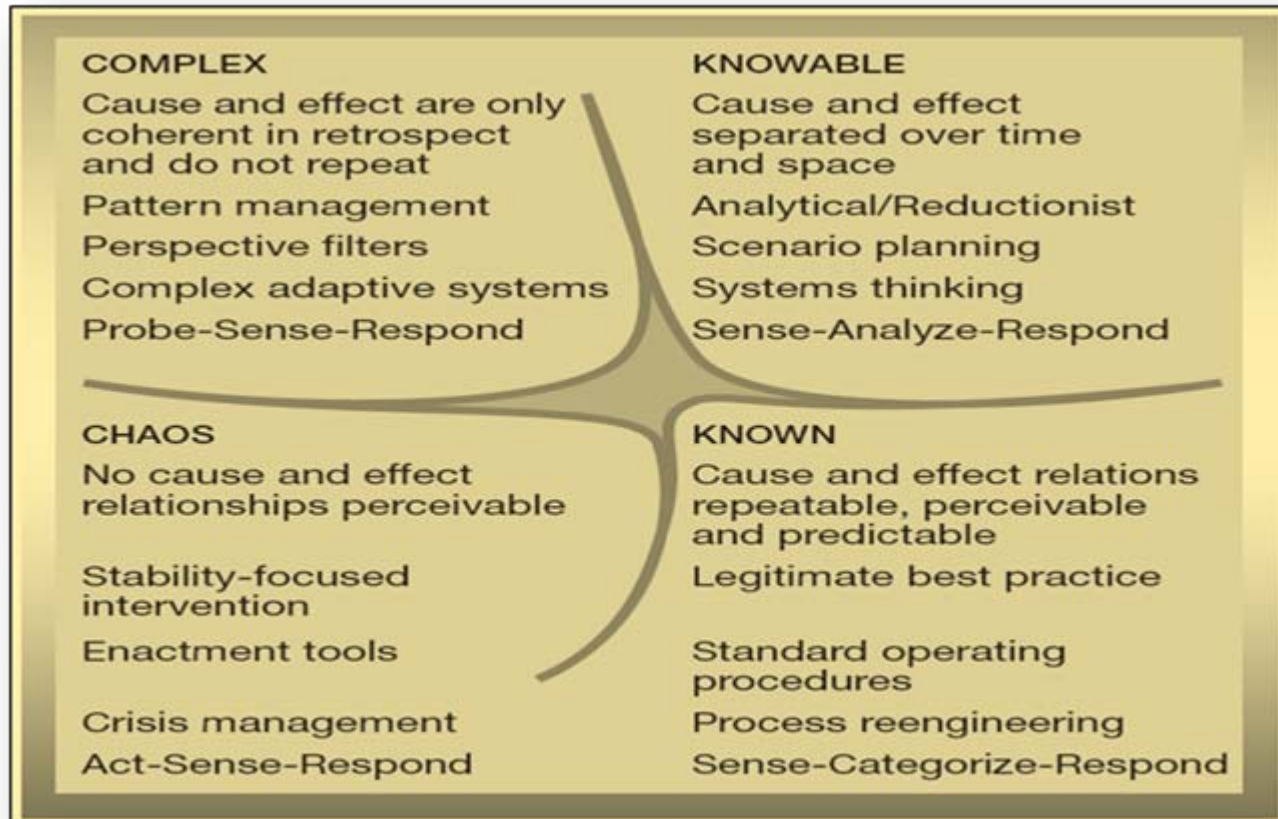
PERFORMANCE ASSESSMENT

- Pre-test ($M = 79.6$, $SD = 4.6$)
 - Post-test ($M = 87.8$, $SD = 4.9$)
- (Wilcoxon's $Z = 2.533$, $p < .05$)

