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Manpower and Personnel Integration (MANPRINT) and Network Integration Evaluation 13.2: Observations on Cognitive Load in Mission Command

by John K. Hawley

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14. ABSTRACT
Cognitive load refers to the aggregate mental load placed on multi-echelon commanders and staff members by an increasingly complex command post (CP) work setting. The primary Manpower and Personnel Integration (MANPRINT) objective during Network Integration Evaluation (NIE) 13.2 was to determine whether CP personnel perceive cognitive load to be a problem. NIE results indicated that cognitive load is an issue at some levels of command and for some staff members. The command echelon that appeared to be most impacted by excessive cognitive load is the company level. CP equipment suites provide considerable information that must be processed, assimilated, and acted upon by command and staff personnel. The term most often used by CP personnel to describe cognitive load is "information overload." At the battalion level, the staff member that appeared to be most impacted by excessive information processing requirements and resulting cognitive load is the battle captain. The battle captain is the integrating and coordinating agent for information flowing into and out of the battalion CP. The primary drivers of excessive cognitive load are (1) component ergonomic deficiencies, (2) poor integration of the individual items forming the CP, and (3) inadequate training on individual systems and CP equipment suites.

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1. Background

Network Integration Evaluation (NIE) 13.2 was conducted from 29 April to 23 May 2013 on the ranges at Ft. Bliss, TX, and White Sands Missile Range (WSMR), NM. The NIEs are a series of semiannual exercises (identified by fiscal year) intended to integrate and mature the Army's tactical network in an operational context. During an NIE, the Army also (1) conducts integrated and parallel operational tests of selected Army programs of record, (2) evaluates developmental and emerging network capabilities in an operational environment, and (3) assesses non-networked capabilities in an integrated operational environment.

The Human Research and Engineering Directorate (HRED) of the U.S. Army Research Laboratory (ARL) participated in NIE 13.2 in three capacities. First, HRED personnel provided Manpower and Personnel Integration (MANPRINT) support to the Army test community during formal operational tests of individual equipment items. Second, HRED personnel supported the evaluation of system of systems used within the exercise. A system of systems is collection of task-oriented systems that are integrated to create a new, more complex system that offers more functionality and performance than the simple sum of the component systems. And third, HRED personnel from the Ft. Bliss Field Element provided support for the evaluation of individual equipment items and systems of systems used within a broader unit context. The focus of much of the discussion to follow is this third level of MANPRINT support.

MANPRINT is the Army's formal initiative for Human-System(s) Integration (HSI). Historically, MANPRINT has been applied at the individual system level for programs of record. MANPRINT applied at the system of systems and organizational levels is a relatively new undertaking. A large-scale exercise like the NIEs permits such macro-level MANPRINT work to be performed. The unit of MANPRINT interest at the system of systems level is an integrated equipment suite used to support a specific warfighting function, an example being mission command. At the organizational level, the unit of MANPRINT analysis is the impact a set of individual components and systems of systems used within the broader unit and mission context. In NIE terminology, these equipment sets are referred to as Capability Sets. A primary interest at this third level of MANPRINT assessment is the aggregate organizational, personnel, and training impact associated with the introduction of new Capability Sets.

HRED's first look at the third level of MANPRINT support referenced above was during NIE 13.1. After observing field operations and reviewing database entries during that exercise, HRED staff members concluded that the cognitive load associated with mission command was emerging as a MANPRINT concern. (Note: Entries in the NIE databases are provided by military experts on individual systems, systems of systems, or concepts and are not directly related to cognitive load. However, they often indirectly refer to cognitive-load-related issues.) Follow-on conversations with personnel from other organizations supporting the NIEs confirmed this observation. Consequently, the primary focus of HRED's MANPRINT support at the organizational level during NIE 13.2 was cognitive load issues associated with mission command. In present usage, cognitive load is defined as the aggregate mental load placed on commanders, key staff members, or other personnel by an increasingly complex mission command work setting. As a construct, cognitive load is discussed in greater detail later in the report.

The MANPRINT support team's primary objective during NIE 13.2 was to characterize the nature of cognitive load within the contemporary mission command environment by addressing the following questions:

1. Do commanders, key staff members, or other mission command operators perceive cognitive load to be a problem?

2. What is the underlying nature of the problem? What aspects of contemporary mission command appear to be driving cognitive load?

3. Going forward, what are some potential solutions to the problem of growing cognitive load on commanders and key staff members?

These three questions frame the results-oriented discussion of cognitive load as a factor in contemporary mission command. Data relevant to these questions were obtained from (1) field observations during NIE operations, (2) interviews with commanders and key staff members, and (3) a review of NIE database entries. Units visited by team members during NIE 13.2 included 4-27 Field Artillery (FA) (the battalion tactical operations center [TOC] and one battery command post [CP]) and 1–6 Infantry (IN) (the battalion TOC and three company-level CPs).

During these unit observation and interview sessions, HRED personnel were accompanied by a military escort officer (a major or a lieutenant colonel) provided by one of the primary NIE support organizations. The escort officers were experienced military operations research analysts and were familiar with unit operations and NIE 13.2 equipment and objectives. They assisted HRED's MANPRINT personnel in (1) gaining entrée to unit CPs, (2) making essential introductions to unit command and staff personnel, (3) understanding what was transpiring as the unit's operations were observed, and (4) focusing follow-on interviews on key aspects of cognitive load in mission command. HRED personnel also used the escort officers after the fact to assist in making sense of and clarifying observations and conclusions. The extensive literature base on human factors applied to military system design and field operations along with work on military adaptation and innovation provided a conceptual backdrop for MANPRINT data obtained during NIE 13.2 and subsequent discussion points.

