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Maritime Operations Centers with Integrated and Isolated Planning Teams

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Topics: Topic 1: C2 Concepts, Theory, and Policy
Topic 5: Experimentation and Analysis
Topic 8: C2 Assessment Tools and Metrics

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Maritime Operations Centers with Integrated and Isolated Planning Teams

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ABSTRACT

The Maritime Operations Center (MOC) was designed to effectively utilize the planning elements of Future Operations (FOPS) to provide more rapid, accurate resource allocations consistent with the vision of the Commander. MOC staff simultaneously participate in the planning effort, while executing the current operation, and supporting headquarters during planning and execution. Frequently, an operational planning team (OPT) – a task-organized team formed to conduct integrated planning for a specific mission – is formed by the MOC because it offers the advantage of a focused group of subject matter experts approaching the problem in an integrated manner. However, performance problems may be realized with the OPT being isolated in situations that require the OPT to coordinate closely with the rest of the MOC. An experiment was conducted in which the MOC planned with either an integrated or an isolated planning team where the (1) FOPS team was supported by a decision aid/ planning tool that fosters coordination or (2) FOPS team used a planning tool with a reduced coordination capability. In line with the theme of this year's symposium – The Evolution of C2 – this paper describes an experiment conducted to gain insight into advantages and disadvantages associated with forming an OPT.

INTRODUCTION

As part of the Office of Naval Research (ONR) Adaptive Architectures for Command and Control (A2C2) program, the Naval Postgraduate School (NPS) has been conducting empirical research to design and analyze adaptive C2 structures for future U.S. Navy and Joint forces. (Diedrich, Entin, Hutchins, Hocevar, Rubineau, & MacMillan, 2003; Entin, Diedrich, Kleinman, Kemple, Hocevar, Rubineau, & Serfaty, 2003; Hess, Entin, Hess, Hutchins, Kemple, Kleinman, Hocevar, & Serfaty, 2000; Levchuk, Kleinman, Pattipati, Kemple, & Luoma, 2000; and Hutchins, Kemple, Kleinman, and Hocevar, 2005). Through the integration of analytical modeling, human-in-the-loop experimentation and computer simulation, this research has followed a "model-test-model-experiment" paradigm wherein models and associated simulations define and guide experiments, and the results from the experiments are fed back to improve and enhance the models.

The A2C2 program has transitioned its research results to the Navy on a number of issues. The models were used to provide input and support to several commands regarding implementation of FORCENet, Expeditionary Strike Groups (ESGs) and the Maritime Operations Center (MOC). For example, the A2C2 models were used by the Strategic Studies Group when examining ways to implement FORCENet concepts. Two organizational structures were designed for Carrier Group One (CARGRU-1) that were used in a one-week experiment at NPS and then CARGRU-1 employed one of these structures during GLOBAL 99. Following this effort, A2C2 was asked to explore the adaptive command and control (C2) construct in support of the newly emerging ESG concept. Based upon our interaction with ADM LeFever the A2C2 project was asked to experiment with C2 issues related to Expeditionary Strike Groups (ESG). Based on validated results we were asked to remain involved in ESG research.

In recognition of recent needs for organizational change within the Navy the A2C2 research program has developed a multi-disciplinary research agenda to conduct experimentation on issues critical to Maritime Operations Centers (MOC). Objectives for this year's empirically-focused research are twofold, to: (1) continue our model-based experimentation and (2) explore new paradigms for empirical studies of adaptive C2 architectures for MOC laboratory research. Our research method for this new focus area on MOC C2 structures and processes entails (*i*) identifying key C2 issues via literature and attendance at MOC events, (*ii*) interacting with the Fleet and other subject matter experts, and (*iii*) analysis of selected points and paths in the research space via A2C2 model-driven experimentation. Potential research issues and questions include identification and exploration of potential "trouble spots" and recommending alternative organizational structures and processes; adaptation and scalability across structures and processes; and coordination with *external* forces and entities/agencies including information and command flows in combined operations and coordination between MOCs.

