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Human-Systems Integration (HSI) and the Network Integration Evaluations (NIEs), Part 2: A Deeper Dive into Mission Command Complexity and Cognitive Load

by John K Hawley

NOTICES

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14. ABSTRACT

This report is the second in a series discussing Human-Systems Integration (HSI) within the context of the Network Integration Evaluations (NIEs). The focus of these reports is the impact of complexity and cognitive load on mission command performance in digital Command Posts (CPs). Cognitive load is defined as the aggregate mental load placed on battle-staff personnel by a complex mission command work setting. NIE results suggest there are 3 primary contributors to excessive cognitive load in NIE CPs: 1) design, 2) integration, and 3) training. These factors combine and act to increase the aggregate level of perceived complexity and cognitive load for CP 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. While some of the cognitive load associated with mission command in NIE CPs is intrinsic to role, high levels of extraneous cognitive load are needless consequences of insufficient attention to HSI in component design and integration coupled with inadequate training for both individual system users and for battle staffs operating as a team.

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1. Introduction

1.1 Background

This report is the second in a series addressing Human-Systems Integration (HSI) support provided by the US Army Research Laboratory's (ARL's) Human Research and Engineering Directorate (HRED) to the Brigade Modernization Command (BMC) for the Network Integration Evaluations (NIEs). (Note: HSI was previously referred to as MANPRINT [Manpower and Personnel Integration]. MANPRINT was the Army's formal program for HSI.) The NIEs are a series of semiannual exercises (identified by fiscal year) intended to integrate and mature the Army's tactical networks 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 first report on this subject (Hawley 2014) addressed HSI support provided to the BMC for NIEs conducted during Fiscal Year (FY) 2013, with an emphasis on NIE 13.2. The primary focus of the following discussion is HSI results from the FY 2014 series of NIEs.

ARL HRED participated in the FY 2014 series of NIEs in 3 capacities. First, HRED personnel provided HSI support to the Army Test and Evaluation Command (ATEC) during formal operational tests of individual equipment items. Second, HRED personnel supported the Director, System of Systems Integration and Engineering (SoSI&E) in the evaluation of selected system-of-systems used within the exercise. In present usage, a system-of-systems is a 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 Fort Bliss, Texas Field Element provided support to the BMC for the evaluation of individual equipment items and system-of-systems used within a broader team and unit context. The emphasis of much of the discussion to follow is this third level of HSI support.

A Command Post (CP) is an example of a system-of-systems as that term is used above. The CP consists of a number of individual component systems, each designed to address a single aspect of the mission command warfighting function. The combination of these components within a single entity (the CP) forms a more complex system-of-systems that if structured properly offers more functionality and capability than the simple sum of the individual components.

Historically within the Army, HSI has been applied at the individual system level for programs of record (e.g., the individual component systems comprising a CP). Application of HSI at the broader system-of-systems, team, and organizational levels is a relatively new undertaking. A large-scale exercise such as the NIEs permits such macrolevel HSI work to be performed. The unit of HSI interest at the system-of-systems level is an integrated, humans-plus-machines suite used to support a specific warfighting function—for example, mission command. At the organizational level, the focus of HSI analyses is the impact of individual components and system-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 HSI assessment is the aggregate organizational, personnel, and training impact associated with the introduction of new Capability Sets (CSs).

1.2 Approach

HRED's first look at the system-of-systems level of HSI support referenced above was during NIE 13.1. After observing field operations and reviewing NIE database entries created during that exercise, HRED staff members concluded that the cognitive load associated with mission command was emerging as an HSI concern. (Note: Entries in NIE databases are provided by military experts on individual systems, system-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 HSI support to the BMC 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 battle staff members, or other personnel by an increasingly complex mission command work setting. As a construct impacting mission command, cognitive load is developed in additional detail in Hawley (2014).

Prior to the start of NIE 14.1, the BMC Commanding General (CG) tasked ARL HRED's HSI support team to conduct what he termed a CP "Ease of Use" assessment. The objective of the CP Ease of Use assessment was to, "Evaluate solutions that simplify and protect the network while enhancing the command post by decreasing its physical complexity and cognitive burden on commanders and staff." The BMC CG further identified 4 subordinate analysis issues to frame this overall objective:

1) Identify cognitive systems engineering issues impacting the horizontal and vertical integration of mission command systems within CPs as configured in NIE 14.1.

2) Assess the impact of Soldier New Equipment Training (NET) on system capability understanding. Also determine the effects of NET implementation within the tactical context as an enabler for commander decision making. Make recommendations for beneficial changes.

3) Assess Soldier NET from a "CP-as-a-System/Platform" perspective and its implementation within the tactical context. Provide recommendations for beneficial changes.

4) Evaluate complexity and cognitive load within CPs as configured in NIE 14.1. Provide specific examples of sources of complexity and cognitive load in current CP operations. Evaluate cognitive "pressure points." Provide recommendations to reduce complexity and cognitive burden.

2. NIE 14.1 Data Collection and Reporting

2.1 Data Collection

Data relevant to these analysis issues were obtained from: 1) field observations in CPs during NIE operations, 2) interviews with commanders and battle staff members, 3) interviews with exercise Observer/Controllers (O/Cs), and 4) a review of NIE database entries. During unit observation and interview sessions, HRED personnel were accompanied by a military escort officer (typically 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 equipment and objectives. They assisted HRED personnel in: 1) gaining access to unit CPs, 2) making essential introductions to unit command and battle staff personnel, 3) understanding what was transpiring as the CP'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, conclusions, and recommendations. The extensive literature base on human factors applied to military system design provided a conceptual backdrop for HSI data obtained during NIE 14.1.

2.2 Reporting and Assessment

Following NIE 14.1, ARL HRED's support team reported back to the BMC CG on the results of the Ease of Use assessment. In present context, Ease of Use assessment refers to a usability-type analysis performed by observing CP personnel in their operational work setting and asking questions about that work while it is being performed. More detailed postexercise focus group sessions provided additional usability results, along with clarification of specific work-related observations.

The team's assessment suggested that 3 HSI-related problem areas were at the root of many of the observed mission command complexity-cognitive load issues in CPs as configured during NIE 14.1. The problem categories are described in the following sections.

2.2.1 CP Component Design

Many of the individual systems (often referred to as "boxes" or "widgets") used to support mission command were neither user friendly or sufficiently reliable. There were 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. Another aspect of the design problem concerns the "stovepiped" nature of the way in which the mission command systems comprising CPs are developed and evaluated. A CP is a system in and of itself (i.e., a system-of-systems). However, the *components* comprising the CP are developed and evaluated mostly in isolation, and often by different proponents and vendors. Their relationship with other CP components is not always considered, nor is their design based on an understanding of complex cognitive work in context. Consequently, the pieces of the CP "puzzle" do not always fit together smoothly to support mission command as an integrated warfighting *system*. The underlying issue here is, *if* the CP had been considered as an integrated system, would this component have been conceived and designed as it was? This is a hypothetical "what if" issue above and beyond the component integration problem discussed next. It should be noted that this stovepiping problem is not unique to mission command systems or to the Army.