The next section provides relevant definitions and some brief conceptual background material on the topics of complexity, cognitive complexity, and cognitive load as they impact mission command. The key element of this conceptual background material is a Four-Quadrant work model that serves as an umbrella scheme for understanding how Army personnel engage in complex cognitive work while at the same time making sense of and adapting to the technologies that are used to support the cognitive work associated with achieving mission goals. That material is followed by a results section presenting the team's MANPRINT-related observations and conclusions. The final section of the report (1) integrates the conceptual background material with observed results, (2) discusses the implications of the team's MANPRINT results and conclusions, and (3) points the way to future work on cognitive load in mission command and related topics.

2. Complexity and Cognitive Load

2.1 Complexity Defined

When considering human performance topics in a work setting like mission command, it is not possible to avoid the issue of system and tactical complexity and the impact of that complexity on users. That said, a necessary first step is to define the term complexity, or the state of being complex. The dictionary definition of complex (Merriam-Webster, 2009) refers to a system having many interconnected or related parts, or a system that has a complicated structure—not simple or straightforward. A second theme that emerges in an attempt to define complexity is the degree or orderliness or predictability of a system or process (Dekker, 2005). An unpredictable or unreliable system or process, by definition, presents a high degree of complexity for users. Unpredictability is moderated by the amount of time available to exercise the mission command function. It should be noted that mission command physical systems and operational procedures provide a mechanism for controlling and directing the activities of subordinate military organizations. Mission command is technology-supported cognitive work. Hence, the terms "system" and "controlled process" as used here are directly applicable to the later discussion of cognitive load within the context of mission command.

A definition that appears to encompass both of the above themes is given in Hollnagel and Woods (2005). Following these authors, system or process complexity is a function of (1) the number of parameters needed to define the system or process in space and time, and (2) the amount of information needed to *adequately* comprehend the system or process and its operating environment. Note the use of the word *adequately* in the previous sentence. Some observers of complex systems question whether *complete comprehension* of a complex system and operating environment is ever possible. The impact of complexity on information consumers revolves around the second portion of Hollnagel and Wood's definition. That is, the amount of information needed to adequately comprehend the system and operating environment at any point in space and time. The requirement to adequately comprehend both the system and its operating environment is the key to exercising effective control and has significant implications for both system design and user job preparation.

3. Mission Command as a Macrocognitive Work System

A second background idea to be introduced is that of mission command as a macrocognitive work system. Macrocognitive work systems are systems in which people use advanced technology to collaborate for the purposes of conducting work (Patterson and Hoffman, 2012). The most important functions that the system as a whole (humans plus their supporting physical systems) must accomplish are: (1) sensemaking, (2) detecting problems, (3) adapting, (4) re-planning, (5) coordinating, and (6) deciding (Hoffman and Best, 2012). Sensemaking is defined as a motivated and continuous effort to understand connections (among people, places, and events) in order to anticipate their trajectory and act effectively (Klein et al., 2006). Supporting processes are: (1) maintaining common ground (a common operating picture [COP]), (2) developing actionable mental models, (3) managing risk, and (4) managing uncertainty. The primary functions cited above are the goals of the work; supporting processes are the ways in which human cognition is applied to achieve primary goals. In present usage, a mental model is a memory representation, with salient memory-imagery components, depicting relevant states of affairs, but linked to or expressed in terms of the target domain's concepts, principles, and knowledge (Klein et al., 2006). The term target domain refers to the work domain the system was constructed to support—mission command in the present discussion.

4. Cognitive Complexity

One salient feature of macrocognitive work systems is that they frequently are described as cognitively complex. This statement is generally considered to be descriptive of contemporary mission command. For example, in an historical review of the impact of advancing technology on military operations, Murray and Knox (2001, pp. 176–177) concluded that "Technology did not simplify war, as contemporary superstition now claims: *it made it exponentially more complex* [authors' italics]. Each new scientific development, each new weapons system, demanded fresh thought and ever-greater tactical, technical, and logistic expertise." More recently, in a review of the impact of enabling technologies on individual Soldiers and small unit leaders, Thanh et al. (2010, p. 10) cautioned that ". . . technology has improved small unit performance but rarely has it reduced workload, and more often technology has increased the number of tasks a Soldier/Leader must perform. This tendency has created a much larger burden on small units with potential negative consequences in core basic skills at the small unit leader level." These authors went on to state that "Increased capability generally comes with additional tasks for leaders and competes for time to sustain primary core warfighting tasks."

Thanh et al. (2010) conclusions were based on a review of what they termed the "cognitive literature," along with results from a number of experiments and exercises conducted at the Maneuver Battle Lab at Ft. Benning, GA. The thread running through all of these remarks is that technology has made contemporary mission command and warfighting in general more cognitively complex, and complexity is the driver behind cognitive load.

There are no generally accepted definitions of the term cognitive complexity. Nonetheless, a high level of cognitive complexity seems to imply that a task or job is difficult to perform well for cognitive reasons—not a matter of speed, strength, or coordination. Another way of phrasing this definition is that the macrocognitive work systems used to support mission command when coupled with the operating environment meet the definition of "complex" given previously: A lot of "moving parts" to keep track of along with a large amount of information needed to adequately comprehend the system and operating environment at any point in space and time. High levels of ambiguity or uncertainty in one or more of these components tend to elevate the perceived level of cognitive complexity.

Use of the term cognitive complexity in the present context (i.e., to describe a work environment) is not the same as the use of that term as a personality dimension. When used as a personality dimension, cognitive complexity refers to the extent to which an individual differentiates and integrates an event (Streufert and Swezey, 1986). Persons who are high in cognitive complexity are able to analyze (i.e., differentiate) a situation into many constituent elements, and then explore connections and potential relationships among the elements. Such people are often described as multidimensional in their thinking. Cognitive complexity theory assumes that the more an event can be differentiated and the parts considered in novel relationships, the more refined the response and successful the solution. While less cognitively complex people can be taught a complex set of detailed distinctions for a specific context, high-complexity people are very flexible in creating new distinctions in new situations.

