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# Operational Replanning with User Defined Operational Picture: Warfighting Experiment & Operational Assessment Plan

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## ABSTRACT

In adapting C2 to the 21st century we plan to conduct a controlled Human-In- The- Loop (HITL) experiment with new Network Centric Warfare (NCW) technology which will be introduced to sixteen experienced warfighters in the form of a collaborative User Defined Operational Picture (UDOP) with Blue Force Readiness and intelligence database access enabled by an IP wide area network as a possible improvement over their use of current baseline technology in the form of the GCCS with Common Operational Picture (COP) capability. We examine here the general methodology of using controlled HITL experiments employing combat scenarios as an Operational Assessment for testing and evolving more effective C2 technology for the warfighter. (See the Award-winning *TTCP GUIDEx*, 2006)

Our general theoretical hypothesis views the warfighting team as a Complex Adaptive System (CAS), and asserts that a team’s use of shared informational schema contributes to their shared mental models resulting in increased combat effectiveness in the battlespace.(See Gell-Mann, 1994,1997) In particular, we hypothesize that the results of this experiment will show significant improvements on the NCW performance metrics of Situational Awareness, Shared Situational Awareness and bottom-line Combat Effectiveness due to use of the new NECC(Net-Enabled Command Capability) technology employed in the experiment trials. The especially important role of enhanced operational replanning quality, and speed, enabled by the new technology, will be carefully examined here, since recent experimentation results suggest them as NCW metrics that warrant more scrutiny by the research community. (See Hiniker & Entin, 2006). Thus we expect that collaboration and synchronized replanning will play important roles impacting combat effectiveness in this C2 experiment.

## INTRODUCTION

Net Centric Warfare (NCW) has been defined as an information superiority-enabled concept of operations that generates increased combat power by networking sensors, decision makers, and shooters to achieve shared awareness, increased speed of command, higher tempo of operations, greater lethality, increased survivability, and degree of self - synchronization. (Alberts, Garstka, and Stein (2000)) Situational Awareness (SA), as well as its sharing by linked warfighters (SSA), is thus deemed to be a major causative factor in increasing combat power. (Hiniker & Entin, 1990, 1992: Perry, et al, 2004; Hiniker, 2005; Hiniker & Entin, 2006) Increased Speed of Command, and the associated increased speed and quality of planning, have recently received some empirical support as NCW contributors to combat effectiveness. (Hiniker & Entin, 2006) Besides the higher connectivity created through the construction of broader band networks, the major information technologies that are indispensable for enabling NCW for a warfighting team are a Common Operational Picture (COP) coupled with a shared whiteboard for collaboration over the map of the battlespace. DISA's most advanced versions of these technologies are the User Defined Operational Picture (UDOP)**,** as instantiated by NECC C2 Common Services, combined with NCES e-collab whiteboard with shared map planning and voice functionality. In addition, warfighter access to remote data base capabilities such as a Blue Force Readiness database and an improved Red Force Tracker database should contribute directly to the speed and quality of replanning, and hence also contribute to increased NCW combat effectiveness.

Does greater Speed of Command via improved speed and quality of replanning utilizing remote data bases by a distributed warfighting team enabled by a network in fact cause improved combat effectiveness? What are some of the causal mechanisms involved? The **purpose** of the experiment described here is to demonstrate and to analyze the differences in operational effectiveness between current warfare practices and NCW practices using the combined technologies of the UDOP with collaboration technology, and the improved remote intelligence and blue force readiness databases while capturing quantitative measures of NCW parameters under controlled conditions. Here collaboration technology is instantiated through the NCES e-collab with shared map planning capability and audio.

