Integration and Application of Human Systems Integration (HSI) in C4ISR: Assessment of Network Centric Warfare Capabilities

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ABSTRACT

Naval warfare in the 21st century will become increasingly information intensive, requiring warfighters to process and respond to large amounts of data in a reduced time frame. Reliable, network-centric information technology systems are indispensable for ensuring well coordinated command and control (C2) and mission planning and execution. The US Navy's network centric warfare construct, FORCEnet, has underscored the importance of creating network-based information technology systems that can be used easily, efficiently, and effectively. Human Systems Integration (HSI) addresses the relationship between human users and FORCEnet technologies in order to promote effective and efficient mission performance. HSI assesses how human users affect a system and how a system affects the humans who interact with it.

Trident Warrior 2004 (TW04) was a fleet experiment, conducted in September 2004, that provided an opportunity to collect performance data in a realistic field setting during simulated combat operations. In TW04, HSI addressed the relationship between human users and FORCEnet technologies in order to promote effective and efficient mission performance. HSI focused on determining the impact of improved user interfaces to FORCEnet systems.

Four Measures of Effectiveness (MOEs) were assessed:

- *Shared situation awareness among distributed, collaborating teams.*
- *Improved speed-of-command in using multi-tiered sensor and weapon information.*
- *Efficient utilization of FORCEnet systems by the warfighter.*
- *Efficient and adaptable team performance.*

The results of the HSI assessment can be summarized as follows:

- *As FORCEnet technologies enabled greater access to task relevant information among distributed teams, situation awareness improved.*
- *The FORCEnet technologies rated as having high usability imposed the lowest workload demand.*

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A Knowledge Center concept was intended to provide a unified reference source for C2 procedures and technology applications. This would have provided a "system of systems" for a more adaptable use of FORCEnet technologies for novel situations. Technical difficulties, however, prevented collection of any operational data. But, demonstration of the concept did elicit positive feedback.

1.0 INTRODUCTION

Naval warfare in the 21st century will become increasingly information intensive, requiring warfighters to process and respond to large amounts of data in a reduced time frame. Reliable, network-centric information technology systems are indispensable for ensuring well coordinated C2 and mission planning and execution. The FORCEnet initiative, which is the command and control component of Sea Power 21, has underscored the importance of creating network-based IT systems that can be used easily, efficiently, and effectively.

This executive summary presents Human Systems Integration (HSI) issues important to the evolving suite of FORCEnet functional capabilities. HSI addresses the relationship between human users and FORCEnet technologies in order to promote effective and efficient mission performance. HSI considers all aspects of the human-system interface, particularly human factors engineering, manpower, personnel, and training. Together, these elements define how human users affect a system and how a system affects the humans who interact with it.

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Together, these four MOEs furnished the foundation needed to formulate and implement an analytic plan that enabled meaningful HSI assessments of the systems used during TW04 in support of the FORCEnet technical objectives.

A hierarchical approach was taken to the analysis of FORCEnet processes in which successively more specific assessment factors were defined. At the highest level, FORCEnet capabilities described operational objectives in terms of the four MOE areas. Each of these topics was then considered in terms of its objectives and functional capabilities to support focused analysis of HSI processes in operational settings. The HSI functional areas were Call for Fires; C2 / Collaboration, and Network Operations). At the most detailed level of analysis, each functional capability was evaluated in terms of its component HSI threads, which were phrased as questions addressing a specific operational issue assessed during TW04.

The inter-relationship of the four HSI MOEs and the three HSI functional capabilities is summarized in the table below, which includes a brief description of area evaluated by each combination of these factors. For each of the MOEs, a number of measures of performance (MOPs) were addressed in the form of questions.

Table 1. Relationship of TW04 Functional Capabilities to HSI MOEs.

Functional Capability	HSI Measures Of Effectiveness			
	Shared Situation Awareness	**Human Performance**	**Efficiency of Asset Utilization**	**Team Efficiency and Adaptability***
ISR & Fires	Shared ISR situation awareness among afloat & reach-back teams.	Time to access ISR information and perform Fires tasks.	Usability of ISR systems for reach-back and remote operations.	Overcome skill gaps among distributed teams. Effective team performance and info sharing. Agility in responding to novel situations.
Common Operational Tactical Picture	Shared situation awareness of the common operational picture.	Time to access tactical information via web-services.	Usability of web-based systems for accessing tactical information.	
Communications & Networks	Awareness of network status and bandwidth mgmt capabilities.	Time to perform operational tasks under varied network quality.	Usability of network capabilities.	