Cognitive complexity (as the term is used to describe a work setting) is related to but somewhat different from the more familiar construct of cognitive workload. Cognitive workload is a well-researched construct and is considered measurable using scales like NASA's Task Load Index (TLX) (Hart and Staveland, 1988). At present, there are no comparable measurement scales for cognitive complexity. High-cognitive complexity may, however, lead to high-judged levels of cognitive workload on the part of users. Also note that even in the case of cognitive workload, the obtained data reflect *subjective* judgments of task or role demand.

A notion that appears to be useful in differentiating cognitive complexity from cognitive workload is outlined in Hoffman and Best (2012). These authors use the term macrocognitive work to denote the high-level objectives associated with a macrocognitive work system. Examples of these macrocognitive processes include re-planning, decision making, problem detection, and collaboration (the primary activities listed previously). Macrocognitive functions are supported by more elemental, task-level activities referred to as microcognitive work. In some sense, the term cognitive complexity is associated with the primary activities accomplished using the macrocognitive work system—"broader picture" functions. Cognitive workload, on the other hand, tends to be associated with the task-level activities that support macrocognitive work. Cognitive workload is more elemental and task-specific in nature.

Viewed this way, cognitive complexity and cognitive workload are not independent constructs. Rather they might best be thought of as representing the end points on the continuum of activities defining cognitive work. Cognitive complexity represents the more holistic end of this continuum, while traditional cognitive workload represents more elemental actions defining the opposite end.

Cognitive complexity is an emergent property of the environment or job, coupled with the associated technology suite, but also depends on the characteristics of the individuals or teams performing that job. What might be reported as complex for one individual or team would not necessarily be judged complex for another individual or team having different characteristics. For example, it is reasonable to assume that high levels of fluid intelligence, some aspects of crystallized intelligence (domain-referenced knowledge), job-related experience, and possibly some personality factors such as flexibility, speed of closure, or cognitive complexity (viewed as a personality characteristic) might be correlated with a job's perceived cognitive complexity (Carroll, 1992; Hoffman et al., 2013). The latter authors assert that the key to dealing with cognitive complexity and resulting cognitive load is cognitive flexibility. They define cognitive flexibility as an ability to adjust thinking and attention in response to changing goals or environmental conditions. Some aspects of cognitive flexibility likely reflect innate (and perhaps somewhat immutable) personal characteristics, while others are amenable to improvement through training and job-relevant experience. As implied in Carroll's (1992) massive historical and integrative work *Human Cognitive Abilities*, issues related to individual differences in cognitive abilities and the relationship of these abilities to job performance are complex and often interactive.

A number of characteristics of the macrocognitive work systems used to support a given activity also can be expected to impact perceived cognitive complexity. Examples of these moderating factors are: (1) component design, (2) integration of components to form the work system, and (3) component and system reliability. To the extent that the components defining the macrocognitive work system are not well designed or integrated or are unreliable, perceived cognitive complexity is likely to be higher than in a more "optimal" situation. Operator familiarity with the individual components of the work system along with how those components as a set are used to accomplish overall objectives also can be expected to impact perceived cognitive complexity. An unfamiliar work system is likely to be judged more complex than one with a more familiar set of components. It is also reasonable to assume that perceived complexity might lessen over time as users become more familiar with the equipment comprising the macrocognitive work system, irrespective of design-related issues. Even a poorly designed system can be "handled" give enough experience with it. However, design shortfalls might still prove problematic in critical, time-sensitive situations.

5. Cognitive Load

As noted previously, cognitive load refers to the aggregate mental load placed on commanders and staff members by an increasingly complex mission command work setting. Recall also that cognitive load is related but not identical to the more familiar concept of cognitive workload. Commanders and key staff members likely do not experience excessive cognitive workload in the same sense that a console operator might. That is, commanders and key staff typically are not overwhelmed by the sheer number of discrete physical or cognitive actions required to perform their duties—as might be the case with a console operator. That is not to say that mission command using multiple and often complex equipment items is not a cognitively challenging requirement for commanders and key staff members. Engaging in the sensemaking and mental model development activities required to establish and maintain appropriate situation awareness is a cognitively challenging task, although not demanding in the same sense as with a console operator. The distinction cited previously to differentiate these classes of performances is macrocognitive versus microcognitive work. In keeping with this distinction, the primary focus of the discussion to follow is macrocognitive work.

In order to better understand the human performance dynamics underlying and contributing to cognitive load and ensuing mission command performance, consider the model of macrocognitive work presented in figure 1. Elements of this model are adapted from Hoffman and Best (2012). Hoffman and Best's model of macrocognitive work is comprised of four quadrants or related sets of processes. The upper left quadrant labeled Sensemaking in the World is the key performance requirement underlying effective mission command. This activity involves observing the world and making actionable inferences about it (refer to the previous definition of sensemaking as a cognitive activity). The intent of Sensemaking in the World is to determine how best to act upon that world to achieve one's objectives. Hoffman and Best refer to the "act upon" process as Flexecution with the World (Quadrant 3). Flexecution is short for "flexible execution." Satisfactorily acting on the world cannot always be achieved following a rigid, unthinking set of procedures—rote drills. Critical thinking and problems solving skills, applied within the context of a suitable mental model, sometimes are necessary to act flexibly as opposed to acting rigidly to achieve one's objectives. Flexible execution depends on these skills and often requires considerable relevant experience. A comment from the NIE 13.2 database emphasizes this point: "Soldiers mentioned that during the previous night's raid, dismounted troops were having issues with maintaining reliable communications. It seems this is not an unusual situation for the troops though, and they talked about having to stay flexible and use the systems as best they can and any way they can to pass information to higher."