In addition, this experiment will serve as an early Operational Assessment in the **Test and Evaluation** of a combination of Capability Modules (CM) as contributors to the effectiveness of the Adaptive Planning Capability Definition Package (CDP) which is expected to increase significantly the measures of the Key Performance Parameters of the Combat Loss Exchange Ratio and the Speed and Quality of Replanning and Shared Situational Awareness in the combat mission threads played out by the participating warfighting teams here when compared to their performance with the current baseline technology. (See DoD/DAU, 2003; TTCP GUIDEx, 2006) Here the subset of CMs utilized in the experiment will be drawn from the mature members of the following collection: UDOP/iCOP (User Defined Operational Picture); TMS/CWS (Red Force Tracker); Blue Ground Force Tracker; Weather; and SORTS (Blue Force Readiness). All of these CMs are considered to be shared Schema that may contribute to more complete and more accurate representations inside the warfighting team of the relevant aspects of the external combat environment.

Such early Operational Assessments of prototypes are important to the efficient evolutionary development of C2 technology. In the development of C2 technology it is useful to benchmark progress through the use of standard measures of performance and effectiveness. Thus use of the standard performance parameter of Situational Awareness was made in a 1990 experiment (Hiniker & Entin, 1990) and again in 2006 in an experiment with a similar scenario and set-up. The comparison of the results of these two experiments demonstrated noteworthy evolution in C2 capability for the warfighter over the intervening decade and a half (Hiniker & Entin, 2006). The baseline condition in the first experiment consisted in local tactical pictures located at the two ship captain posts and a big picture Gulf view located at the remote team leader's command post. This experiment showed significantly higher Situational Awareness by the warfighters in the COP prototype treatment condition. The later experiment used the COP condition as baseline and found comparable and significant improvements in Situational Awareness in the post-replanning phases of the experiment when warfighters employed the new collaborative UDOP technology. Similar significant improvements were found for bottom-line Combat Effectiveness when comparing experiment results over the decade. (Hiniker & Entin, 1992) Such comparisons in the evolution of technological progress in C2 would be more difficult to draw without the use of such standard measurements of operational performance parameters. (See Measurement Appendix)

In the current experiment, we examine the impact of these surviving collaborative UDOP technologies coupled with new network enabled distributed intelligence and readiness databases while focusing on the measurement of their contribution to effective adaptive planning by the warfighting teams. In this paper, we will first present our experimental approach to evaluating the new C2 technology. Next we describe the specific warfighting scenarios employed and the NCW metrics to be taken during them. Then we present a broad Complex Adaptive Systems (CAS) view of NCW, including the role of schema, and derive our experimental hypotheses. Finally, we describe the analysis methods to be used for testing the hypotheses with the metric data obtained during the experiment trials and the kinds of conclusions one may draw from the findings.

