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A Framework for Cognitive Human Dimension Studies in Future Battle Command Systems

Topic 10: Collaborative Technologies for Network-Centric Operations

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Abstract

The objective of this paper is to provide an event report on a workshop on human dimensions in future battle command systems. The realization are: (a) Inform the relevance of human dimensions in future modular forces with network-enabled Battle Command System; (b) Identify analyses requirements for human-technology collaborative work systems, and (c) Inform the requirements for human dimension training developments. The workshop identified cognition and visualization as one of the primary components of human dimensions based on cognitive factors. Some of these include decision making, visualizing, concept formulation and battlefield awareness--selecting the critical time and place to act, and knowing how and when to make adjustments when in contact with the enemies. The workshop used military subject matter experts. The workshop recommendations do not advocate any standard or must follow "issues." It was noted that the human dimensions will have to transcend the constructivist and physique concepts to mentalist and cognitivist.

1.0. **Introduction**

Hammes[1] has termed fourth-generation warfare—one where the adversary is not known, battlefields are defined by complex interactions of human and technologies; orchestrated needs to turn information into adaptive decision process; there is more demand for the commanders, battle staffs, and troops to be agile, adapt, and change along the axes of battlefield information; and more than ever, the persistent needs for situation awareness and sensemaking of the battlefield information space. A battle command system architecture represents a system of systems approach to representing how technology and human elements will interact to provide the service personnel the enabling environments so as to that improve battle agility, unmasked situation awareness of "seeing the enemy first", small forces with increased mobility in any terrain, and the ability to provide the commander and battle-staffs with information in the right format, at the right time and for the intended purpose. According to General Frederick M. Franks, Jr (1996)., battle command means seeing what is now, visualizing the future state or what needs to be done to accomplish the mission and then knowing how to get your organization from one state to the other at least cost against a given enemy on a given piece of terrain. With these requirements, the human dimensions constitute the important elements of future.

The Army's TRADOC Pamplet 525-3-3 (DoD, 2007) outlines seven key operational ideas that characterize the capabilities of the future force; one of which is Network-Enabled Battle Command. The concept asserts that throughout future campaigns Network-Enabled Battle Command will facilitate the situational understanding needed for the self-synchronization and effective application of joint army

[1] COL T. X. Hammes (2004). Hammes, T.X. (2004). 4th-generation warfare. *Armed Forces Journal*.

combat capabilities in any form of operation. Enabled with technology capabilities, the human endeavors are expected to shift towards more requirements of meta-cognitive skills which have to be enabled by seamless management of sensory information and modalities of processing them. However, while the commander's attention and memory capabilities are relatively static, there are many speculations on the use of technology to amplify the human cognition (Schmorrow, Cohn, and Nicholson, 2008) by taking opportunity of how humans process information, most particularly, the understanding of information processing at the neural levels (Parasuraman and Rizzo, 2000)

Human dimensions comprise of many inter-related constructs that span the regimes of social, biological, psychological, informational, ecological, physical, moral, and cognitive components. Our current understandings of these constructs are driven by the nature of battlefield elements, battle command structures, and the types of technology. During the American Civil War, the force-on-force interactive combat was enabled by a horse-power technology and a stove-piped command and control (C2) structure (Fuller, 1993)[2]. All that changed during the first Gulf War when General Glosson (2003) and his "Black Hole" air campaign planners demonstrated the power of technology in decreasing human and equipment fratricides, execute fast-tempo and agile operations, and share information seamlessly across all commands echelons with minimum delay times. Building on the lessons learned from the current Iraqi and Afghanistan conflicts, the future wars will take place in asymmetric and austere environments where the enemies will lack specific identify. Truthfully predicted by COL. Fuller[3] , the future will be a war of entrenchments and general disintegration of social organizations through famine, national bankruptcy, ethnic rivalries, and so on. More advanced technology such as unmanned aerial vehicles, intelligent mobile robots, and unobtrusive use of satellite to tract and detect enemies in concealed and camouflage urban corridors, and agents that can detect chemical and biological weapons will begin to be more useful. In any case, the soldier in the sea, land, or air will still interact with all these enabling technologies. With this, three aspects of human dimensions in the future battle systems were observed and used to drive the related insights:

- Battle command is a human-centric organization.
- People remain the essential and critical center of gravity for war –in its operation, defeat or victory.
- There are no bad regiments; but bad colonels (Napoleon).4

[2] COL. J.F. Fuller (1993) notes that "through discovering the laws of motion and steam-pressure, they discovered truths, not necessarily absolute, but sufficiently general to enable thousands of artists to make use of them and apply them in a million of ways (pp. 23)."