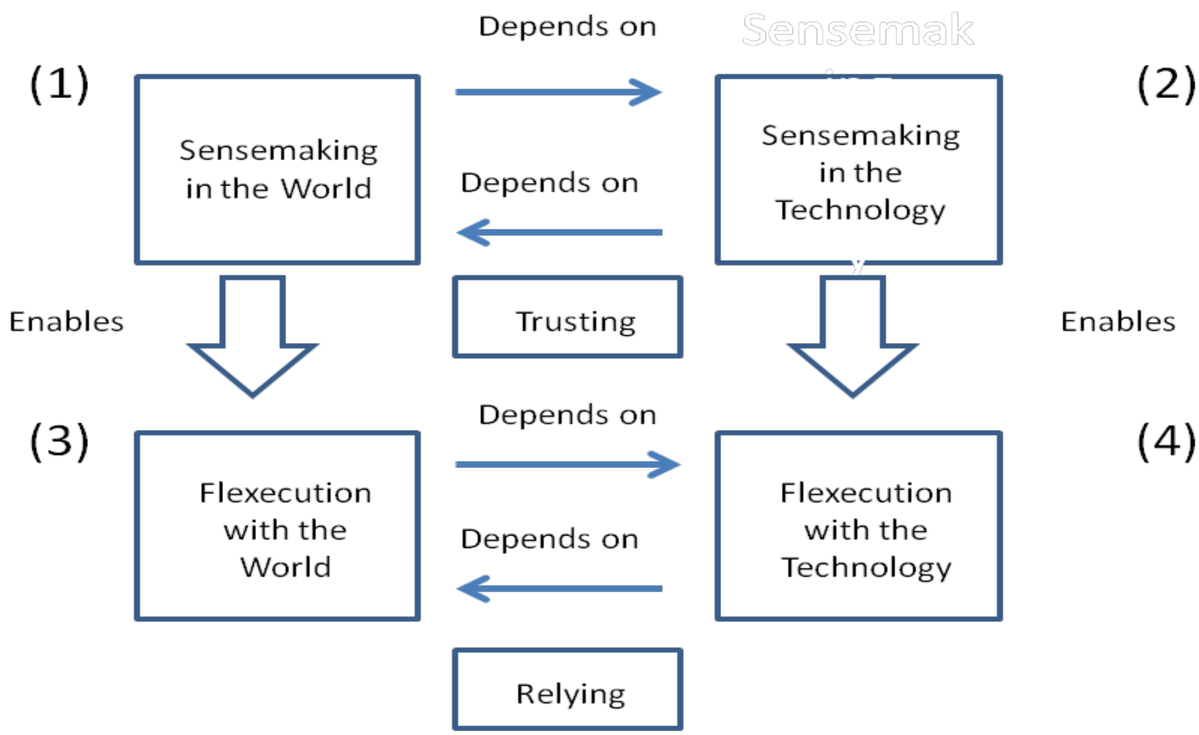

Figure 1. A Conceptual model of macrocognitive work (adapted from Hoffman and Best [2012]).[*]

Sensemaking in the World (Quadrant 1) is mediated, in whole or in part, by the available technology suite: sensors, computational systems, displays, etc. Recall the previous remark that mission command is technology-mediated work. Commanders and key staff are thus required to understand and make sense of the technology available to them to aid job performance. Hoffman and Best refer to this activity as Sensemaking in the Technology (Quadrant 2). Trust in supporting technology is a product of the interplay of Sensemaking in the World and Sensemaking with (or in) the Technology. If the technology used to support Sensemaking in the World is "clunky" and unreliable or if users simply are unfamiliar with it, trust in technology will suffer. In a worst case situation, commanders will simply refuse to use technology they do not understand or trust and fall back on more proven methods. This is particularly true in a life-and-death situation like military operations. Falling back on more proven methods is frequently observed and documented during the NIEs. Another comment from the NIE 13.2 database supports this view: "Network position reporting is not accurate to support local situation awareness (SA) requirements in kinetic missions such as attacks and raids. There was a noticeable lag in reporting other's individual position location information (PLI). This lag resulted in lack of trust in the network and a preference for using JCR [Joint Capability Release] from the point of view of the FSO [Fire Support Officer]."

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[*] Adaptation of the figure is used with the approval of Mr. R. R. Hoffman.

Flexible execution of one’s actions in the observed/controlled world (Quadrant 3) depends on the user’s ability to flexecute with the technology (Quadrant 4). Reliance on (or willingness to use) that technology suite results from successful interplay between flexecuting the work in the world and the user’s ability to flexibly execute with that technology. Command and staff personnel must be able to realize their intentions using the technology suite available to them. The ability to execute flexibly with the available technology suite is a function of a user’s familiarity with that technology used in a representative mission setting. Also note that the ability to flexibly execute with the technology represents a performance “step beyond” simply being trained on how to operate elements of that technology suite. Routine New Equipment Training (NET) emphasizing equipment operation versus use in the target job environment is not sufficient to enable flexible execution with the technology. This performance capability also requires time and role-relevant experience with feedback to develop.

When performing macrocognitive work as in mission command, users have to devote time and effort to making sense of their technology as well as making sense of the observed or controlled world. They have to learn how to use that technology; they have to understand what the technology does and does not do. Users then have to learn to flexibly execute using that technology suite. They often have to cope with its shortcomings and awkwardness and create workarounds. If a user has to abruptly shift attention from the quadrant of Sensemaking in the World and focus instead on trying to make sense of the supporting technology suite, user attention and effort are shifted away from primary mission goals. NIE 13.2 observations, interview data, and database entries frequently refer to such distractions resulting from unreliable equipment or being unfamiliar with its use. Macrocognitive work will suffer due to distraction and increased cognitive load (Koopman and Hoffman, 2003). Difficulties or disruptions within or across any of the four quadrants comprising the Hoffman-Best model of macrocognitive work due to (1) inadequate component design, (2) component unreliability (3) poor integration of components to support mission command as a warfighting function, (4) inadequate training and experience in the mission command role itself, or (5) lack of familiarity with how to use the available technology to accomplish mission goals will increase perceived cognitive load and potentially adversely impact mission command performance.