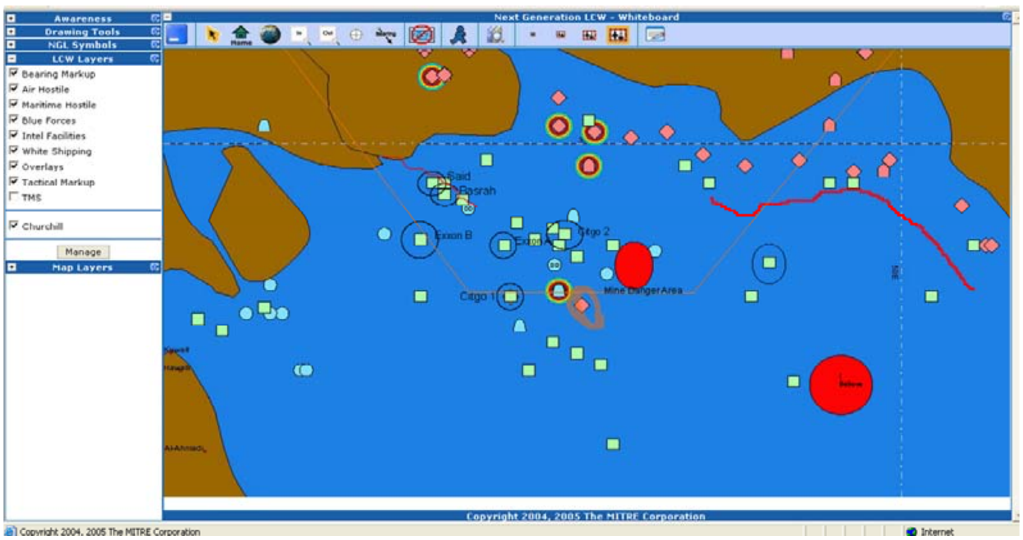
## APPROACH

The NECC Delta Experiment introduced above is another "true experiment" with controls examining the effectiveness of some new C2 technology, drawn from NECC, utilized by a distributed command team of joint warfighters collaborating and replanning over an IP Network with access to remote operational planning data bases while engaged in simulated combat scenarios compared to the effectiveness of warfighter performance employing current baseline condition technology. In the approach adopted here, variably equipped warfighting teams are experimentally created in a **controlled Human-In-The-Loop (HITL) experiment** utilizing the JTLS wargame simulator, and their performances are systematically related to combat outcome. (See TTCP GUIDEx, 2006) In the experiment each of four warfighting teams, each composed of an Air

Force officer, a pair of Naval Tactical Action Officers (TAO) and an ashore higher level operational planner at CJTF with the authority to change Rules of Engagement (ROE) and provide additional blue forces, play out four battles composed of modified versions of a Persian Gulf air/sea counter-terrorist combat **scenario**, termed Operation Storm Petrel II, crossed with two versions of information technology, the collaborative UDOP with associated distributed intelligence databases and the baseline GCCS COP/CHAT ensemble. The baseline technology is that currently in use by most of our forces for scenarios similar to ours.

The mission of the blue teams, including the two ship captains protecting two major and six minor oil platforms off Basrah in the Persian Gulf, is to identify and to prosecute advancing terrorist fast attack craft and pirated aircraft. In each scenario run, one of the Naval officers plays the role of captain/TAO of the guided missile destroyer USS Winston S. Churchill with all its resources (e.g. guns, missiles, helicopter), the other Naval officer plays the role of captain/TAO of the guided missile destroyer USS Mason with all its resources and the Air Force officer plays the role of Air Operations Coordinator (AOC) – controlling all fixed wing blue aircraft in the simulation. A joint staff officer plays the role of the ashore higher level operational planner at CJTF who provides changes to the readily available additional blue forces, assistance with changes to the team plan, and timely alerting and delivery of relevant intelligence and changes to the ROEs over the net. Opposing these blue forces are a dozen terrorist fast attack craft, Boghammers, and two pirated Cessnas or two stolen MIG 29s under red control as played by a JTLS simulator operator. There are also two other blue ships, USS Arctic and USS Ardent, and dozens of neutral ships and commercial aircraft in the area. Each of the four slightly modified scenarios is divided into three time phases: TP1 consisting of Stage Setting and initial combat operations; TP2 consisting of Replanning triggered by a surprising new terrorist assault against oil platforms or US Naval ships, involving red fast attack craft or pirated aircraft, or an abrupt change in the ROEs from higher blue authority; and TP3 consisting of the End Game of the combat operation. The basic scenario is analogous to the Basrah terrorist incident of Spring 2004 as well as to Operation Praying Mantis of 1986, and bears some similarities to the March 2007 Iranian capture of 15 British sailors off Basrah. (See Fig. 1 below)

**Figure 1. UDOP Screenshot of Operation Storm Petrel Scenario**




**NCW Metrics.** For all four newly created four-man teams and for each time phase of all four trials, **Situational Awareness (SA)** is defined as the proportion of the crisis relevant, or mission critical, set of warfighting platforms in the battlespace, red, blue or neutral, correctly identified as important by the commander. (Hiniker & Entin, 1990; Hiniker, 2002; Perry et.al, 2004; Hiniker, 2005; Hiniker & Entin, 2006)) During the simulated combat operation, using the JTLS wargame simulator, the commander's realization of the situation, his Situational Awareness, is obtained by his drawing on a map the platforms he deems important at that time, i.e. by his personal Cognitive Operational Graphic (COG). The commander's proportion correct is then obtained by comparison with the platforms on the simulator's Ground Truth map at the same time. Greater overlap between the commander's COG and Ground Truth is indicative of greater Situational Awareness by the commander at the time. Greater overlap between the COGs of the team of three commanders is indicative of greater **Shared Situational Awareness (SSA)**.