2.2.2 CP Integration

Many of the individual systems within CPs were not well integrated to support mission command as cognitive work. When used within the context of a discussion of mission command complexity and cognitive load, 3 aspects of integration must be considered:

1) **Physical Integration.** Physical-technical integration refers to the network of sensor and communications capabilities that link users through various interfaces and enable them to acquire and share information. This aspect of integration primarily refers to mission command component connectivity and interoperability.

2) **Operational Integration.** Operational integration refers to integrating technical functions with the human cognitive processes they are intended to support and making that cognitive work more reliable. Practically, operational integration involves the incorporation of mission command materiel solutions into battle-staff processes and procedures to increase their effectiveness and efficiency in execution. Achieving effective operational integration requires attention to issues such as, 1) the design of human interfaces, 2) communication systems and practices, 3) battle-staff training, 4) battle-staff teamwork, and 5) CP organization and management procedures. Effective operational integration supports users in making sense of information transmitted via technical connections, intuitively understanding the implications of that information, and responding appropriately.

3) **Perceptual-Cognitive Integration.** Well-designed CPs must support decision-makers at all levels with the insight and foresight required to make effective decisions, to manage associated risks, and to consider second and subsequent order effects. This involves the cognitive ability "at a glance" to see and understand a tactical situation and thereby enable independent decision and correct action. These capabilities, often labeled perceptual-cognitive integration, are the product of both adequate technical integration and effective operational integration of mission command components into the Military Decision Making Process (MDMP) and CP practices (Mission Command White Paper 2012). Perceptual-cognitive integration is not a process per se. Rather, adequate physical integration coupled with suitable operational integration create the conditions for perceptual-cognitive integration.

Mission command is technology-supported cognitive work. Core mission command activities are cognitive in nature. That is, the equipment is there to support human cognitive activities such as sensemaking, mental projection to the future, and decision making. Results from NIE 14.1 (and previous NIEs) suggested that physical and operational integration to support mission command as cognitive teamwork generally had not been addressed adequately. Various items of equipment do not interoperate smoothly, and operational integration of new equipment items into mission command procedures has not been suitably addressed. The result is an inadequate level of perceptual-cognitive integration. Commanders find it difficult to use mission command equipment suites to form a composite "picture" of the battlespace. Previous research indicates that attempting to integrate and use disparate, often incompatible components in a CP has been a problem at least since the introduction of digital technology (Howse and Cross 1999).

2.2.3 Training, Practice, and Experience

Many of the personnel using mission command systems had not been adequately trained individually or as a set (system-of-systems). Moreover, battle-staff personnel considered as a team had not been provided sufficient time to become familiar with the equipment suites used to support mission command as a warfighting function. Trust in and reliance on technology emerge from familiarity and positive experiences with that technology. The level of expertise required to effectively use 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 mattered significantly during NIE 14.1. Also, there were numerous remarks in the NIE 14.1 database concerning "lack of trust" in the equipment provided to NIE participants. There were suggestions that some of this lack of trust derived from lack of equipment familiarity. NIE participants simply had not had time to become comfortable with mission command equipment or equipment suites and conversant with their potential uses.

The HSI team's report emphasized that the factors listed above combined and acted to increase the aggregate level of perceived complexity and cognitive load for commanders and their battle staffs. The mission command role itself is intrinsically complex and demanding. However, a work setting with a large number of design-related "rough edges" gives the impression of being more complex and intimidating than one that is better designed and integrated for effective use. Thus, while some of the cognitive workload is intrinsic to the tasks, additional workload is a needless consequence of insufficient HSI. The lack of training and familiarity results in a greater need to cognitively monitor what one is doing and what is happening (a knowledge-based activity). With adequate familiarization and training, this activity becomes skill- or rule-based, which reduces the need for monitoring and frees up cognitive channels, thereby reducing cognitive load (Rasmussen 1983). Errors are more likely if skill sets are knowledge-based. Training and equipment familiarity are important considerations in perceived complexity, cognitive load, and performance reliability.

3. NIE 14.2 Data Collection and Reporting

ARL HRED's HSI work for the BMC CG continued into NIE 14.2. Prior to the start of NIE 14.2, the mission command complexity-cognitive load issue was elevated in status to a formal Department of the Army (DA) Objective. Becoming a formal DA Objective meant that the issue would receive additional command emphasis and resources, and that analysis results would be included in the BMC's Executive Summary of NIE results. Analysis results and recommendations also would be reported in a separate section of the DA Objectives Annex report for NIE 14.2.

The HSI support team "came late" to the formal planning process for NIE 14.2. Consequently, the team carried forward the objective and issues used in the BMC CG's CP Ease of Use assessment. When used within the context of a DA Objective, analysis issues are formally referred to as Priority Questions. HSI-related results from NIE 14.2 are organized around the BMC CG's Ease of Use objective (now a DA Objective) and the 4 subordinate issues listed previously. Results for each of these Priority Questions are now addressed in turn.

DA Objective: Evaluate solutions that simplify and protect the network while enhancing the command post by decreasing its physical complexity and cognitive burden on commanders and staff.

Priority Question 1: What cognitive systems engineering issues impact the horizontal and vertical integration of mission command systems within CPs as configured in NIE 14.2?

Cognitive systems engineering is a specialty discipline under systems development that addresses the design of sociotechnical work systems (Hollnagel and Woods 2005). A sociotechnical system is one in which humans provide essential functionality related to deciding, planning, collaborating, and managing. Drawing on contemporary research and insights from cognitive, social, and organizational psychology, cognitive systems engineering seeks to design work systems that are effective and robust. The focus is on amplifying human capabilities to perform cognitive work by integrating technical functions with required human cognitive processes and making that cognitive work more reliable. Cognitive systems engineering involves activities such as: 1) the design of human interfaces and interactions, 2) communication systems and collaboration methods, 3) training systems and methods, 4) teams, and 5) management systems and methods. A CP is an example of a sociotechnical system that can potentially benefit from the application of cognitive systems engineering principles and practices.

Commanders and their staffs tended to view network-enabled CPs such as those used in NIE 14.2 as "complicated and fragile" (i.e., unreliable). For example, a draft briefing addressing NIE 14.2 emerging results prepared for the Vice Chief of Staff of the Army (VCSA) dated 28 May 2014 stated: "Sending graphics from CPOF [Command Post of the Future] to JBC-P [Joint Battle Command-Platform] is complicated and unreliable; not all graphics transfer correctly. When transmitted from JBC-P to NW [NETT Warrior], graphics must be broken down into smaller packages and reassembled by the receiver." Similar comments occurred frequently in the NIE database. As a result, CP personnel constantly have to "work the workarounds" to meet mission objectives. Commanders and staffs routinely commented on the distracting and frustrating impact of having to manage their mission command equipment suites on their more important role of "managing the fight." This diversion of cognitive resources to managing mission command equipment suites is a nuisance task that has significant implications for perceived cognitive load and overall mission command performance.