5.1 NIE 13.2 MANPRINT Results

As noted in the Background section, MANPRINT results from NIE 13.2 are organized around the three questions listed previously concerning cognitive load and its impact on mission command. Each of these questions is now addressed in turn.

Question 1. Do commanders, key staff members, or other mission command equipment operators perceive cognitive load to be a problem?

The short answer to this initial question is, “yes.” Cognitive load is an issue for some levels of command, for some key staff members, and for some other mission command system users. Interview results indicated that cognitive load can be a problem during high operational tempo events or when a unit is surprised and quick action is necessary. The term most often used by NIE participants to describe cognitive load is "information overload." As one company commander put it, "We have too much information to be processed in the time allowed. It's too much for one person to handle. Sometimes, I don't know what I'm missing." The remark that ". . . it's too much for one person to handle" is supported by multiple database entries indicating that company-level commanders preferred command vehicles having more than one mission command workstation. Having more than one workstation permitted them to share the information processing load across several people. An associated comment that occurred frequently was that commanders did not want to be "tied" to their computer screens and keyboards. They frequently observed that being tied to mission command equipment interfered with effective command. Several commanders commented favorably on the idea of using their executive officer (XO) as an intermediary between them and mission-command-related information sources—referred to as the Digital XO concept. In their view, this permitted them to command their unit effectively while still staying abreast of relevant information provide by mission command support systems. In essence, the Digital XO serves as a "cognitive filter" for information flowing to the commander. This informal adaptation in response to perceived information overload has been tried out, but not formally or rigorously evaluated. For example, there is likely to be an increased coordination burden associated with the Digital XO concept.

The level of command that appeared to be most impacted by excessive cognitive load is the company/battery/troop level and below. Mission command equipment suites at these levels provide considerable information that must be processed, assimilated, and acted upon by command and staff personnel. There also are considerable demands for information to be provided to upper command echelons to maintain their situation awareness. These information processing requirements place a significant load on company-level (and below) command personnel. Lower-level command echelons typically do not have formal staff elements like those found at battalion or brigade. Company-level commanders often adapted to excessive information processing demands by forming ad hoc company-level staff elements—when their command vehicles permitted this adaptation—or by relegating the bulk of their information processing requirements to their XO.

At the battalion level, the staff member that appeared to be most impacted by excessive information processing requirements and the resulting cognitive load is the battle captain. The battle captain is the integrating and coordinating agent for information flowing into and out of the battalion TOC. This can be a very demanding role, particularly for an inexperienced officer.

During an interview with an admittedly inexperienced battle captain from 4–27 FA, he remarked that the battle captain has to integrate fires-related information from 13 (his count) different information sources. He went on to state that he was not familiar with the individual strengths and weaknesses of each of these information sources and often had to rely on the individual system operators to provide necessary clarification—if time permitted. This interviewee also noted that he was not fully aware of role expectations for a battle captain in a FA battalion. He indicated that he had received no specific training or practice getting ready for this critical role. The battalion XO and more experienced battle captains provided mentoring and guidance when opportunity and the tactical situation allowed, but that level of intermittent performance support was not judged to be sufficient. There was also some discussion of whether adequate facilities exist on Ft. Bliss to train command and staff personnel and teams to handle the rising demands of contemporary mission command outside of a large-scale exercise like the NIEs. The 4-27 FA battle captain stated that he would like to have attended an orientation course or session that would have better prepared him for the role of battle captain. In technical parlance, this interviewee was saying that he had no effective mental model to guide his activities in this key role. He had to develop a mental model "on the fly" over the course of the event. Note that an appropriately detailed mental model is crucial to the sensemaking activities occurring in Quadrant 1 of figure 1.

HRED's MANPRINT support team noted a similar pattern in the other battalion TOC visited—1-6 IF. The battle captains observed and interviewed there were rather junior (one was a second lieutenant with less than a year in service), inexperienced (another was not an Infantry or Armor officer), and on questioning did not appear to fully understand their role requirements or how to carry them out. Training and on-the-job experience are key factors in managing cognitive load, and the NIEs are a good setting for providing essential training and experience for command and staff personnel. However, one must be cautious making inferences about equipment and concept suitability based on results obtained using incompletely trained and inexperienced personnel. Training, equipment testing, and concept evaluation often present conflicting objectives.

Question 2. What is the underlying nature of the problem? What aspects of contemporary mission command appear to be driving cognitive complexity and load?

The previous paragraphs make a reasonable case for a conclusion that excessive cognitive load is an emerging MANPRINT and human performance issue in contemporary mission command. The second question to be addressed concerns the source of the problem. To begin addressing that question, it is necessary to accept the proposition that mission command is an intrinsically complex activity. Contemporary mission command equipment suites provide a wealth of information to be processed, comprehended (made sense of), and acted upon by command and staff personnel. Moreover, there are a large and growing number of systems supplying this information. To emphasize this point, consider the following statement attributed to the current Chief of Staff of the Army (CSA), General Raymond Odierno:

> "DCGS-A [Distributed Common Ground Station–Army] has fundamentally changed how we do intelligence. When I was a division commander in 2003 in Iraq, I had less intelligence than we now get down to company commanders in Afghanistan."

HRED's MANPRINT team did not observe DCSG-A in use during NIE 13.2, but the relevance of the CSA's remark to the present discussion is direct: There is more information flowing into a battalion TOC and possibly into a company-level CP now than was provided to a division TOC a decade ago. Moreover, battalion- and company-level staff elements have not been restructured to accommodate this flood of information. There is a price associated with all of this information, and that price is complexity. Cognitive load is driven by complexity. As a side note on this remark, DCGS-A was used at the company level during NIE 13.1. The result was that company commanders did not want DCGS-A. In their view, the system required too much bandwidth for the judged value of the information provided. Thus, DCGS-A was not used at the company level during NIE 13.2.