[3] COL. J.F. Fuller: The war…in which the combatants measure their physical and moral superiority, will become a kind of stalemate, in which, neither army being able to get at the other, both armies will be maintained in opposition to each other, threatening each other, but never being able to deliver a final and decisive attack…That is the future of war—not fighting, but famine, not the slaying of men, but the bankruptcy of nations, and the break-up of the whole social organization---it will be a great war of entrenchments… (pp. 27).

4 This quote is often attributed to Napolepn I, 1769-1821.

2. The Setting

The workshop took place during the 8th Symposium on Human-Interaction with Complex Systems and the 1st Topical Issues on Sensemaking at Norfolk, VA, from April 3-4, 2008. The workshop was by invitation only and the participants included subject matter experts (SMEs) from US Army Combined Arms Center-Battle Command Battle Laboratory (CAC-BCBL), Army Capabilities Integration Center (ACIC), Defense Advanced Research Projects Agency (DARPA), Human Research and Engineering Directorate (HRED) of the Army Research Laboratory (ARL), and North Atlantic Treaty Organization (NATO). The participants, led on day one by retired Army Colonel Calvin Johnson and on day two by retired Army Lieutenant General Richard Keller, were tasked with the following objectives: (i) Identify the elements of human dimensions in future modular forces with network-enabled Battle Command System; (b) Identify the human requirements for human-technology collaborative work systems for; and (c) Indentify the training requirements that will impact human dimensions in future BCS.

The procedure was interactive with open dialogs with the audience. The panelists presented their personal opinions and allowed the audience to critique and give rebuttals. LTG (retired) Keller broadened the scope of discussion with the use of case vignettes as a commander to demonstrate the values of technology, human, and the interaction of both human and technology. It was noted that the human remains the center of gravity of every war and as technology development is advanced, the human dimension elements must be developed tangentially and interactively beyond the current stipulations in the training doctrines. It was observed that the human dimension issues will deal with increasing cognitive requirements that must be studied through complimentary disciplines of situation awareness, sensemaking, and situation understanding using such emerging tools as social network theory and cognitive neurosciences. Issues to frame higher order cognition were identified for knowledge management, decision support systems, sensory attention, and neural-level information processing with bias towards technology capabilities and the occasions of their degradations. A note on this was observed from General Glosson's (2003) lessons learned from use of technology on the first Gulf War[5] in which the decision support system for sorties failed to adapt to changing tasking profiles. Throughout the report, the term Battle Command was used to describe the war fighting functions performed by humans—mostly, the commander and the battle staffs, and BCS is used when referring to the suite of technology systems that humans use in the conduct of operations.

3. Important Workshop Emerging Insights

It was observed that human dimensions in the battlefield are not new. However, in order to prepare the future soldiers for new wars and the use of technologies that will help in those wars, the human dimensions must receive priorities in several complementary areas. Predominant among these are cognitive elements, social elements, ecological elements, and leadership elements. Training requirements for each element were identified.

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[5] General Glosson (2003): "The Computer Aided Force Management System (CAFMS) was never going to make it. In fact, CAFMS had hickuped and failed when we stressed it in exercises (pp. 108)"

3.1. Cognitive Elements

The human cognitive dimension issues dealt with the increasing cognitive requirements in lieu of too much information technology in the battlefield which is often the culprit of cognitive (or mental) workload. Requirements for studying higher order cognitive skills were elucidated. COL (retired) Calvin Johnson led the panel with a focus on visualization and cognition skills, including the defining moments when the commander has to use the available mental models and expertise to cope with technology failures.

The Army's Field manual 3-0 (DoD, 2008) doctrinal information on "Visualization, Detection, and Decide" requirements include visualization as our attempt to allow the sensemakers to "see the same thing" in place and time so as to gain real-time situation awareness. Through visualization, the team members can share their mental models, present their perspectives either textually or graphically. Many conceptual discussions of future force highlighted the importance of visualization in enabling command and control. For instance, network-enabled operations are founded on the premise that if the future force fully exploits both shared knowledge (collective visualization) and technical connectivity, then the resulting capabilities will dramatically increase mission effectiveness and efficiency. The same (DoD, 2008), notes that "Commander's visualization is the mental process of achieving a clear understanding of the force's current state with relation to the enemy and environment." Visualization represents an aspect of embodied cognition because the cognitive processes are mitigated with the environment of information displays.