Phase 2: Refine the Visualization Model



Sensemaking Strategies



KURTZ & SNOWDEN, 2003

Forms of Sensemaking Knowledge

LOGICO-SCIENTIFIC KNOWLEDGE

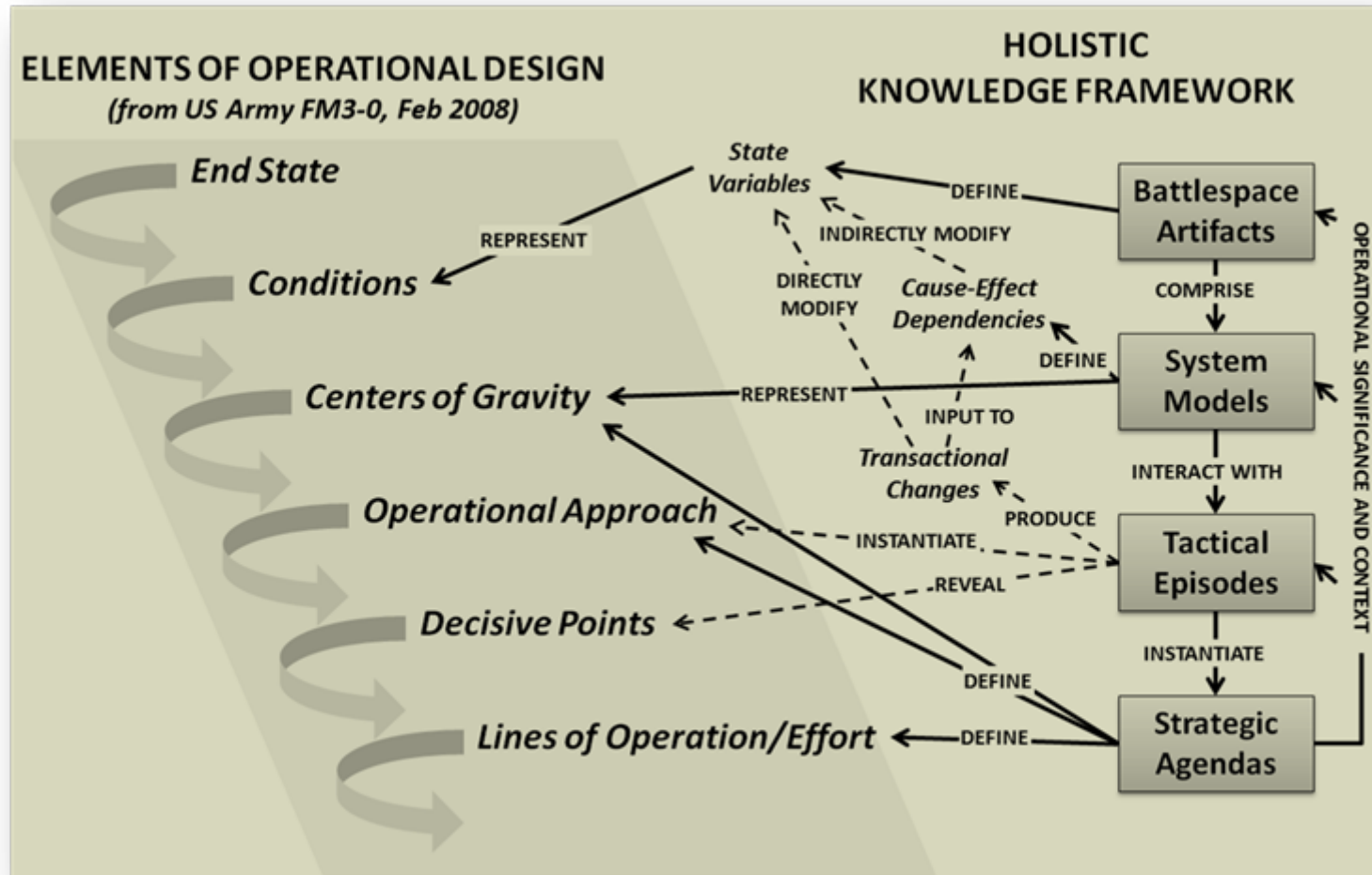
- Objective: Establish a body of universal truths
- Nature: Empirically validated truths, objective definition
- Method: Formal reasoning using predicate logic and proofs
- Application: Theory-driven, context-free, objective, ahistorical

NARRATIVE KNOWLEDGE

- Objective: Endow experience with meaning and intentionality
- Nature: Plausible explanations, bracketed by experience
- Method: Abductive just-in-time reasoning using story-telling
- Application: Meaning-driven, context sensitive, intentional, paradoxical