It is useful to think of cognitive load as being composed of *intrinsic* plus *extraneous* loading factors (Sinclair, 2007). As argued above, intrinsic load is a significant factor in contemporary mission command. Some aspects of intrinsic load are irreducible—the command role is simply demanding. However, there are a number of extraneous factors that adversely impact cognitive load above and beyond the intrinsic level. Several of the extraneous (or compounding) factors observed and reported during NIE 13.2 are listed and discussed as follows.

1. Design. Some of the individual systems (boxes and widgets) used to support mission command are not user friendly or sufficiently reliable. There are numerous reports in the NIE database about individual equipment items being error-prone, unreliable, and not user friendly. Moreover, similar remarks regarding the same systems have been recorded across several NIEs. Various test reports for individual equipment items prepared by the U.S. Army Test and Evaluation Command (ATEC) address these issues in detail. Those details will not be reported or discussed here.

2. Integration. Many of the individual systems used to support mission command as a warfighting function are not well integrated to support command as cognitive work. When used in this context, integration refers to both physical integration (connectivity and interoperability) and rational assembly of components to support mission command as human-centered, cognitive work. Mission command is technology-supported cognitive work. Core mission command activities are cognitive in nature. The equipment is there to support human cognitive activities such as sensemaking and decision making. More attention must be paid to the collaborative nature of the mission-command-related work that goes on in TOCs, CPs, and on other platforms. To a great extent, complex cognitive work is teamwork. Integration must facilitate rather than impede this collaboration. Data from NIE 13.2 suggest that integration to support mission command as cognitive teamwork generally has not been addressed adequately.

One Stryker platoon leader summarized this latter aspect of the integration problem succinctly as follows: "System integration into vehicles needs to be studied and determined based on a task and duty decomposition of vehicle occupants. Vehicle integration factors that negatively impact system accessibility and use overshadow and in many cases prevent systems from being used to their full extent."

3. Training, Practice, and Experience. Many of the personnel using mission command systems have not been adequately trained on them individually or as a set (a system of systems), and have not been provided sufficient time to become familiar with the equipment suites used to support mission command. Trust in and reliance on technology are the products of familiarity and positive experiences with that technology (reference the Hoffman-Best model of macrocognitive work illustrated in figure 1). The level of expertise required to effectively use the emerging suite of mission command support technology cannot be developed as part of traditional NET or a short, follow-on orientation program within a receiving unit. Interview results indicated that hands-on experience gained during previous NIEs with equipment items and equipment suites really mattered during NIE 13.2. Also, there are numerous remarks in the NIE 13.2 database concerning "lack of trust" in the equipment provided to NIE participants. There are suggestions that some of this lack of trust derives from lack of equipment familiarity. NIE participants simply have not had time to become comfortable with mission command equipment or equipment suites and conversant with their potential uses.

In a post-exercise focus group, one company commander summarized the training, practice, and experience problem quite succinctly. This company commander noted that the 10th Mountain Division, which has received much of this new equipment, complained that the equipment is "too complex." He noted that 2/1 AD[*] struggles to fight using the new equipment, and they have been working with it for the past two years. So it is reasonable to expect that others with less experience will be even less successful. The company commander also stated that tools that are fielded need to be simple enough for anyone to use them, and Soldiers will not use things that they do not understand. During the same session, the brigade network operations chief acknowledged that while things seem to run smoothly at the brigade level, events are much more hectic at lower echelons where there are many more systems, and fewer personnel to manage them (NIE 13.2 HQ DA Objectives Annex, 2013).

The factors listed above combine and act as extraneous factors to increase the aggregate level of perceived cognitive load for command and staff personnel. The mission command role itself is intrinsically complex and demanding. However, a work setting with a large number of design-related "rough edges" will give the impression of being more complex (and intimidating) than one that has been better designed and integrated for effective use. Training and equipment familiarity also are important considerations in perceived complexity and cognitive load.

Question 3. Going forward, what are some solutions to the problem of growing cognitive load on commanders and key staff members?

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[*] 2nd Brigade Combat Team, 1st Armored Division—the NIE 13.2 participating unit.

HRED's final priority question to be addressed during NIE 13.2 involved potential solutions: What can be done to address the problem of growing cognitive load on commanders and key staff members? The previous paragraphs identify and discuss a number of contributors to extraneous cognitive load in mission command. It should be emphasized that these extraneous loading factors are those most readily remedied and should be considered first before pursuing more involved solutions. Extraneous loading factors are a primary focus of MANPRINT. Potential means of reducing extraneous cognitive load in mission command include the following:

1. Improve and refine the design of individual equipment items used in mission command. Make individual items better matched to mission command functional requirements and more user-friendly. MANPRINT-related Human Factors Engineering (HFE) results from operational tests and the NIEs must be followed-up and not allowed to linger. Design flaws and observed rough edges must be corrected. At a more fundamental level, items used to support mission command should be designed with Norman's (1999) idea of an *information appliance* in mind. Following Norman, an information appliance is a device that is specially designed to perform a specific function in a user-friendly way. Examples of common information appliances include many contemporary tablet computers and smart phones. To do this, it is necessary to start with a consideration of user needs first with technology considerations coming last—the opposite of the way things typically are done in defense acquisition.

2. Reduce the number of systems used in mission command to an essential minimum. Database entries and interviewee remarks are critical of the excessive number of systems used during the NIEs and the information overload and complexity problems that situation creates. As one database entry put it, "There are way too many systems in the POP [Point of Presence]. It currently has the commander ensuring [that] all of the RFIs [Requests for Information] are sent up more than the commander focusing on tracking the fight and commanding the troops." Another remark noted that ". . . the CO [Commanding Officer] gravitated to the speediest and most reliable source of information . . . He prefers those information sources that have been pared down to the information that he needs to know and execute his mission." As a cautionary postscript on the above comments, redundancy in an equipment suite generally helps users by providing more than one option for performing a task. However, too many equipment options coupled with inadequate training, experience, and practice can mask essential options from users and result in comments like the above. The key idea in the above suggestion is *essential*.