None of the above comments should come as a surprise. CP component design and integration have not yet been approached from an overarching system-of-systems perspective. Moreover, rigorous and inclusive cognitive systems engineering principles and practices have not been applied during their design and development. The draft Command Post 2025 Concept of Operations (CONOPS) developed by the US Army's Mission Command Center of Excellence emphasized this point, remarking that:

> "Current Army command posts are the result of unsynchronized requirements and efforts of multiple programs and are not integrated as a system. [. . .] This lack of synchronization results in a level of complexity that cannot be overcome by the unit's organization, people, or available training resources."

The lack of an overarching system-of-systems perspective coupled with a failure to consider the CP as a sociotechnical system is a significant contributor to perceived complexity and associated cognitive load.

Army HSI efforts have traditionally been applied at the individual system level, and that has been the case with most of the individual equipment items comprising NIE 14.2 CPs. What has not been adequately addressed is evaluation of HSI issues arising out of the relationships between Soldiers and technology, not just at the individual system level, but also at the team and organizational levels. Some of the most demanding aspects of CP operations as observed during the NIEs are emergent properties that only show up when the systems comprising the CP are brought together and configured in a particular way. *Emergence* is a term used to describe system behavior that might not be observed without the situational interaction of lower-level components or contributors (Vicente 2006). These emergent properties might not show up in an isolated assessment of individual mission command component systems. An example of one of the emergent aspects of CP operations is knowledge management (KM) on the part of the battle staff. Observed KM deficiencies are addressed in additional detail under Priority Question 4.

The solution to the problem discussed in the previous paragraph is straightforward but complex in application. Overall CP design must be approached as an integrated platform from both materiel and operational perspectives (i.e., CP-as-a-Platform). The materiel acquisition side of CP design and fielding must be better integrated and coordinated. This would be a significant step toward addressing the "fragility" comment noted previously. From an operational, user experience perspective, designers must apply cognitive systems engineering principles and practices as the CP is being developed, and not as an afterthought. Considering the CP from a materiel, "widgets alone" perspective will not resolve the growing cognitive load problem.

The previous paragraph addresses the long-term development of an objective CP-as-a-Platform. What about the short to midterm evolutionary development of CPs going forward? In the aftermath of ARL's CP Ease of Use assessment conducted during NIE 14.1, the BMC CG tasked ARL's BMC support team to characterize the following 3 aspects of CP operations in terms of their contribution to complexity and cognitive load: 1) Developing and maintaining a Common Operating Picture (COP); 2) Building Operations Orders with graphic overlays; and 3) Distributing these products to lower echelon units and dismounted forces. Interestingly, these aspects of CP operations are the same deficiencies noted previously in the extract from the VCSA briefing.

The ARL team was not able to fully complete this action prior to or during NIE 14.2. The team is prepared to continue this analysis, but subject matter expert support and access to the new mission command equipment items are required. Based on direct observations of CP operations, interviews with commanders and battle-staff members, and NIE 14.2 database entries, the problems noted in the referenced VCSA briefing likely have something to do with: 1) component features and their integration (subtle incompatibilities that show up when components are put together and used as a set—emergence again), 2) lack of necessary levels of user and team proficiency, plus 3) interactions between the 2 problem categories. As one NIE 14.2 database entry phrased it, “both training and materiel shortcomings” contribute to these deficiencies. Some of these issues might be resolved through more detailed analysis as the BMC CG requested and that the ARL team is prepared to continue. Results might be useful in 1) suggesting areas for enhanced physical integration of components, 2) revisions to CP procedures to improve operational integration, 3) improved training for individuals and teams, and 4) informing specifications for a next-generation integrated CP.

Priority Question 2: Assess Soldier NET on capability understanding and its implementation within the tactical context as an enabler for commander decision making. Provide recommendations for beneficial changes.

NET provides for the initial training and transfer of knowledge from the Materiel Developer or vendor to testers and users. It represents the knowledge that is needed for operation, maintenance, and logistic support during testing and initial introduction of new materiel into the Army inventory. NET is intended to assist commanders in achieving operational capability in the shortest time practical by training Soldiers, crews, and maintainers on how to *operate* and *maintain* new or improved equipment. It also provides unit leaders with training support components needed to sustain the proficiency of operators and maintainers of the new or improved equipment. NET is provided as needed prior to testing and handoff of equipment to gaining commands. In present terminology, *operate* should not be confused with *use effectively* in a tactical environment.

Based on NIE observations and user reports, it is obvious that NET alone is not sufficient to prepare the unit to participate meaningfully in an NIE. As noted above, NET is intended to provide for the transfer of *initial* system-related knowledge from the developer to testers and first users. NET is not intended to serve as a substitute for, or to be considered the equivalent of, various aspects of follow-on, unit-based training in developing mission-essential levels of individual, crew, team, or unit proficiency. Moreover, the NET concept arguably is being misapplied prior to the NIEs. NET is an orientation and familiarization or “delta” training event; it is not an adequate substitute for full-spectrum skill development across the unit. In current terminology, a delta training event is intended to transition a potential user’s skill set from one component to another that is considered an upgrade or replacement. It is *assumed* that users are fully proficient in the use of predecessor components prior to attending NET.

In addition to problems with NET application, there is inadequate follow up to NET within the unit. NET must be part of a more integrated and comprehensive approach to pre-NIE participant preparation, taking into account the "realities" of both skill acquisition and retention. This is particularly true for critical, high-skill areas such as network operations or mission command. Moreover, the current "checkerboard" application of NET prior to an NIE (i.e., fitting NET into "gaps" in the unit's existing training calendar) is almost guaranteed to result in considerable skill decay. The training literature is clear and states that significant skill decay can occur within relatively short timeframes (days to weeks) for any form of skill or learned material (Hoffman et al. 2014b). NET resources effectively are wasted when significant time gaps occur between participant training and event performance, unless NET is followed up by suitable skill-reinforcing training activities. In the case of the NIEs, the gaps between training and event performance can be as long as 6 months.

NET can and should be improved to make it more effective in those situations *where the concept is appropriately applied*. Potential areas for NET improvement include the categories listed below. Recommendations concerning NET improvements are based on the NET Evaluation Framework provided in the appendix. In present context, the term "framework" refers to a conceptual structure for evaluating pre-exercise NET and suggesting potential areas for improvement.

1) Attention to NET attendees and their readiness to benefit from training:

   - The personnel who attend NET should be those who will use various equipment items or groups of items during the NIE;
   - Attendees should be "cleared" for NET in terms of essential training and experience prerequisites;
   - Unit leaders must not be allowed to exempt themselves from NET; and
   - NET attendance must be more than a course checkoff or seat-filling exercise.

2) Attention to NET instructional processes:

   - Improved pretraining screening to ensure that proposed NET conforms to sound instructional principles and practices;
   - Checking to ensure that NET performance objectives have been identified and are verifiable, not simply topic-oriented;

- Instructor selection: Participant feedback and direct observations suggest that the best NET instructors address both technical and tactical aspects of equipment use (i.e., how to use the system in a tactical context);
- Availability of course reference materials and takeaways: NET instructors should provide attendees with reference materials and instructional takeaways to reinforce and refresh the material covered during instruction; and
- NET realism: Realistic expectations about how much actual learning can be accomplished during the time allocated for NET.