A MOC empirical research campaign is underway where the emphasis is on *operational versus tactical* activities, and *planning versus execution*. Because of its complexity, its mission to oversee large operations, and its dynamic structure, the MOC is an ideal organization for research on organizational structures, C2, and the process of mission planning. Since the MOC was designed to effectively integrate the planning elements of Current and Future Operations (COPS and FOPS) to provide more rapid and accurate resource allocations that are consistent with mission requirements, our first experiment focused on the MOC with emphasis on intelligence, surveillance, and reconnaissance (ISR) (Hutchins, Kemple, Kleinman, Miller, Pfeiffer, Weil, Horn, Puglisi, & Entin, 2009). Two alternate structures for ISR personnel were: (1) centralized in a stand-alone ISR cell or (2) decentralized by embedding an ISR capability into both the COPS and FOPS cells.

Teams with an independent ISR cell were associated with more effective FOPS plans and exhibited a trend of higher performance across most major performance variables. Teams with an independent ISR cell received the highest ratings across all observer-based measures of cell coordination, cell orientation, cell monitoring, and quality of actions taken by cell members. Teams with embedded ISR reported significantly higher perceptions of social cohesion and mission cohesion than teams with independent ISR, and reported higher values of perceived teamwork process and cell efficiency. Latencies were no different between teams, cells, or FOPS tasks, and were not related to performance across teams/tasks/cells. On this highly-structured, iterative task, the advantages of team process (familiarity, cohesions, efficacy) that were gained by embedding ISR within FOPS and COPS were overshadowed by the ability for COPS/ISR to work in parallel in separate battle areas.

Among the most salient scientific contributions of the A2C2 program to C2 research is the conduct of model-based experimentation. Analytical models are used to guide experiments via *a priori* predictions of performance and process measures across alternative C2 structures, and by conducting sensitivity analyses to suggest values for design parameters so that the experiments are conducted in regions where the dependent variables (DVs) are sensitive to changes in the independent variables (IVs). Models are also used as a reference or guidepost for examining the DVs and collected data, primarily via model-data comparisons. For experiment MOC-1 "optimal" resource allocation and scheduling algorithms, developed by the University of Connecticut were used to determine the parameters for the planning task (Mandal, Han, Pattipati, & Kleinman, 2010). These included the number of assets each FOPS planner would be assigning, the number of tasks that these assets would need to be assigned to, and the resource requirements of the individual tasks. Model outputs included the optimal assignment accuracy, such that tasks were adjusted so that the planning exercise could indeed be attained with 85%+ accuracy. In turn, this provided mission guidelines and requirements that were placed on the FOPS planners, as well as a way to evaluate the produced plan post-experiment.

This year NPS maintained its research objective to evaluate, via empirical study, alternative C2 concepts for the MOC at the operational level of war. Our approach utilized model-based experimentation, with particular emphasis on simulator-embedded models for decision aids and agents to assist and augment human participants.

BACKGROUND

The MOC is a distinct functionally organized element of the Maritime Headquarters which conducts planning, and directs, monitors, and assesses functions in support of combat across the full range of military operations. Current Operations (COPS) focuses on monitoring and assessing the execution of the commander's intentions. Future Operations (FOPS) conducts operational-level planning for near-term operations.

Navy strategy envisions a network of scalable maritime headquarters, with agility to transition between command roles, and to deploy forward command elements rapidly as needed to meet the requirements of the Combatant Commander. Senior Navy leaders have stated a need to refocus and enhance the Navy's ability to function at the operational level of war and to train commanders capable of commanding at that level (U.S. Fleet Forces Command, 2007). MOCs were conceived to enable these capabilities while providing a degree of standardization among the maritime headquarters (MHQ with MOC CONOPs, 2007). The initial plan establishes MOCs for each of the numbered fleets (e.g., the Seventh Fleet in the western Pacific Ocean, the sixth Fleet in the Mediterranean, etc.). The emerging "Maritime Headquarters with Maritime Operations Centers" concept may also have a role in maritime domain awareness (MDA), a key concept of the Navy's new maritime strategy, *A Cooperative Strategy for 21st Century Seapower* (www.navy.mil/maritime/MaritimeStrategy.pdf).