(Hiniker, 2002; Perry et al, 2004; Hiniker & Entin, 2006)  Thus these SA metrics take account of the fit for each mission relevant weapons platform between its psychological world cognition, its information world record and its physical world ground truth existence. Such COG measures, together with a set of additional measures including current Plan quality and teamwork are obtained by trained observers for all commanders at the end of each of the three phases of each of the four combat scenarios.

**Planning quality (P)**, itself, is measured by summing, and then averaging for the team, the seven-point Likert scale observer evaluations of five items comprising the quality of performance of the stages of the OODA Loop planning cycle: observation, orientation, decisionmaking, execution, and overall planning and plan execution performance. (Hiniker & Entin, 2006)

**Speed of Command ($t_d$)** is measured by summing the team's time to size up the situation plus time to replan plus time to act plus time to complete the decision cycle with battle damage assessment and begin to review the new situation.  (See Measurement Appendix) Each replanning cycle begins with a surprising new, unanticipated move by red or with a higher level ordered change in the blue ROEs.  Thus Speed of Replanning, $\mathbf{t_r}$ , is the time taken within the new decision cycle between the team's newly sizing up the changed situation and the team's beginning the new course of action.

Finally, the **combat Effectiveness (E)** of the warfighting team for each time phase derives from the JTLS wargame simulator tally of the loss exchange ratio of warfighting platforms for the time phase, red losses/ red plus blue plus neutral losses. (Hiniker, 1991; Hiniker and Entin, 1992; Hiniker & Entin, 2006)

During the experiment all teams operate as "edge organizations" in that command is relatively decentralized, team member interactions are relatively unconstrained, and information is broadly distributed.  What differentiates the teams is the technology they use.  Four, four-man joint warfighting teams will prosecute the Operation Storm Petrel II scenario during 16 counter-balanced trials conducted in summer 2007 as a Limited Objective Experiment (LOE) at the JFCOM Joint Systems Integration Command laboratory under two different **technology treatment conditions:**

- In the **C2 Baseline treatment condition**, all four military players share the same GCCS COP view of the Gulf and communicate via CHAT, using the current intelligence product obtained under current time lines. This is the technology suite with which most of our players have operational experience.
- In the new **NCW treatment condition**, the airman receives track and intelligence data injects, and C2 common services tailored to air Community of Practice, the two sea captains receive track and intelligence data injects and C2 common services tailored to maritime Community of Practice, and the higher level planner at CJTF receives all of these data plus access to the Blue Force Readiness data base and all four warfighters jointly collaborate in combat using a common NCES e-collab whiteboard with drawing functionality and with VOIP and joined Operational Context with stated Commander's Intent forming a common Community of Action. Here all communications for the distributed team, including Operation Storm Petrel web portal access, information searches, and simulator and operational data base updates, are conducted over an IP broadband wide area network.