3) Insistence on some level of performance verification as a NET quality check:
    - Require knowledge and skill checks during and at the conclusion of NET;
    - Bear in mind that NET is primarily concerned with "knowing about," with a lesser emphasis on "knowing how to do";
    - Appropriate levels of "knowing how to do" must be developed during follow-on individual, team/crew, and unit training—usually in a unit context.

The most important part of determining the extent to which the Soldier "knows how to do" is the development of objective and usable performance measurement technologies. Developing such measures has been a challenge to leaders and trainers for decades (Seibert et al. 2011). Instead of relying on paper notes and memory, raters armed with observer-based, scaled performance measures implemented to mobile apps (e.g., tablet computers), would be able to collect and record real-time performance data at both the individual and team level.

Facilities exist at Fort Bliss, Texas (e.g., the 1st Armored Division's Mission Training Center [MTC] and the BMC's Mission Command Complex [MCC]) to provide some of what is necessary to ensure that participants are prepared to perform at the levels required by the NIEs. However, these facilities cannot provide everything that the unit requires for adequate pre-event preparation. Some essential pre-event training can only be conducted when the unit has access to the networks and the actual versions of the various mission command systems that will be used during the NIE. As one focus group participant put it, "We never see the full fires network setup until we get out to the box."

In summary, the following points are concrete recommendations for beneficial changes to pre-NIE NET and other aspects of participant preparation:

- NET must be based on a solid foundation of individual, crew/team, and unit proficiency. Even "good" NET that is well executed, but used alone is not sufficient to achieve this goal. The unit contends that it does not have the time to attend necessary training beyond NIE-related NET and specific Army Forces Command (FORSCOM)-mandated gunnery and other training requirements.

- Verify that individuals, crews, and teams are ready to participate meaningfully in NET. Check that essential training and experience prerequisites have been met.

- As currently conceived and conducted, NET is of mixed quality and questionable effectiveness. NET can and should be improved to be more effective. The NET Evaluation Framework given in the appendix provides additional detail.

- Component NET must be followed by appropriate amounts of individual and collective sustainment training in the unit. Not addressing this need adds to the Soldier performance risk associated with skill decay and incomplete or inadequate learning. One of the emerging lessons associated with the deployment of the new generation of CP components (CPOF, JBC-P, etc.) is that these systems require training well beyond what is provided during NET. Traditional NET typically focuses on "buttonology"—the basics of system usage (and sometimes maintenance). Effective use of these systems requires a deeper understanding of overall system capabilities and how these capabilities support command decision making. That level of training is arguably a "bridge too far" for traditional NET. Adequate follow-on training is also essential prior to team-oriented training addressing the operations of the CP-as-a-Platform. Participants in the post-NIE brigade and battalion commander focus group reinforced this point, noting that, "[We] can't expect Soldiers to go through 40–50 h of training and use systems efficiently; [we] need [collective] sustainment training."

- The unit must be able to train with the network and equipment configurations they will actually use during the NIE. There is some question concerning whether adequate time is available immediately prior to an NIE (i.e., during the Integration Motor Pool [IMP]) to meet this requirement. Adequate time for pre-event training is a serious issue and should not be ignored or dismissed with the claim that "things have always

> been this way" or "inadequate training is an 'NIEism' that we just have to live with." The new class of digital mission command systems is less forgiving of user performance inadequacies than their less complex predecessors (Hawley 1996). Moreover, from a practical perspective, inadequate participant training can negatively impact the validity of any inferences derived from NIE results (Hawley 2007).

Priority Question 3: Assess Soldier NET from a "CP-as-a-System/Platform" perspective and its implementation within the tactical context. Provide recommendations for beneficial changes.

The previous discussion emphasized that CP component design and integration have not been approached from a system-of-systems or cognitive systems engineering perspective. The lack of an overarching system-of-systems perspective during CP design along with a failure to consider the CP as a sociotechnical system (battle staff plus equipment), is a significant contributor to perceived complexity and associated cognitive load. It is arguable that the CPs observed during the NIEs have not been explicitly or purposively "designed" in the standard use of that term. Rather, they consist of a collection of loosely integrated individual systems placed in the CP and intended to support the mission command warfighting function. Moreover, each of the individual components has been developed and evaluated in isolation as a single system. Little consideration typically has been given to how these systems fit together as an integrated suite to support mission command.

The definition of a system-of-systems cited earlier notes that the functionality and performance of the whole is more than the simple sum of the component systems. That being the case, one cannot adequately evaluate a system-of-systems by assessing the individual components in isolation and then rolling up the results to represent the whole with the expectation that the resultant will be a fully functioning whole. For example, the CS-13 Culminating Observations, Insights, and Lessons report from 4/10 Mountain amplifies this point, noting that, "There are no standalone capabilities within CS-13" (4-BCT, 10th Mountain Division 2013). Considering the CP as a sociotechnical system requires addressing not only component design and integration, but also issues related to battle-staff training, team composition and structure, and CP management practices (Standard Operating Procedures [SOPs]; Tactics, Techniques, and Procedures [TTP]; etc.).

Pre-event training for battle staffs across the brigade was not approached in an integrated manner. The same criticism leveled at CP hardware configurations in the CP 2025 CONOPS could also be made with respect to training for CP operations—component-focused, unsyncronized, and conducted by different proponents. Complex cognitive work such as that performed in a CP is teamwork. The battle staff is a team and must be trained as a team. A relevant lesson from team training research is that even a team of experts does not automatically translate into an expert team (Hoffman et al. 2014b). Contemporary CP operations involve both task work and teamwork skills. Essential teamwork skills cannot be developed through individual training alone. Some of the difficulties observed during NIE CP operations can reasonably be attributed to the lack of a "crew-based mentality" when structuring and training the battle staff. The battle staff cannot be treated as a "pickup" team and be expected to perform satisfactorily using increasingly complex mission command equipment suites.

The above statement is particularly true of the battle captain. The battle captain plays a key role in battle-staff operations and in transforming data and information into knowledge that a commander is able to use to support decision making. The battle captain's role can no longer be viewed as just another duty to be assigned to a relatively junior officer and requiring little or no formal training, follow-on preparation, or performance certification. For example, the HSI support team observed many instances across NIEs in which a battalion-level battle captain was a junior lieutenant having little or no formal training in mission command, the MDMP, the equipment used to support a battle captain (most frequently CPOF), or any of the supporting mission command systems used in the CP.

A team-based approach to integrated CP NET was supposed to take place prior to NIE 14.2—the Mission Command Systems Integrated Training (MCSIT) event. In retrospect, that event must be viewed as a failure. Participants in the post-NIE brigade and battalion commander focus group characterized the MCSIT event as follows:

> "The tools the trainers brought were 180° from what we needed to do; they taught in PowerPoint; training needs to be a precursor to NIE scenarios; i.e., [operations] order to S-2 to conduct IPB [Intelligence Preparation of the Battlefield]; allow us to build products so that you find out whether you can push graphics from JBC-P to CPOF and to other ABCS [Army Battle Command Systems] systems; trainers are not integrated and have their own agenda. They only taught what they were comfortable teaching; it was a step back; they couldn't come to our level."