General William S. Wallace (2005) was observed to note that in the Battle Command concept, commanders use a personal decision-making process that incorporates visualizing the operation, describing the operation in terms of intent and guidance, and then directing actions within that intent. Many other military doctrines have defined battle command to include visualization as a tool to predict the current and future states of the battlefield. Essentially, visualization is "seeing and knowing" the friendly and enemy forces and then deciding how to get from one to the other at least cost. Visualization models in the battlefield should allow the commanders and battle staffs to frame better hypotheses about the information in the environment, and reason bottom-up or top-down (deduction or induction) or laterally (abduction) in order to gain an understanding of the context of interest. The representative visualization process often used include link maps, conceptual maps, symbols, decision trees, semantic diagrams, and videos, animations, and data plots.

Several studies that have strong bearings to cognition and visualization are noted here as an after workshop reference. They include, but are not limited to:

(a). Barnes (2003) who developed a general model of visualization to describe how "commanders visualize the sequence of events that will move his forces from the current state to the end state (pp.2)." It is noted that the ultimate purpose of visualization aids is to increase the commander's ability to understand the battle dynamics, consider options, and predict outcomes.
(b). Card, Mackinlay, and Schneiderman (1999) note that visualization is the use of computer-supported, interactive, visual representations of data to amplify cognition. The

differences between scientific and information visualization are listed. The former, information visualization is an important way to amplify human cognition.
(c). Shadrick, Leedom, Manning, and Lickteig (2008) identify visualization 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 state. It is critical to successful battle command. Four distinct dimensions of visualization are identified for generic battle command tasks: Build, Synchronize, Assess, and Exploit. Different visualization skills are required at each task level.
(d). Cassella (2008) identify cognitive skills required to be trained for visualization and noted that visualization leads to many aspects of human endeavor: situation understanding, situation awareness, sensemaking, creativity, and insightful knowledge. It is noted that the current inventories of knowledge, skill and ability need to be upgraded to include measures of surface knowledge, i.e., knowledge of universal principles; deep knowledge, or knowledge based on experience and interaction with tools; and meta-knowledge, i.e the ability of individuals or teams to know something about themselves, about what they know, and how to use the knowledge in novel situations.

In support of the cognitive skills, intelligent decision support system was advocated with the characteristics in Exhibit 1.

3.2. Social Elements

The human dimensions is a part of a larger in socio-cognitive system. The US Army Functional Concept for Battle Command 2015-2024 (DoD, 2007) and Joint Vision 2020 (GOV, 2000) note that, among several other factors, there is a growing concern regarding the fact that today's technology-enabled battlefield environments must view human-system representation and modeling as a network of system of systems: human-human, human-system, system-systems, and their various combinations in a lattice of socio-cognitive dimensions. The future war fighter is faced with changing battlefield environments that are asymmetric and whose doctrines are centered in understanding the socio-cultural aspects of the enemies. The doctrinal elements anchored on PMESII (political, military, economic, social, infrastructure, and information) elements must be reconciled against courses of actions mitigated by the DIME (diplomatic, information, military, and economics) strategies. In terms of social dimension, Exhibit 2 shows a subset of important discussions:

3.3. Ecological Factors

The second panel dealt with coping with situational complexity of the battlefield, and was a synergistic continuation of the requirements for cognition and visualization. LTG (retired) Richard Keller led the discussion with case studies reminiscent of actual BCS operations. It was observed that the military environment is more than a battlefield; it's a network of interrelated political, military, economic, social, informational, and infrastructure systems that are beyond a military-only ability to visualize. Issues in ecological niches were enumerated. These include terrain, weather, geo-spatial features of the enemy landscapes, and so on. The constructs were anchored on Kurt Lewin's theory that noted that a group of individuals co-locate in a "field" or "social space" and are influenced by the niches within that space. This field, noted Lewin is not external or independent of the group but, in fact, represented the group's perception of its environment –a concept that is related to the present day military notion of shared situation awareness.