3. Improve system integration of individual items that form work systems for mission command. Examples of several of physical integration problems include transference of position location information from the network to Joint Battle Command – Platform (JBC-P) and overlays between JBC-P and Command Post of the Future (CPOF). Poor system integration is particularly troublesome and problematic when integrating new mission command equipment into legacy platforms—as the previous Stryker-related

comment indicated. This is system of systems level MANPRINT work and must be emphasized going forward. Work systems supporting mission command and other warfighting functions must be properly designed for effective use.

4. Improve the training and experience level of command and staff personnel and teams. Explore what can be done using existing mission command training capabilities to better prepare command and staff personnel and teams for the NIEs and for employing Capability Sets in receiving units after fielding. Current NET practices followed by overview and orientation training in receiving units do not appear to be effective in preparing receiving units to adequately use new equipment. Hands-on experience really matters. Echoing this point, Thanh et al. (2010, p. 6) concluded that:

   "The fielding of enabling technologies has a tremendous impact on the organization receiving the equipment that will have second and third order effects. In order to mitigate the second and third order effects, leaders must set the right conditions to provide the adequate training programs to properly allow the Soldiers time to operate these technologies. The small unit leaders' maturity, training and experience are considerations in expectations in regard to applications of technology."

An observation from the Army's successful experience in developing and deploying Stryker Brigade Combat Teams (BCTs) also is relevant to this point (Stryker Brigade Coordination Cell [BCC], 2003):

> "Stryker BCTs are complex organizations. Transformation of the BCT is much more than conducting NET and essentially is a holistic effort required to convert to a new organization, receive new equipment, and ultimately train to a higher level of unit proficiency."

There are many parallels between the development of Stryker BCTs and the deployment of Capability Sets to modernize legacy BCTs. In essence, the modernizing BCT is being "transformed," as that term is used in the above quote. The development of Stryker BCTs is generally considered to be an example of best practices with respect to fielding a new type of unit with new kinds of equipment. There are lessons in the Stryker experience both for preparing a unit for participation in NIEs and for Capability Set deployment to new units. In a case study assessment of the impact of network-enabled operations using the Stryker BCT as an exemplar, Gonzales et al. (2005, p. 35) cautioned that ". . . training is more important than ever in the Stryker brigade and other digitized units because the networking and battle command systems employed are more complex than those used in analog-equipped units. If soldiers and commanders are not adequately trained on the NCW [network-centric warfare] systems and are not proficient in their use in stressful battlefield conditions, then these NCW systems can be a hindrance rather than a help in combat."

6. Discussion

In summary, cognitive load refers to the aggregate mental load placed on commanders, staff members, and other users by an increasingly complex mission command work setting. The primary organizational-level MANPRINT objectives during NIE 13.2 were to determine whether commanders, staff members, or other mission command operators perceive cognitive load to be a problem and to identify and characterize the sources of that load. Based on observations, interviews, and database entries, it was determined that cognitive load is an issue for some levels of command and some staff members, particularly during high-operational tempo events. The level of command that appeared to be most impacted by excessive cognitive load is the company/battery/troop level and below. Mission command equipment suites provide considerable information that must be processed, assimilated, and acted upon by command and staff personnel. There also are considerable demands for information to be provided to upper command echelons. The term most often used by NIE participants to describe cognitive load is "information overload." Company-level command echelons typically do not have formal staff elements like those found at battalion or brigade that can be used to spread the information processing load. At the battalion level, the staff member that appears to be most impacted by excessive information processing requirements and the resulting cognitive load is the battle captain. The battle captain is the integrating and coordinating agent for information flowing into and out of the battalion command post. This can be a very demanding role, particularly for an inexperienced officer. The primary drivers of extraneous cognitive load are: (1) individual equipment items that are unreliable and not user friendly, (2) poor integration of individual equipment items to form the work systems that support mission command, and (3) inadequate training on and experience with individual systems and equipment suites on the part of using personnel. In present context, extraneous load refers to cognitive load above and beyond the intrinsic complexity of the mission command role itself.

Complexity and resulting cognitive load can be managed but cannot and perhaps should not be eliminated without careful consideration of essential and potentially beneficial information needs. Scientific work on complex systems (e.g., Carlson and Doyle, 2002; Hollnagel and Woods, 2005; Hoffman and Woods, 2011; Hawley and Mares, 2012) supports a broad consensus that intrinsic complexity cannot be reduced. To adequately deal with the issue of complexity in these times of great technological change, it is necessary to accept complexity as a persistent and pervasive fact, and deal with it. It is hazardous to attempt to avoid complexity by making reductive assumptions about it and attempting to implement simple, quick-fix solutions. Simplistic solutions merely transform the root problem of complexity, most often by hiding it from users. Quick-fix solutions rarely if ever cope with or eliminate complexity. Apparent simplicity can be misleading. Moreover, we should not be seduced into being too optimistic about our ability to reduce the amount of training and experience required for complex systems—or into complacently believing that old training concepts and practices will prove sufficient. Norman (2011) argues that managing complexity is a partnership. Designers have to do things that help to “tame” equipment complexity. Users have to do their part as well. They have to take the time to learn the structure of the new technology and practice necessary skills.

A related caution concerns generalizing results from an event involving immature equipment used by inadequately trained and inexperienced personnel. It is unreasonable to expect that externally valid results can be obtained from an event in which hurriedly trained and inexperienced participants are thrown together with a complex and immature equipment set backed up by unproven doctrine, concepts, and procedures (Hawley, 2007). Unfortunately, these features are often the case during the NIEs. External validity, in present usage, refers to the certainty with which inferences from an event like the NIEs reflect what might occur during real-world combat operations.