It is arguable that the MCSIT event alone—even if successfully conducted—would not have prepared battle-staff personnel to function effectively as teams or as a team-of-teams across the brigade's command echelons. Brigade and battalion leaders remarked that, "The only training [we receive] is during NET . . . there is no time for collective training . . . this BDE doesn't have the ability to do sustain[ment] training because of constant changes to software and systems." A caution from the training literature is relevant to this last comment: Developing training for a complex task is itself a complex task (Hoffman et al. 2014b). Effective training for a complex, team-based activity like mission command requires special expertise and resources that generally are not available in a standard Army brigade. Moreover, there is more to the conduct of effective individual and collective training than access to adequate training equipment (i.e., Training Aids, Devices, Simulators, and Simulations [TADSS]). More than 50 years of training research has consistently shown that training design and implementation issues generally trump issues pertaining to training equipment and simulator fidelity (Salas et al. 1998). As these authors assert in the title of the referenced article, "It is not how much you have, but how you use it." The "how you use it" part is the most complex aspect of the task of developing effective training for a complex, team-based activity like mission command.

Given the growing complexity and team-related nature of contemporary CP operations, the time might have come to consider CP training along the lines of Crew Resource Management (CRM) for commanders and their battle staffs. Once almost exclusively an aviation program, CRM is now broadly viewed as the use of all available human, informational, and equipment resources toward effective and efficient operations in operational domains dependent on crew or team performance (Helmreich et al. 1999).

In summary, the following points are concrete recommendations for beneficial changes to pre-NIE NET and other aspects of participant preparation from a "CP-as-a-Platform" perspective:

- Training for battle staffs across the participating unit's command echelons must be approached in an integrated manner, matching the system-of-systems nature of the CP itself.

- Battle staffs must be formally structured and trained *as a team*. This might require battle rostering battle staffs and performance certifying them as a team—as is currently done with various weapons platform crews, such as the M-1 Abrams or M-2 Bradley. Battle rostering battle staffs also might help to alleviate one of the observed problems with CP-oriented NET: Who attends? In the case of the battle staff, the rostered team participates as a group.

- Special training and development attention must be paid to the battle captain as a key role in CP operations: the orchestration of KM processes within the CP. KM skills must be identified and explicitly trained in a team context. During focus group sessions, the unit leadership was adamant that they must conduct this training themselves; they view battle staff training as a unit responsibility. However, it is not clear that the unit has the capability to adequately develop and conduct such training.

- Leadership and senior staff at all levels must not exempt themselves from battle-staff team training events. Commanders at all echelons must learn to work with their supporting battle staffs to leverage the extensive decision support capabilities that network-enabled mission command systems now provide. Moreover, new technology can change the nature and structure of the work performed in CPs; commanders and senior staff must adapt to these changed work demands.

- The battle staffs at various command echelons across the brigade must also learn to work as a team-of-teams. This will necessitate more extensive use of brigade-level Command Post Exercises (CPXs) prior to an NIE.

Priority Question 4: Evaluate complexity and cognitive load within CPs as configured in NIE 14.2. Provide specific examples of sources of complexity and cognitive load in current CP operations. Evaluate cognitive "pressure points." Provide recommendations to reduce complexity and cognitive burden.

The underlying theme in the referenced DA Objective is managing complexity. From an operational mission command perspective, NIE results strongly support an argument that "unmanaged" CP complexity has unnecessarily added to the cognitive load on commanders and their battle staffs. Contemporary CPs might be complex—because a complex tool is often necessary to do complex things—but that tool need not be unnecessarily complex. The consensus of literature and experience within the cognitive systems engineering domain is that managing complexity is a partnership. Designers have to produce products that help users navigate the inherent complexity of the domain. However, users of these products also have to do their part. Users have to take the time to learn the structure of their new tools and practice the skills involved in their effective use (Norman 2011). There are no "silver bullets" to overcoming complexity in contemporary CP operations. Both well-designed components and system-of-systems along with well-designed training, delivered in appropriate amounts, are the solutions to managing complexity. In the case of CPs as configured in NIE 14.2, neither of these aspects of complexity management has been particularly well done.

Providing specific examples of sources of complexity and cognitive load in current CP operations is consistent with a methodology routinely used in applied human factors work termed the *critical incident technique* (Flanagan 1954).

Critical incidents are ones where there might be loss of life or property, as in aviation accidents. The critical incident method is used to: 1) identify and characterize problems in the relationship among humans and technology, and 2) suggest solutions to these problems. These challenging situations are sometimes called cognitive "pressure points." With respect to CPs, cognitive pressure points are places in the mission command operational flow where situational demands or CP features stymie or overwhelm the problem-solving and coping resources available to the battle staff. These can include pressure points resulting from design and component integration, macroergonomic (platform-level) CP deficiencies, or battle-staff expertise deficiencies—knowledge, skills, and experience. The intent of the assessment is to explore and describe how technological changes transform cognitive and collaborative activities and performance demands within the CP and how the battle staff must adapt to cope with these demands.

The critical incidents discussed in the paragraphs to follow are described and evaluated with the above intent in mind. These critical incidents (Flanagan 1954; Seibert et al. 2011) can become the foundation of benchmarked, scaled collective performance measures for training assessment. Prototype, behaviorally anchored rating scales are compatible with any industrial or military team-level work environment where teams must coordinate on complex tasks.

3.1 Information Overload

An O/C report from the 1st Squadron, 1st Cavalry Regiment's CP, dated 8 May 2014 made the following observation regarding the Query Tree (QT) widget (multiuse tool) used to support intelligence analysis. The QT widget is one component of the Distributed Common Ground Station–Army (DCGS-A) system.

> "Users are unable to siphon relevant exercise information from the Query Tree due to several design-related features and naming convention SOPs that blend or hide information among thousands of real-world SIGACT [significant activities] entries. . . . Users are unable to filter [relevant] information. . . . The time required to sift through thousands of irrelevant entries makes the QT widget an extremely inefficient tool for intelligence analysis. . . . The inability to adequately locate relevant information quickly and efficiently in the QT widget delays S-2 analytics beyond the point of operational necessity."

On first glance, the QT problem described above is one of simple information overload: Too much information is provided to intelligence analysts for them to process in a timely manner. Consequently, they cannot readily separate relevant “signal” from background “noise.” This also could be a problem of inadequate training and experience: Analysts simply do not know where to look for relevant data. However, the O/C noted that the information filtering problem reflects an underlying design deficiency: Naming convention SOPs [that] blend or hide relevant information among thousands of entries. Design features for systems such as the QT widget often reflect the views and preferences of engineers and programmers and not user needs or capabilities. Menu options and naming conventions should be organized in ways that reflect users’ needs and expectations. Users must then be adequately trained to use the QT tool to support S-2 analytics. The O/C author also noted that the current design and use of the QT widget, “delays S-2 analytics beyond the point of operational necessity.” In other words, the QT widget cannot readily be used to inform commander decision making in the CP.