- Decision support tools should be developed with a diverse use of human expertise—people see the same problem with different lenses and construct different hypotheses to contextualize the problem; the experienced commander develops a repertoire of constructs, algorithms, and principles to explain every situation that may arise.
- The tools should be able to reason in contextual and situational problems with different scales, risks, and uncertainties.
- The tools should have decision-centric interfaces to capture individual decision making styles; recognize Personal Construct Theory (PCT) since the world is perceived by a person in terms of whatever meaning that person applies to a situation. Variations occur at different levels of information abstraction (sensemaking) and situation understanding.
    - Adaptive, content-sharable, and consistent human-machine interface (HMI).
    - Ubiquitous support for knowledge management.
    - Human essential information network capability: information exchange capability through video, voice, graphics, texts, signs and gestures, and so on.
    - HMI functionalities tailored to optimally use different human modalities of information and communication processing.
    - Provides pervasive document processing capability, including, text mining and interpretation, processing of dynamic video streams for digitally shared tactical pictures, mix mode interchange of information modalities; e.g., converting video streaming into texts, textual messaging into graphic forms or sound.
    - HMI with access to authenticated users, context free query, and support for biometric information of authorized users.
- Create tools that can help the commanders to know what they did not know before, and avoid creating tools which are only duplications of the commander's mental models. Such tools should be able to reason spatially, temporally, retrospectively, prospectively, and with ability to anticipate the adversary intents and courses of actions.
    - Create ad hoc cognitive tools that are reconfigurable, adaptable, and ready for plug and play into situation foxholes.
    - Create cognitive tools that can explore frontiers of artificial ignorance; i.e., explore decision making space and regime to identify contextual information that the commander does not currently know and their impacts on command decision making.

Exhibit 1: Some example decision support system characteristics for enhanced decision cognition

Within the battlefield, commanders often attempt to impose their view of reality on the troops so as to influence the conduct of war and shape or mold their operational environment in accordance with their commander's intent and mission. Key decisions reflect certain understandings or assumptions regarding the battlefield. These actions—under certain conditions—cause the operational environment to respond in ways that conform to the commanders understanding of the situation. In short, through such enactment of the environment, commanders become part of the evolving ecology within which they operate. Several human dimension issues were noted as shown in Exhibit 3.

3.4. Leadership Skills

Future C2 structures are expected to place significant challenges on the commanders and the battle staffs. Additionally, leaders in this environment will be forced to cope with leading ad hoc rotating complex multi-team systems with unmanned aerial vehicles and robot platoons. Situations such as this outstrip the current theories of leadership training. The commander will also face the challenges of dealing with non-military tasks such as serving as a peace maker, a governor of a state, a police, a humanitarian care giver, an emergency relief worker, and so on.

- Human dimensions in Joint Battle Command systems remain problematic. Achieving human network interoperability requires the understanding of socio-cultural cognition, the important being the cultural human terrain of the enemy.
- The operational impacts of socio-cultural and human terrain networks, node-to-node commander's intent with mixed and joint command structures will continue to be a limiting factor in successful operations.
- More typically, battle staffs and commanders working jointly and collaboratively—each holding a unique perspective on the problem space—must collaborate to form a shared understanding of the operational work domain. Issues on cultural sensemaking, team/group situation awareness, language understanding, and many socio-cultural issues must be addressed with new and existing ethnographic techniques for data mining.
- Social and cultural barriers must be recognized and reconciled through real-time interactive training. Social barriers include the lack of interpersonal familiarity and trust. Cultural barriers include differing views of authority and responsibility. Organizational barriers include parochial attitudes and the unwillingness to share information across organizational boundaries. Each of these obstacles can significantly degrade the ability to achieve missions. Analytical consideration of these obstacles is an important element in the future training doctrines.
- Actors in Joint- and /or Coalition- Task Forces must be considered as members of a collaborative work community. Issues that deal with collaboration, cooperation, trust, negotiation skills will have to be trained to the force communities' members.
- The enemy's socio-cultural footprints will need to be tracked and modeled analytically from genotype and phenotype perspectives so as to predict the enemy's influence, power, intent, and prospective strategies in the battlespace.

Exhbit 2: Some example socio-cultural factors in human dimensions

• The ability – know-how and know-where – to find relevant and up-to-date information, as well as the skills required to contribute meaningfully to the knowledge production process. This includes the mastery of networking skills and skills required to be part of and contribute meaningfully to communities of practice and communities of learning. This implies that the basic communication, negotiation and social skills should be in place.
• The ability to identify, analyze, synthesize, and evaluate connections and patterns of information in dynamic environment.
• The ability to contextualize and integrate information across different forms of different command nodes with different human terrain information.
• The ability to reconfigure, re-present and communicate information.
• The ability to manage information (identify, analyze, organize, classify, assess, evaluate, etc.).
• The ability to distinguish between meaningful and irrelevant information for the specific task at hand or problem to be solved.
• The ability to distinguish between valid alternate views and fundamentally flawed information.

Exhbit 3: Some examples of ecological issues that affect human dimension

The commander must be an intelligent agent to be responsive to changes; adapt to those changes; learn from situation outcomes; and lead prudently by example. This CALL (Change, Adapt, Learn, and Lead) model defines the levels of the future leadership requirements that will meet the needs of the human dimension of C2 when in contact with the changing and often unknown and chaotic battle environments. Some leadership challenges were noted as shown in Exhibit 4.