Viewed from a larger perspective (i.e., beyond viewing the NIEs primarily as a vehicle for test and evaluation of individual systems and systems of systems), the NIEs are a potentially rich source of information regarding the mechanics of unit-level innovation and adaptation to the demands imposed by contemporary information-intensive mission command operations. In a comment on the historical evolution of command as a warfighting function, Van Creveld (1985, p. 2) remarks that two questions frame the issue of the impact of new technology on command practices: “What is the effect of new devices on existing practices, and how can the [new] devices be put to best [more effective] use?” Based on the HRED team’s observations during NIE 13.2, the first of these questions has begun to be addressed. However, the latter question has not been pursued in any depth. Best practices for using new mission command equipment suites to enhance old command practices or to use these capabilities in new and innovative ways have not been systematically identified, validated, and disseminated to receiving organizations.

The NIEs also can provide valuable insights into supportability issues critical to the successful fielding of Capability Sets to units beyond the NIEs. In this respect, it should be emphasized that the NIEs provide a level of support (in the form of Field Service Representatives [FSRs] and other auxiliary personnel) to the participating units considerably in excess what would normally be available to other units receiving new equipment. In all likelihood, this extra level of support is necessary to make these new systems and technologies work well enough to permit their use and evaluation during the NIEs. It has been noted, however, that reliance on FSRs and other forms of external support can distort commanders’ understanding of the true capabilities of their tactical units (Demchak, 1991). Recall Thanh et al. (2010) conclusion that fielding enabling technologies has a “tremendous impact” on receiving organizations. The NIE 13.2 database is full of examples illustrating the impact of new equipment on the receiving organization. Recall also the company commander’s post-NIE 13.2 focus group observation that 2/1 AD struggled to fight using the new equipment, and they had been working with it for the past several years. In his view, it is unreasonable to expect that other units with less experience and support would not experience similar or greater difficulties adapting to the new equipment.

In an in-depth study of modernization across the U.S. armed services, Demchak (1991, p. 9) concluded that ". . . dramatic changes in organizational interaction and structure are needed to make operations with highly complex machines successful." The focus of much of Demchak's work was U.S. Army modernization in the 1970s and 1980s. However, it is arguable that this conclusion is still relevant today. In fact, it may be even more relevant given the shift in types of modernizing technologies between the 1980s and the present. Modernization in the 1980s primarily involved electro-mechanical technologies. The use and impact of information technology was considerably less then than now. Today's modernization primarily involves information and networking technologies. Levy and Murnane (2012) argue that the increasing use of information processing technology in the workplace fundamentally changes the nature of work and the skill, knowledge, and experience requirements of the people who perform that work. In essence, information technology dominated work is more cognitive and conceptual in nature. These technology insertions impact the unit's organizational structure, personnel needs, and skill requirements. Unit modernization involves far more than simply giving a unit new equipment and assuming that they somehow will make it work. Demchak's (1991) study suggests that actually this was not the case in the 1970s and 1980s, and it definitely should not be expected to be the case now.

The Hoffman-Best Four-Quadrant model of adaptation to new technology introduced previously suggests that not adequately attending to both design and supportability issues will lead to lack of trust in and reliance on new technologies applied to mission command. Both of these problems have been observed during the NIEs. To end on a positive note, however, consider another comment from the NIE 13.2 database: "If the network is fully functional, Soldiers acknowledge that [network] capabilities speed movement and maneuver." The operative term here is "fully functional." It is also necessary that commanders, staff members, and individual Soldiers know how to use these new technical capabilities to their full potential. That takes time, experience, and a reasonably stable technical performance environment—along with a command climate that fosters tactical innovation and adaptation using that new technology.

With respect to the latter (innovation and adaptation), Demchak (1991), Koopman and Hoffman (2003), Russell (2010), and others observe that with new and often more complex equipment and its associated incremental "knowledge burden" (Demchak's term), organizations like the military quickly sprout a number of spontaneous quick fixes in response to emergent operational problems. Emergent problems are those that occur during initial operational use and cannot be anticipated. Military units have an imperative to survive regardless of the circumstances. Consequently, they tend to innovate around problems locally in ways that are not always formally blessed or documented. An example of this from the NIEs is the so-called Digital XO concept: Using the XO as an intermediary between the commander and mission command information sources in company-level organizations. The Digital XO represents a local adaptation in response to information overload. Demchak asserts that such adaptations tend to grow into informal norms and procedures that become critical to organizational success. These adaptations also can change the true capabilities of the force in both positive and negative ways. Both of these phenomena (emergent problems along with spontaneous innovation and adaptation) are frequently observed and reported during the NIEs. Adaptation and innovation are more difficult to observe during a training exercise or in a more structured test setting. In a test environment, they usually are not allowed to emerge. Test plans require equipment to be used as intended. Spontaneous adaptations and their impact on the organization (individually and collectively) are a worthwhile topic for in-depth study during future NIEs.

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List of Symbols, Abbreviations, and Acronyms

2/1 AD	2nd Brigade Combat Team, 1st Armored Division
ARL	U.S. Army Research Laboratory
ATEC	U.S. Army Test and Evaluation Command
BCC	Brigade Coordination Cell
BCT	Brigade Combat Team
CO	Commanding Officer
COP	common operating picture
CP	command post
CPOF	Command Post of the Future
CSA	Chief of the Army
DCSG-A	Distributed Common-Ground Station–Army
FA	Field Artillery
FSO	Fire Support Officer
FSR	Field Service Representative
HFE	Human Factors Engineering
HRED	Human Research and Engineering Directorate
HSI	Human-System(s) Integration
IN	Infantry
JBC-P	Joint Battle Command – Platform
JCR	Joint Capability Release
MANPRINT	Manpower and Personnel Integration
NCW	network-centric warfare
NET	New Equipment Training
NIE	Network Integration Evaluation

PLI	position location information
POP	Point of Presence
RFIs	Requests for Information
SA	situation awareness
TLX	Task Load Index
TOC	tactical operations center
WSMR	White Sands Missile Range
XO	executive officer

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