## A CAS VIEW OF NCW AND EXPERIMENT HYPOTHESES

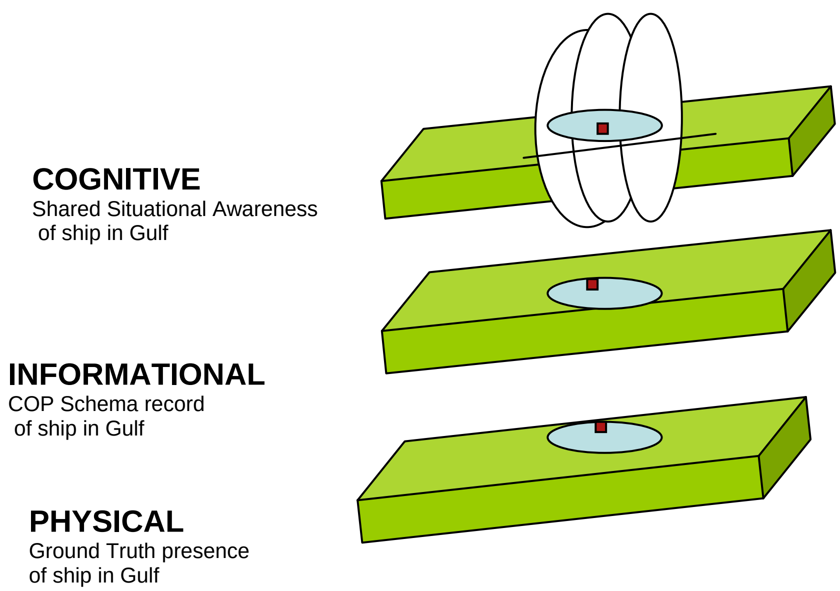
It is useful to conceive of the warfighting team, either distributed or local, as a Complex Adaptive System (CAS). The collaborative UDOP with associated distributed intelligence databases provide shared schema for the warfighting team, i.e. shared representations inside the warfighting team of the relevant external environment. (Hiniker, 2002) These shared representations or "schema" provide the CAS with descriptions, predictions, and prescriptions for effective interactions in the environment. (Gell-Mann, 1994; Gell-Mann, 1997) The UDOP represents the current situation; and the e-collab whiteboard permits shared graphic representation of future planned situations in the battlespace. The intelligence databases provide up-to-date information on the location of red warfighting platforms, i.e. red combat elements; and the readiness database provides information on the current readiness status of blue warfighting platforms, both local and global. Such informational schema, representing the relevant aspects of the situation and what to do about it, form the major portion of the relevant message traffic passed around the communications system, and taken together these messages constitute replicas of the state of the command decision process, itself. (See Girard, 1990) For the most part, in this “information world”, observations and assessments come in and go up; plans and directives come down and go out. (See Alberts, Garstka & Stein, 2000 for a useful, recent explication of the distinctions between the informational, cognitive and physical domains in C2 research)

The shared schema when internalized by human warfighters constitute shared mental models (Rouse and Morris, 1986), and should enable the warfighting team, conceived of as a unified CAS, to complete the group OODA (Observe-Orient-Decide-Act) Loop process more rapidly and effectively leading to greater combat effectiveness. UDOP schema should mainly aid SA of the battlespace; e-collab shared whiteboard schema should mainly aid Planning activities in the battlespace: and distributed intelligence and readiness databases contribute to both sets of processes. Internalized schema have proved useful to effective human action. Klein, for example, has demonstrated that schematic representations of prototypical situations are often directly associated with scripts that produce single step retrieval of actions from human memory, thus prompting rapid “recognition-primed decisionmaking.” (See Klein & Salas, 2001).

A mental model, or internalized schema, is a symbolic representation which may take one of two basic forms, linguistic representations and discourse models (See Chomsky, 1962). Discourse models make explicit the structure not of sentences but of situations as we perceive or imagine them (Johnson-Laird 1983, p. 419). Indeed pure linguistic representations do not say anything about how words relate to the world; whereas a discourse mental model, or “picture” model in the conception of Wittgenstein (1922), represents the reference of discourse, i.e. the situation that the discourse describes. The COP, for example, provides such a “picture” model that should be an aid to a team’s sharing accurate discourse models of the battlespace (Hiniker, 1998). Whereas there may be many different discourse models available in a warfighting team, for a given individual at a given point in time his “Situation Awareness” reflects the current state of his mental model of the situation (Endsley 2000, p. 12). Endsley, working primarily with fighter pilots and air traffic controllers, has demonstrated that better “situation awareness” is “probabilistically linked” to better performance. (See also Hiniker & Entin, 1990) In short, mental models of the situation and goals, e.g. “Commander’s Intent” or team mission, help select what information from the welter in the environment is attended to and thereby help increase the likelihood of better decisions and better performance of action.