*Team Efficiency and Adaptability objectives were not specific to the functional capability areas.

2.0 DATA COLLECTION INSTRUMENTS

Participant questionnaires, participant interview forms, and participant observation forms ("observer logs") were used to collect data during TW04. Each of these instruments was designed to meet a particular data collection requirement. In general, responses to the questionnaires and interviews were used to obtain a more complete understanding of the participant observations. Participants were also given opportunities to amplify their responses as well as comment on topics not covered by questionnaire and interview items. HSI experts also performed formal usability analyses of several systems and physical ergonomics reviews of several workspaces "off-line" from the Sea Trial.

3.0 SUMMARY OF MAJOR FINDINGS

The table below summarizes how well the FORCEnet technologies examined during TW04 supported the military functional capabilities in terms of four HSI MOEs. Color codes are used as a simple way to indicate how well the HSI requirements were met. Because there were frequent technical problems with some of the newer technologies, some functional capabilities were reduced. In evaluating the HSI aspects of these technologies, it is important to separate the technical problems from potential HSI problems so that appropriate remediation can be taken. Accordingly, the table focuses on HSI issues.

Table 2. FORCEnet Functional Capabilities Summarized in terms of Major TW04 HSI MOEs

Functional Capability	HSI MOE			
	Shared Situation Awareness	Human Performance	Asset Utilization Efficiency	Team Efficiency and Adaptability
ISR & Fires	Y	Y	Y	
Common Operational Tactical Picture	Y	G	G	
Communications & Networks	G		G	

G Meets requirements but can be improved with minor modifications.

Y Functional but requires substantial modifications.

Inadequate data were available for valid assessment.

3.1 Shared Situation Awareness

For ISR and Fires shared situation awareness, overall, was marginal. WebCOP was unavailable and there was an intermittent ability to communicate. Shared situation awareness was degraded between the FIST (ashore) and the JIC (afloat). It was difficult to post ISR products in a timely manner and collaborate on the content. Hours were expended to exploit video clips that had inadequate resolution to be effective. There were a number of disparate databases, which were not always updated to be consistent with each other, added confusion and sometimes made it difficult to locate ISR products.

Although shared situational awareness for the Common Operational Tactical Picture was better, it needs improvement. The GCCS-M eWeb provided a good view of the tactical situation, but access/availability was limited. Only minimal training had been provided. The Blue Force Tracker was considered a useful way to remain aware of Blue force locations via remote databases. Chat and email were useful tools for collaboration and supporting situation awareness. Network connectivity problems, however, impacted the ability to exchange information. The distributed chat architecture provided a means to recover situation awareness when collaboration connections were lost, but the user interface needs improvements.

For Communications and Networks, situation awareness was good, but the workload was high. ADNS provided IT operators with excellent awareness of network status and bandwidth management capabilities. The information provided watch standers on network status was adequate and useful for maintaining awareness of outages, loading, and related issues. Improvements in user interface design, team organization, and operating procedures will help reduce workload demands.

3.2 Human Performance[1]

For ISR and Fires, the FORCEnet capabilities supported the operator, but need improvements. SACC personnel were able to access necessary targeting information from the JIC in a timely manner. Various problems, however, were experienced in exchanging information between the FIST and the JIC. The workload was high, the COP was unavailable at the FIST, and usability was poor.

For the Common Operational Tactical Picture, the FORCEnet capabilities facilitated operator performance. The use of reach-back METOC assets were successful and provided needed information quickly and easily. The NITES Next system was easy to use and the information was well organized. There was limited availability of the Navy-Marine Corps Portal and a limited opportunity to examine the benefits of portal configuration.

3.3 Asset Utilization Efficiency

For ISR and Fires, asset utilization efficiency was considered marginal. There were incompatible versions of software between the USS TARAWA and the FIST that increased response time to transfer images of acceptable quality. There were usability problems in creating target folders and network reliability was a significant problem. The collaboration tools available to JIC were limited to chat and email. The workload was moderate, but usability was considered poor and the utility marginal. The JIC and SACC were able to collaborate effectively on intelligence information and were to transfer information efficiently and quickly.