- The leader’s role in creating conditions for team effectiveness and managing multi-national coalition teams.
- Developing methods, strategies and tools to facilitate the creation of leadership expertise earlier in the career pipeline.
- Commanders must be able to plan and execute on-the-go to cope with evolving novel enemy strategies.
- Needs to be educated on leading adaptive organizations that are relatively “unstructured” and authorities are distributed.

Exhibit 4: Some leadership challenges in future battle command systems

3.5. Training Factors

Human dimension training is anchored mostly on the cognitive and socio-cultural factors. Also, the commander is viewed as an “intuitive statistician” who must process disparate, multivariate, dynamic information as the battle condition evolves. The commander’s dimension also has a side for dealing and coping with psychological innuendos such as battlefield fatigue, fear, motivation, morale, cultural diversity and so on. In view of all these evolving battle system characteristics, the commanders are required (and must be trained) to demonstrate their cognitive expertise and to make decisions in complex and/or chaotic scenarios without having to go through tedious analytic reasoning process. In general, however, this requirement has been a norm rather than an exception. This is the reason the current military doctrines and standard operation procedures emphasize the training of cognitive skills as observed by Halpin (1996).

The commanders and battle staffs need to be trained for particular types of knowledge structures in order for them to operate in environments that require agile decision making without either too much data or lack of enough information when challenged with uncertain battle tasks. Much of this knowledge is conceptual in nature, as opposed to operational or procedural. The presence of conceptual elements in the knowledge structures is the key to having a "deeper understanding" of the problem space. Examples include introspective insights into situation understanding and use of self-referencing awareness or tacit knowledge (Polanyi, 1966) when situation awareness devices are degraded to failed modes. Several training issues were noted as shown in Exhibit 5.

4. Conclusions

As noted in Army’s TRADOC Pamphlet (DoD, 2007)), “Battle command is clearly a human endeavor.” These endeavors are mitigated by advances and changes in technology, changing nature of war, and concepts in which wars are fought. The human dimension is therefore a holistic concept that represents the soldier as a system within the BCS system architecture. This paper has presented a subset of those human dimensions that need to be strengthened and used as performance shaping factors in assessing BCS effectiveness.

As the soldiers must cope with adaptive asymmetric battlefields, the human dimensions span across many aspects of human knowledge, skill, and ability that must be trained to deal with organizations that learn through technology. Higher order cognitive ability, extraordinary socio-cultural traits, ambidextrous leadership ability, and the ability to transition from only technology-enabled situation awareness to the ability to visualize the battlefield dynamics are some of the human dimensions characteristics that will be required in the future BCS. All these values have one common trait—they must be trained and metrics of their contributions to battle effectiveness developed. The workshop recommendations do not advocate any standard or must follow “issues.” It was noted that the human dimensions will have to transcend the constructivist and physique concepts to mentalist and cognitivist.

- Training and education of the future commanders need to be centered on technology pedagogy while emphasizing professional self- and group- developments and experiential training.
- The training and education courses should be packaged to be rapidly adaptable and portable similar to intelligent ad-hoc network systems.
- The commanders and the battle staffs must have access to education and training opportunities anywhere, any time by using technology platforms that can integrate and use COT (Commercial Of the Shell Technology).
- Encourage and train for ambidextrous leadership: ability of the commander to envision multiple opportunities and prioritize the ones relevant to problem contexts.
- Future commanders must possess a "joint and expeditionary" mindset.
- The commanders must be trained to acquire proficiency in the use of a wide range of new technologies, particularly within the information arena.
- Commanders should be trained for critical thinking skills and tested for cognitive readiness performance with metrics that can be used to measure abilities to perform higher order cognitive tasks while reasoning from the first principles and making inferences to predict higher order battle effects.
- Commanders must be cognizant of battlefield changing viewpoints and evolving adversary strategies by thinking like the enemy.
- Commanders and the field soldiers should be trained to adapt to technology degradation and make independent decisions with less time and risk.
- Training systems should emphasize meta-cognition using knowledge-based models—mental models, cognitive maps, heuristics generated from experiential knowledge, etc.
- Training systems must be tailored to recognize creativity while decoupling individual and group ingenuities from organizational constraints.
- Thinking outside of the box, such as imagining the impossible scenarios, events, and their consequences should be emphasized.
- Training systems should be pedagogic, tailored to all command levels, with goals that address different levels of task complexities.

Exhibit 5: Some examples of human dimension trainability factors

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