Since the informational schema are shared as mental models by human warfighters, their effectiveness is, of course, subject to the human cognitive constraints of bounded rationality, analogous to the effects of channel capacity constraints on the speed of information transmission over a network: Performance impairing information overload can and does occur at both the cognitive and the informational levels of a socio-technical system. (Levis et al, 1987; Hiniker, 2002) Finally, at the “ground truth” level of the physical world, as well, human actors, sensors, weapons platforms, communications networks, and associated software and data bases can and do become impaired in the course of warfare. (See Fig. 2 below)

**Figure 2. Three Viewpoints on Elements in the Battlespace**



Thus the interactions of the schema-sharing CAS with its environment entail both simple linear and complex non-linear relationships. Human information overload is an instance of a non-linear relationship in that a small positive change in informational workload near the cognitive crash threshold results in a very large degradation in performance. Furthermore, new incoming information to a human actor is not necessarily automatically believed and internalized as part of the mental model; if the new information is dissonant with current belief it may be dismissed, denigrated or otherwise modified. (See Festinger, 1957) Finally, most network interactions involving humans are not simple random network interactions; rather they usually involve “small world” nets including shortcuts or “scale free” nets including hubs and may, under certain conditions, exhibit non-linear “percolation effects” (Moffat and Atkinson, 2005) Here the focus will be upon the existence, rather than the form, of causal relationships between a warfighting team’s use of shared informational schema, contributing to their shared mental models, and the consequent effectiveness of their operations in the battle space. (See Pearl, 2001) Several causal hypotheses regarding expected empirical relationships are proposed below.

**Hypothesis 1.** By facilitating the development of more accurate and more complete shared mental models, use of the collaborative UDOP with associated distributed data bases by a warfighting team causes significant improvement in their Situational Awareness (SA). (See Hiniker & Entin, 1990). This effect should be amplified in scenarios in which the assessment is highly uncertain, i.e. situations in which there are many ambiguous fast moving tracks of potential mission relevance. The tailored expert views afforded by UDOP coupled with the broader channel for team communication provided by the e-collab shared whiteboard coupled with audio should help mitigate the information overload when compared with use of the baseline COP/CHAT technology.

Access to the distributed intelligence and readiness databases should contribute to the accuracy of their Situational Awareness.

**Hypothesis 2.** By facilitating information sharing and group consensus on the important and relevant weapons platforms in the situation, use of the collaborative UDOP with associated distributed databases by a warfighting team causes significant improvement in Shared Situation Awareness (SSA) across the team..

**Hypothesis 3.** By facilitating information sharing and group consensus, use of the collaborative UDOP with associated distributed databases by a warfighting team increases the quality or desirability of their developed Plan (P).

**Hypothesis 4.** This, in turn, increases the synchronicity of the warfighting team's action (A), leading to greater Combat Effectiveness (E).

**Hypothesis 5.** Use of the collaborative UDOP with associated distributed databases should increase the speed with which the warfighting team typically completes the OODA Loop ($t_d$), including the speed of replanning, $t_r$ , also leading to greater Combat Effectiveness (E). (See Appendix for measurement definitions of terms)

## RESULTS

The analysis of the results of hypothesis testing in this experiment will utilize the techniques of Analysis of Variance (ANOVA), following a counter-balanced, within subjects design, to determine whether or not use of the collaborative UDOP with associated distributed databases technology enabled the warfighting teams to perform significantly more effectively on the NCW performance metrics examined when compared to their use of the baseline technologies. Use of these quantitative performance metrics also permits one to estimate the values of the NCW parameters exhibited by the warfighting teams, under each of the treatment conditions. In addition to these objective performance measures, subjective evaluations by the participants of the two sets of technologies will also be solicited and analyzed. We intend to use a modified version of the standard JDCAT measuring instrument for the purposes of gathering such warfighter opinion

## CONCLUSIONS

In this controlled HITL experiment we plan to introduce new NCW technology to sixteen experienced warfighters in the form of a collaborative User Defined Operational Picture with associated distributed intelligence databases accessible over a wide area network to enable a possible improvement over their performance with current baseline technology. The findings from this experiment will have implications in three major areas: the possibility of testing causal hypotheses on the effectiveness of new information technology for the warfighter in a controlled laboratory environment; the related possibility of developing a program systematically to evolve more effective information technology that accumulates greater capability over time; and the possibility of developing more general theory on the determinants of effective behavior of warfighting teams viewed as Complex Adaptive Systems, involving men and machines.