BRUNER, 1986

Mapping onto Operational Design

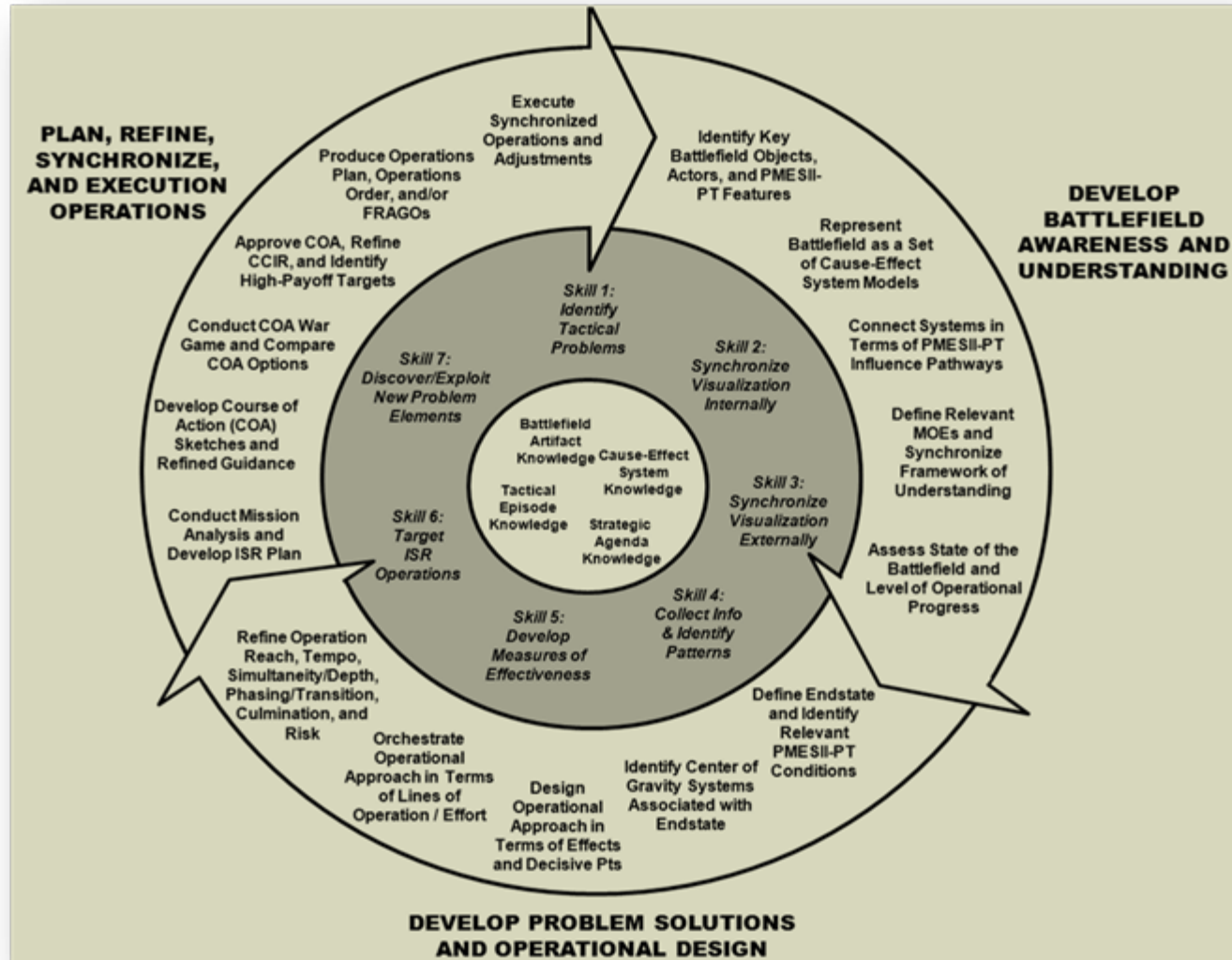


Issues Highlighted in 2nd Interviews

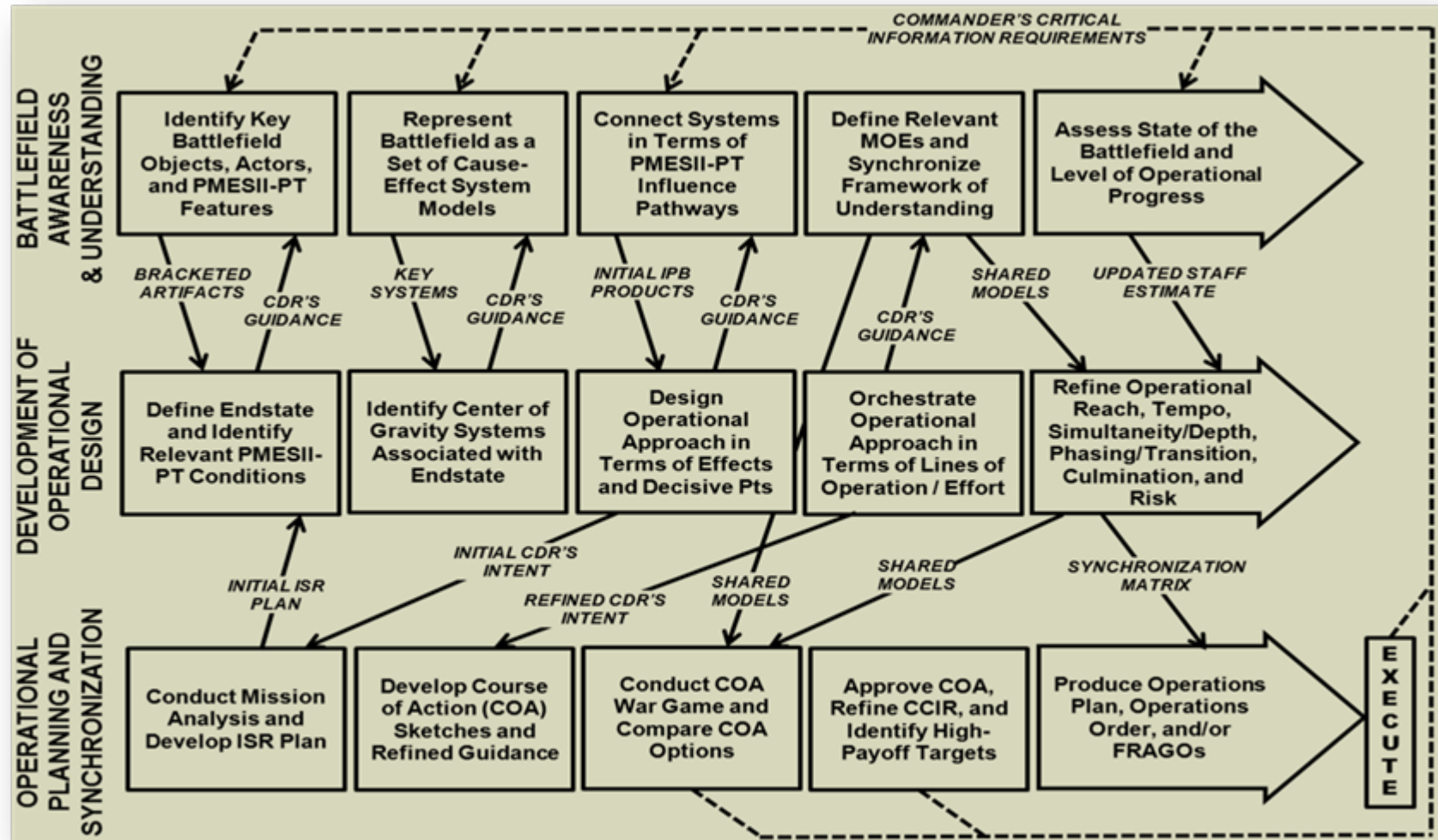
- 18 interviews with officers possessing relevant BCT/BTF command and staff experience
- 2 hour interviews recorded for post-analysis

- Misuse of intuitive (RPD) reasoning and abbreviated MDMP when it is not supported by relevant operational experience
 - Traditional MDMP viewed as a time-consuming, pro forma exercise
 - Continuous series of FRAGOs cannot substitute for deliberate reevaluation of operational requirements and strategy
- Failure to adequately transfer situation awareness and understanding between rotating units
 - New unit experiences steep learning curve
 - Adversaries learn to exploit operational seams
- Operational objectives poorly articulated
 - Reactive operations consist of disconnected series of tactical engagements and effects (e.g., “Ground Hog Day” syndrome)
 - Consequence management consumes considerable resources