The solution to problems such as the QT issue is straightforward and involves work-centered analysis and design followed by rigorous usability testing and performance valuation. The mantra is: *Understand what is going to be done with the tool; design the tool to support that work; and then verify that the resulting product meets initial intent and is usable by the target audience. Put the user and the user’s work needs first rather than fitting users to the tool after the fact.*

3.2 CP KM Deficiencies

The following remarks are extracted from an O/C Drop Card from the brigade CP dated 14 May 2014, along with a supporting comment from a post-NIE command-level focus group:

> “The problem is, how does the TOC [Tactical Operations Center] manage information and create understanding? . . . The BDE [brigade] TOC continues to struggle analyzing and distributing information that flows into the TOC. . . . This is a systems management issue. There is not any cross communication of intel across the TOC floor. The BDE S-2 may collect it [intel data], but the [battle captain] is not populating anything on the COP to establish SA [Situational Awareness]. . . . I cannot help but think that the BDE CDR [commander] is frustrated with his intel and assisted understanding of what is occurring in the battle space. . . . The BDE is piecemealing the fight [each mission command component within the CP is operating semiautonomously with little overall coordination by the battle staff]. The network is pushing information, but the TOC is being overwhelmed with information. A lack of information management from the network is

> causing frustration. . . . Information must be better leveraged to make decisions more rapidly."

The following is an independent supporting comment from a post-NIE focus group:

> "We have the technology/capability but can't seem to figure out how to do it; we struggle to get a picture from platform to platform. How do we solve this? The network has tremendous capability but is incapable of being leveraged by BDE and below to its fullest capacity; for 4 NIEs, we have struggled to get relevant intelligence to the CO [Commanding Officer] and below because of the architecture. . . . We [require] components that enable staff to support the CDR intellectually."

This Drop Card is an insightful comment from an experienced O/C characterizing the roots of mission command dysfunction in the brigade CP from the perspective of complexity and cognitive load. Many HSI issues are implied in these brief comments, but one stands out in particular: Inadequate KM skills on the part of the battle staff, with particular reference to the battle captain. KM is viewed as the process by which data are transformed into information (data in context), and information is then transformed into knowledge that can be used to support command decision making (i.e., to "support the CDR intellectually"). The cognitive processes that underlie KM include collecting, organizing, and summarizing incoming data to form information (data in context). Information is analyzed and synthesized to support knowledge "creation." The final step in the KM process is command decision making. An information paper on training for mission command produced by the Mission Command Center of Excellence characterizes KM as the "Binding Idea" underlying effective CP operations (Training the Mission Command Warfighting Function 2013). The cognitive demands associated with KM are not trivial, particularly in a data-intensive CP setting.

The implications of the previous comments are clear. KM was not being performed effectively in the brigade CP. Consider critical supporting remarks in turn: The network is pushing information (data); the TOC is overwhelmed with information; the brigade battle captain is not populating anything on the COP to establish SA (data are not being organized and summarized into usable information; information analysis and synthesis are not being performed); a lack of information management from the network is causing frustration. And finally a capstone remark from the brigade commander: "For 4 NIEs, we have struggled to get relevant intelligence to the CO and below because of the architecture . . . *We* *[require] components that enable staff to support the CDR intellectually*." The issue here involves more than just the network and CP architecture (CP component design, internal organization, and physical integration). As emphasized in previous sections, NIE 14.2 CPs were not explicitly designed to support a cognitively dominated activity such as mission command in an integrated manner. KM is an important aspect of effective mission command. However, the activities comprising KM do not appear to have been adequately operationally defined and integrated into routine CP procedures or mission command processes. Moreover, battle staffs were not explicitly trained in KM skills. KM is a team activity, and the battle staff was not trained as a team.

In a complex sociotechnical work system like those created by all the new technology on display in NIE CPs, one cannot just throw Soldiers into a transformed workplace (with inadequate training and experience—plus all the old organizational and operating concepts) and expect them to succeed. But that is just what we do—and expect that somehow "the Soldiers will make it work." They might eventually make it work, but they struggle. One should not be surprised by what is continually observed and reported during the NIEs. As Norman (2011) asserted, complexity must be explicitly managed. In the case of NIE CPs, that has not been done adequately, if at all.

4. Discussion: Mission Command Complexity and Cognitive Load Going Forward

". . . ground combat is, without any doubt, the most complex set of interactions in any kind of military operations by any service or any country. Unfortunately, just asserting this does not help much." General William DePuy, 1975

As noted in the previous section, 2 problematic follow-on issues fall out of ARL HRED's HSI work performed at the system-of-systems, team, and organization levels during the FY 2014 series of NIEs. These are: 1) physical and operational integration of CP component systems, and 2) KM by the battle staffs across the brigade's command echelons. Results from the NIEs as reported herein and elsewhere support the observation that contemporary Army CPs are the result of unsynchronized efforts of multiple Program Managers and are not integrated as a system. As such, CPs are both nonstandard and complex from physical and cognitive perspectives. Physically, CPs require significant time to setup and tear down, involve extensive wiring, and are transit-case dependent for mobility (Command Post 2025 CONOPS 2014). NIE results also indicate that current CPs are complex from a cognitive perspective—complicated and difficult to use.

Norman (2011) used the term complicated to mean “puzzlingly complex.” It has been observed that the unit “struggles to fight” using the mission command systems in CPs as configured in the NIEs (Hawley 2014).

The current Army approach to CP development and procurement has inadequately addressed the integration of disparate programs and materiel. What CP integration there is has been approached primarily from a physical perspective and has not adequately addressed operational integration of new materiel into routine mission command processes. As a result, current CPs do not readily support mission command as cognitive work. That is, inadequate physical integration and inattention to operational integration result in a poor level of perceptual-cognitive integration that, “cannot be overcome by the unit’s organization, people, or available training resources” (Command Post 2025 CONOPS 2014, p. 3).

Achieving effective operational integration often necessitates an iterative, “test-and-learn” process making use of cognitive systems engineering principles and practices. These principles and practices are well enough understood to be applied in the formulation and development of the next-generation of Army CPs, as well as eliminating the worst of the “rough edges” encountered in current CPs. Cognitive systems engineering principles and practices are referred to by several names. These include human-centered design, decision-centered design, and work-focused design (e.g., see Lintern 2012). The idea is the same: CP component integration must be considered from the point of view of the team assigned to perform mission command using that equipment suite. Based on results across NIEs, it is obvious this requirement has not been addressed.

Lindell et al. (2003) define what they term a “Hierarchy of Design Needs”. Elements of this hierarchy are illustrated in the table. These authors assert that for a work system’s design to be successful, it must meet user’s basic needs before it can be used to satisfy higher-level needs. In the case of the CPs observed during NIE 14.2, it is not clear, when viewed as an integrated system-of-systems (i.e., CP-as-a-Platform), that requirements for the first level in the hierarchy (Functionality) have been fully met. Beyond that, NIE results strongly suggest that Reliability, Usability, Proficiency, and Creativity needs remain unmet. Furthermore, Proficiency and Creativity *assume* that users are skilled in the use of CP equipment items and in conducting mission command operations using that equipment. NIE results cast doubt on the validity of that assumption.