First of all, we have demonstrated with this HITL Lab experiment and several earlier experiments ( Hiniker & Entin, 1990, 1992 & 2006) that one can test causal hypotheses on the impact of new information technology for creating significantly more effective combat decisionmaking by warfighters. (TTCP, 2006)

It follows from the above that such HITL experimentation can be useful in the evolutionary development of more effective information technology for the warfighter We can, and have, built upon and compared our evolving new technology with a rising baseline of improved technology that leads to demonstrably improved operational performance over the decades. In particular, we have developed C2 technology which significantly improved the warfighters' Situational Awareness and technology which significantly improved the warfighters' measured combat Effectiveness. To increase the efficiency of developing such technology, one can usefully employ these methods of controlled experimentation with prototypes as early Operational Assessments for Test and Evaluation of emerging C2 technologies. (DoD/DAU, 2003) The results of our last warfighting experiment are encouraging in this regard. They showed significant improvements in Situational Awareness, Shared Situational Awareness and bottom-line combat Effectiveness across several phases of the scenario played out by the teams due to use of the new collaborative UDOP. (Hiniker & Entin, 2006). The superiority of the collaborative UDOP technology over the current baseline technology on these NCW metrics was especially pronounced in the post-replanning phases of the scenario. Furthermore, the quality of Planning, itself, when warfighters were using the collaborative UDOP, was consistently and significantly superior to that using the baseline technology for all phases of all scenarios. The current planned experiment, involving network access by the warfighters to additional distributed planning databases, should build upon this demonstrated advantage provided by the collaborative UDOP technology for improved combat planning by a distributed warfighting team.

Finally, Complex Adaptive Systems theory, explicitly involving informational schema, offers an illuminating approach to these information technology development issues. Better schema, i.e. internal models that describe, predict and prescribe actions in the battlespace, when shared and internalized by members of a warfighting team, should make for greater combat effectiveness. It seems self-evident that a more complete and accurate picture of the battlespace will better describe it and thereby enable more effective combat action by a warfighting team that shares the picture. Indeed, experimental evidence shows that COP, and now the advanced UDOP, yield improved Situational Awareness and improved combat Effectiveness. What is not so obvious is that the type of shared schema, whether a linguistic model or a discourse (picture)model, should make an important difference to the team's combat Effectiveness. The results we have obtained so far strongly suggest the superiority of a shared discourse model of the battlespace, e.g. COP or UDOP, over a shared linguistic model, e.g. information relayed via CHAT, especially when it comes to quality operational Planning by the warfighting team. We await more experimental evidence for more definitive answers to such questions.

## APPENDIX

### Measurement Definitions for Collaborative UDOP Replanning Delta LOE

- **Situational Awareness (SA)** = Proportion of mission critical set of warfighting platforms in the battlespace correctly identified by a warfighter (Ground Truth cf. Cognitive Operational Graphic ( COG) @ $t_i$)

- **Shared Situational Awareness (SSA)** = Proportion of overlap between pairs of COGs for complete warfighting team.

- **Plan Quality (P)** = Accuracy of knowledge of scheduled sequence of blue moves. (See text on Likert scale planning process evaluation scoring method)

- **Speed of Command** ($\mathbf{t_d}$ = $t_c + t_r + t_a + t_b$ ), where total speed of command is the sum of time to size up situation + time to plan + time to act + time to complete decision cycle with battle damage assessment

- **Combat Effectiveness (E)** = Loss/Exchange Ratio= red platform losses / (red + blue + neutral losses)

- **Subjective Opinion of Operational Value of Technology** = Participants' scoring of value of the technology on seven point Likert scale.

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