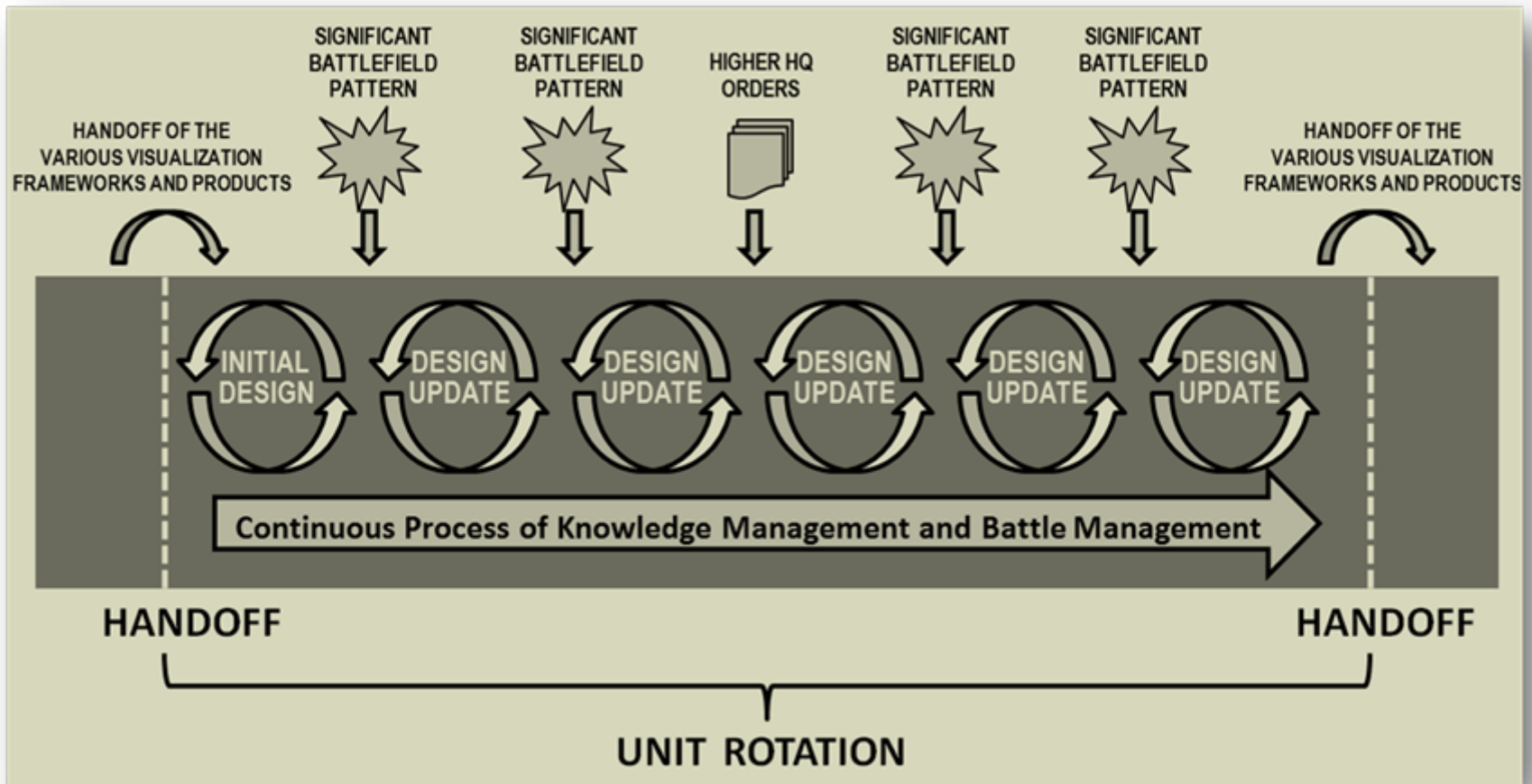
Continuous Visualization Cycle



Flow of Knowledge in Battle Rhythm



Transfer of Visualization between Units



Questions ?