Table Hierarchy of design needs (after Lindell et al. 2003)

Functionality	The work system meets functional requirements.
Reliability	The work system exhibits stable and consistent performance. If the work system performs erratically, or is subject to frequent failure, reliability needs are not satisfied.
Usability	The work system's technologies are forgiving and *easy to use*. If difficulty of use is too great, or the consequences of simple errors too severe, usability needs are not satisfied.
Proficiency	Proficiency involves empowering users to do things better than they could previously. (In the case of NIE CPs, this has not been empirically demonstrated.)
Creativity	All prior user needs have been satisfied, and users begin interacting with the work technologies in innovative ways. The technology can now be used to create and explore areas that extend both the technology and the persons using that technology. (Not achieved during the NIEs)

Beyond problems resulting from inattention to physical and operational integration, the types of operations that the US Army has been engaged in during the past decade or more have led to a degradation of the skills required to establish CPs and conduct mission command in support of expeditionary and full-spectrum mission operations (Command Post 2025 CONOPS 2014). Results from domains related to maneuver unit mission command indicate that widespread use of information and communications technologies changes the nature of the cognitive work those technologies are intended to support. And these changes impact training and development requirements of personnel performing that work (Hawley and Mares 2012; Hoffman et al. 2014a). The discussion of CP problems in the previous section alludes to KM "breakdowns"—arguably attributable to battle-staff sensemaking deficiencies stemming from poor operational integration of CP components and inadequate training and development of the battle staff. It is not possible to make sense of things that are not easy to understand, regardless of the power and sophistication of the available technical facilities. In the words of the brigade leadership (cited previously), commanders and their battle staffs often struggle to form an integrated picture or mental model of the battlespace using current mission command components. Adequate perceptual-cognitive integration remains elusive in NIE CPs.

The Army formally defines KM as the, "art of creating, organizing, applying, and transferring knowledge *to facilitate situational understanding and decision-making*" (Field Manual [FM] 6-01.1 2012). KM supports improving organizational learning, innovation, and performance. KM processes ensure that knowledge products and services are relevant, accurate, timely, and useable to commanders and decision-makers (FM 3-0 2012). It creates value for organizations by increasing operational effectiveness, decision quality, and unit innovation. As noted previously, a White Paper on mission command training prepared by the Mission Command Center of Excellence refers to KM as the "Binding Idea" in CP operations (Training the Mission Command Warfighting Function 2013).

Leistner (2010) characterizes KM as the process of transitioning from data to information, where information is defined as data in context. Data in context are then translated into knowledge that can be used to support command decision making. A number of KM theorists and practitioners caution, however, that the transformation process from data to information and from information to knowledge is a cognitive activity (Leistner 2010; Walker et al. 2009; Wilson 2002). Wilson (2002, p. 2) bluntly states that, "Knowledge is defined as what we know: knowledge involves the mental processes of comprehension, understanding, and learning that go on in the mind and only in the mind, however much they involve interaction with the world outside the mind, and interaction with others."

Walker et al. (2009) provide a related perspective on the cognitive underpinnings of the process of moving from data to information to knowledge. These authors note that "live" network-enabled operations involve far more than simply having a lot of data. Effective mission command requires that data be transformed into required information in a timely manner. Moreover, creating information from data is complicated by the fact that, like beauty, what is considered information is largely in the eye of the beholder. These authors go on to observe that data (objective, measurable realities of a situation) provide the basis for Endsley's (1995) Level 1 SA: the perception of elements in the environment. Endsley's Level 2 SA refers to comprehension of what those elements might mean. In the eye of the beholder, data are becoming information (data in context). Level 3 SA refers to mental projection into the future: actually doing something with that information. Grouped together, Level 2 and Level 3 SA define categories that are more "information- and knowledge-like" than they are "data-like" (or Level 1 SA-like).

Information and knowledge are the products of individual and collective sensemaking activities within the CP. Sensemaking is a cognitively centered activity. Knowledge creation, the final step in the KM process, very much involves attention to the "cognitive preparation"—background, preparation, and experience level—of the battle-staff personnel responsible for transforming data into information, and information into knowledge to support command decision making.

In a recent *McKinsey Quarterly* article, Dewhurst and Wilmott (2014, p. 1) remarked that the advances of so-called "brilliant" machines in supporting senior leaders might "astound us," but only if those leaders "enable them to." They further asserted that technology may require a transformation of the concept of the senior leader's role. The senior leader's role increasingly will focus on: 1) asking the right questions, 2) attacking exceptions, 3) tolerating ambiguity, and 4) employing "soft" leadership skills. These authors went on to observe (p. 2) that:

> "Today's unaware leader risks drowning in minutia . . . Some are already reacting [to this problem] by distancing themselves from technology—for instance by empowering layers of staffers to screen data, which gets turned into more easily digestible PowerPoint slides. In doing so, however, [leaders] risk getting a 'filtered' view of reality that misses the power of the data available to them."

HRED's HSI support team has observed numerous instances of this situation across the brigade's echelons over the course of 4 NIEs. A prime example of such "distancing" is the Digital Executive Officer (XO) concept observed in previous NIEs and discussed in Hawley (2014).

Increased use of information automation is often presented as a potential solution to information overload and KM problems in contemporary CPs. Information automation refers to automating data- and information-handling activities in fast-paced, information-rich settings such as a CP (Billings 1996). Under such an approach, various software applications would be used to assist the battle staff in performing KM processes. Information automation has the potential to be beneficial in many ways, and enable CP operations that would otherwise be difficult to support. However, caution is suggested because information automation can have negative side effects if not implemented properly. For example, a recent Federal Aviation Administration (FAA) report notes that information automation improperly applied in automated flight management systems can increase pilot workload, increase head-down time, distract the flight crew from higher priority tasks, and contribute to crew communication and coordination issues (FAA 2013). Moreover, control vulnerabilities can occur, especially if users are not aware of assumptions made in the support system's design or if the information presented to users is not fully understood. Used in this context, the term vulnerability refers to characteristics or issues that render a system or process more likely to break down or fail when faced with unusual or ambiguous situations. These cautions from the flight management arena are relevant to providing automated support for the KM activities that take place within contemporary CPs.

The word “automation” has often come to be an unfortunate code word for “fewer personnel,” “less expertise,” and “lower cost” (Hoffman et al. 2014a). In other words, there is a widespread belief in some portions of the system development community that automation is a ready means to: 1) reduce the number of people in a given system, 2) reduce the amount of training and experience these individuals and teams require, and 3) lower the costs associated with developing and operating that system. Results from across a number of sociotechnical work domains indicate that this so-called “substitution fallacy” is one of the “deadly myths” associated with automation (Bradshaw et al. 2013). The substitution fallacy refers to a naïve belief among some system developers that automation simply shifts tasks from users to the machine, and a consideration of how users interact with that automated support is not necessary (Hollnagel and Woods 2005). The prevailing view here might be stated as, “Just automate that function and we will get it off our plate.” Decades of human factors research and field experience strongly contradict this view (Bradshaw et al. 2013; Hoffman et al. 2014a). Information automation alone is not likely to be a panacea for the KM deficiencies noted in contemporary CPs. Improperly applied or “clumsy” information automation might, in fact, make the KM problem in CPs worse, as the FAA results caution.