For the Common Operational Tactical Picture, the FORCEnet capabilities provided good utility, but were limited in usability. The NITES Next and the Blue Force Tracker provided value to the users. The Information Management Plan provided a useful set of resource information and was relatively easy to use in the online version.

For Communications and Networks, the FORCEnet capabilities provide good support for network management. Network capabilities were easy to use and required little effort from operators. Watch standers were satisfied with system performance and response latency under IP Compression. There was no impact to task performance. The Bandwidth Managed Voice Technology provided good sound quality. Operators at remote locations found the DAM-WSV server easy to use and that it imposed little or no additional workload. Watch standers on Tarawa were satisfied with web response latency, but the web response on other ships was much slower. Access to NKO via the NIPRnet was too slow to be useful for career management and online training.

3.4 Team Efficiency and Adaptability

From a team efficiency and adaptability perspective, software incompatibilities prevented access to proposed capabilities. Thus, only minimal data were collected and no firm conclusions can be made. The concept, however, of a Knowledge Center for systems of systems information was discussed and it was perceived as valuable. This concept could be adaptable to the dynamic demands for training in a deployed environment.

4.0 CONCLUSIONS

In TW04, HSI first addressed the cognitive and organizational elements that enable systems to be used effectively by real teams in an operational environment and to accomplish key tasks at high levels of performance. Overall, TW04 systems' effectiveness in meeting HSI test objectives was mixed, with asset

[1] For Communications and Networks MOPs, not enough data was collected to perform a meaningful assessment.

utilization showing the best performance and shared situation awareness having the lowest performance. This type of analysis is particularly powerful because it documents the overall impact of FORCEnet technologies from the Warfighter perspective, vice a system perspective. In terms of functional capability, the technologies were least successful for ISR and Fires and most successful for Communications and Network Management.

HSI analysis also identified individual systems that operated efficiently and noted areas for improvement. GCCS-M eWeb, NITES Next, ADNS, Distributed IRC chat, Bandwidth Managed Voice, and the Information Management Plan were effective in improving human performance through greater functionality and usability. Several of the portal systems, WebCOP and Jabber Chat, were not tested because of technical difficulties. As new systems are fielded, attention to HSI is required in order to ensure that network centric warfare effectiveness can be increased while manpower is reduced.

Three HSI hypotheses were examined in TW04 regarding the overall impact of HSI on operational effectiveness. These hypotheses addressed general impacts of HSI rather than specific properties of particular technologies or military functions.

- Hypothesis: As FORCEnet technologies enabled greater access to task relevant information among distributed teams, those teams experience an increase in situation awareness. Systems that provide limited information access and connectivity, either by design or due to technical difficulties, are less likely to contribute to shared situation awareness. Although many technologies in TW04 were intended to provide broad information access among distributed and reach-back teams, some systems experienced technical problems that precluded full information access. Given that, however, the more access that ESG teams had to operational information the greater was their situation awareness.
- Hypothesis: Improved user interfaces will reduce operator workload, making it easier for operators to perform their tasks. This is especially important for FORCEnet systems, which can dramatically increase the volume of information available to operators. Reduced workload also allows for task redesign and reduced manpower. Many of the FORCEnet technologies exhibited moderate levels of both usability and workload; however, those that were rated as having high usability also imposed the lowest workload demand. Of course, workload is also a function of externally imposed demands from the operational situation. Nevertheless, workload imposed by system operating characteristics was related to the quality of the user interface. Therefore, usability is an important criterion both for design and evaluation.
- Hypothesis: A unified reference source for C2 procedures and technology applications that included "system of systems" information would promote more efficient use of FORCEnet technologies and would enable teams to be more adaptable to novel situations and operating problems. The Knowledge Center was intended to provide this. Because of technical difficulties, the Knowledge Center software was not used in the exercise as anticipated. It was, however, demonstrated to potential users. Positive feedback was received on the Knowledge Center concept, and further development is recommended for TW05.

The FORCEnet functional concept highlights the central role of cognitive support, decision-making, and HSI in achieving the full impact of FORCEnet. This point was demonstrated in TW04. Web-enabled technologies that provide easy access to information across distributed teams are needed to enhance operational effectiveness. These systems must be reliable, survivable, reconfigurable, and useful for a wide range of military tasks. But they must also be easy to use and understand, be adaptable and tailorable to user needs, provide on-demand training and job aids, and be compatible with team organization and procedures. HSI processes provide the focus to successfully deploying FORCEnet with reduced manning.