One HSI-related insight from the now cancelled Future Combat Systems (FCS) program was that without significant changes in personnel- and training-related concepts and practices, the Army would struggle to support the materiel side of that acquisition. Old practices in these areas would not prove sufficient to support the new warfighting concepts and their enabling technologies. In many respects, the concepts and equipment demonstrated and evaluated during the NIEs are conceptual descendants of the concepts underlying the FCS program. Viewed holistically, the results in this report support that insight from the FCS program. It is true that the unit often “struggles to fight” with immature and unreliable equipment that is often poorly integrated from a physical perspective. Problems in these areas are eventually resolved. A potentially more intractable set of issues concern operational integration deficiencies along with obsolete personnel and training concepts and practices. Policies and practices in the personnel and training domains will have to be evaluated and adjusted in light of lessons from the NIEs and the deployment and use of CS equipment across Army units. It is often said that information and communications technologies are “skill-biased.” Widespread use of these technologies in a work setting has been observed to raise the skill, knowledge, and aptitude requirements associated with their effective use. Training and personnel practices must be revised to reflect this new performance context. This challenge must be met or the Army will fail to exploit the potential of new technologies. As the brigade commander quite accurately stated after NIE 14.2, “We have the technology/capability but can’t seem to figure out how to do [use] it. The network has tremendous capability but is incapable of being leveraged by BDE and below to its fullest capacity.” A major aspect of the solution going forward involves increased attention to cognitive systems engineering concepts and practices. These include: 1) Well-designed and appropriately integrated CPs, and 2) well-designed training delivered in appropriate amounts. Moreover, there are no technical silver bullets. Materiel solutions alone will not solve the growing complexity-cognitive load problem in CP operations.

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Appendix. New Equipment Training (NET) Evaluation Framework

This appendix appears in its original form, without editorial change.

Background

- A Quality Assurance framework for assessing NET effectiveness and pre-test training adequacy
- Assessment components

  Input: Trainees and their readiness to attend NET

  Process: What goes on during NET

  Output: Job-related skills and knowledge acquired during NET
- The goal is to make NET evaluation evidence-based rather than mostly subjective

Input

Trainee characteristics: Do we have the right target audience, and are they properly prepared to benefit from NET?

1. MOS(s) Awarded
    a. When?
2. Time in Service?
3. Time in Grade?
4. Rank
5. Level of performance certifications obtained?
    a. Table IV, Table VIII, etc.
    b. Software builds qualified on? (PDB 6, 6.5, 7)
    c. Date of last certification?
6. Months of unit time?
    a. Units?
    b. Roles performed?
    c. Time by job position

The goal is to determine the level of skills, knowledge, and experience Soldiers bring to NET.

Process

NET instructional evaluation criteria: Do NET processes meet generally accepted guidelines for effective instruction?

1. Is the focus of NET on job performance?
2. Are tasks and skills (Performance Objectives) identified?
    - Are NET Performance Objectives job- or role-related?
3. Is practice realistic and job-related?
4. Does practice include a mix of job situations?
5. Do trainees practice to job competence (the level required by the test)?
    - Have measurable task- and job-related standards been specified?
    - Is allocated time for NET sufficient to meet job-related performance standards, given pre-NET trainee skill levels and experience?
    - Does NET include a focus on whole-job performance?
    - How much time will elapse between the end of NET and the onset of testing? -- Will trainees have an opportunity to train in the interim?
6. Does hands-on practice equal at least half of training?
7. Instructor qualifications: Technical experience? Tactical experience?

Source: Whitmore (2002).

Output

NET quality checks: Evidence-based versus subjective assessment of NET effectiveness.

- Quality is defined in terms of job-related knowledge and skills acquired during NET
    - Assessed in terms of the "delta" between what the Soldiers brought to the NET situation versus their performance capabilities following NET
- Quality check components:
    - 1. Trainee questionnaire
        - Caveat: Trainees often don't know what they don't know, and won't know until called upon to perform in a tactical situation
    - 2. Knowledge test (knowing about)
    - 3. Task-related skill checks following training blocks (knowing how to perform individual tasks)
    - 4. End-of-NET whole-job skills assessment (knowing how to integrate tasks on the job)
        - Conducted within the context of a standardized post-NET exercise
        - Can the Soldier-trainee perform tasks within the job/role context?

Summary

- Evidence-based versus subjective assessment of NET effectiveness
- Consistent with generally accepted criteria for evaluating course implementation (Whitmore 2002)
- Consistent with Kirkpatrick's Four-Level Training Evaluation Model (Kirkpatrick and Kirkpatrick 2006)
  - **Reaction**: Did trainees like the course and think it was useful?
    - Trainee post-NET questionnaire
  - **Learning**: Did trainees learn the target skills and knowledge?
    - Knowledge tests
    - Skill checks
  - **Transfer**: Can trainees apply these skills and knowledge on the job?
    - Post NET whole-job performance assessment
  - **Results**: Did it impact the organization's bottom line—improved unit performance?
    - Not assessed objectively

List of Symbols, Abbreviations, and Acronyms

ABCS	Army Battle Command Systems
ARL	US Army Research Laboratory
ATEC	Army Test and Evaluation Command
BMC	Brigade Modernization Command
CG	Commanding General
CO	Commanding Officer
CONOPS	Concept of Operations
COP	Common Operating Picture
CP	Command Post
CPOF	Command Post of the Future
CPX	Command Post Exercise
CRM	Crew Resource Management
CS	Capability Set
DA	Department of the Army
DCGS–A	Distributed Common Ground Station–Army
FAA	Federal Aviation Administration
FCS	Future Combat Systems
FM	Field Manual
FORSCOM	Army Forces Command
FY	Fiscal Year
HRED	Human Research and Engineering Directorate
HSI	Human-System Integration
IMP	Integration Motor Pool
IPB	Intelligence Preparation of the Battlefield
JBC-P	Joint Battle Command-Platform

KM	knowledge management
MANPRINT	Manpower and Personnel Integration
MCC	Mission Command Complex
MCSIT	Mission Command Systems Integrated Training
MDMP	Military Decision Making Process
MTC	Mission Training Center
NET	New Equipment Training
NIE	Network Integration Evaluation
NW	NETT Warrior
O/C	Observer/Controller
QT	Query Tree
SA	Situational Awareness
SOP	Standard Operating Procedure
SoSI&E	System of Systems Integration and Engineering
TADSS	Training Aids, Devices, Simulators, and Simulations
TOC	Tactical Operations Center
TTP	Tactics, Techniques, and Procedures
VCSA	Vice Chief of Staff of the Army
XO	Executive Officer

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