Navy Operational Planning

Naval forces have traditionally embraced a fluid form of fighting known as maneuver warfare which causes surprise and confusion within the enemy ranks giving naval forces an advantage. In major regional conflicts, the primary warfighters (the geographic combatant commanders) are the supported commanders. They are responsible for carrying out national tasking as well as conducting and coordinating operations within their theater. Based on the magnitude of the task, the unified commander may need to delegate some planning to supporting and subordinate commands. Delegation ensures that the subordinate staffs who are most familiar with the capabilities and limitations of assigned forces, are included in plan development. As a result, each level contributes uniquely to the plan. Like the governing operation order, the naval plan tests for adequacy, feasibility, and acceptability. Naval staffs are best able to determine whether plans developed by subordinates can accomplish the mission and be executed with available resources. We instantiated this hierarchical relationship between the MOC and subordinate forces in the experiment by having subordinate task forces as the lower entity that MOC planners sent their orders to.

Integrated Product Teams

An integrated product team (IPT) is a management technique employed in the private sector that simultaneously integrates all essential acquisition activities through the use of multidisciplinary teams to optimize the design, manufacturing, business, and supportability processes. The idea is to move away from hierarchical decision making to a process where decisions are facilitated across organizational structures by IPTs (DoD, 1996). The process is designed to facilitate decision making by making decisions and recommendations based on timely input, where an IPT replaces the traditional sequential review and approval process (DoD, 1999).

In 1995, then Secretary of Defense mandated that the DoD perform as many acquisition functions as possible using IPTs. IPTs are advisory bodies to the program manager where a key tenet is to resolve issues and concerns at the lowest level possible, and to expeditiously escalate issues that need resolution at a higher level. Advantages afforded by an IPT are that they: (1) streamline an inefficient process; (2) take advantage of all members' expertise and produce an acceptable product the first time; and (3) focus on a particular topic. Survey results indicate the process shortens the timeline, reduces life-cycle costs, while continuing to meet warfighter's needs (while maintaining, and often increasing, quality) (DoD, 1999)

The purpose of an IPT is to reach agreement on a strategy and plan by identifying and resolving issues early, based upon understanding issues and the rationale for the approach being used. An IPT relies on applying functional expertise in a team-oriented manner and understanding customers (command structure, doctrine, tactics, operational environment), and integrating user's requirements, logistical requirements and constraints. Principles employed by IPTs stress a spirit of teamwork, where participants are empowered and authorized to the maximum extent possible. These principles include the following: (1) Each team member brings unique expertise that needs to be recognized by all; (2) Each person's views are important and need to be heard; this includes full and open discussions, where cooperation is essential, based upon reasoned discussion; (3) A sense of ownership is key to success, where all must feel their contributions are important and are well considered, and decisions are a product of the team.

Empowerment is critical, including frequent communication with their leadership. Qualified members must be professionals who are: (1) current in their functional area; (2) knowledgeable in the mission and organization they are representing; (3) trained in the use of and participation in IPTs. Membership should be limited to the minimum essential to enhance communication and trust and participation should be by principle member. IPTs should be considered when there are requirements for multi-functional expertise, to address multi-faceted, complex situations and issues. The focus is on addressing issues that require balancing cost, schedule, and performance, and having clear objectives.

An underlying premise is that forming an IPT with members who represent the range of skills needed for the entire process should enable teams to consider more and a broader range of alternatives quickly, and in a broader context, and enables better and faster decisions. Once on a team, the role of an IPT member changes from that of a member of a particular functional organization, who focuses on a given discipline, to that of a team member, who focuses on a product and associated processes.

Operational Planning Teams

Operational Planning Teams (OPT) represent the military's implementation of an IPT. When an OPT is used the focus is on an *integrated* approach to planning (MCWP 5-1, Marine Corps Planning Process). Integrated planning does not replace normal staff planning, but increases the staff's participation by demanding greater planning input. Principal and special staffs must have representation within an OPT to ensure the warfighting functions are appropriately represented for integrated planning to occur. Each primary and special staff must be represented in the OPT, as well as all adjacent, subordinate and supporting commands, and as required, subject matter experts (SMEs) are added to the team.

Planning by an OPT considers the warfighting functions during planning, thus eliminating many of the omissions that proved fatal in the past, and is better able to visualize the interactions that will occur in execution. For example, previously the command element would recommend a mission and default the planning to the Ground Control Element (GCE) who would then plan in a vacuum. There was the potential for no consideration of the capabilities and limitations of other elements of the Marine Air Ground Task Force (MAGTF) during the GCE's planning. Now the Marine Corps fights and plans as a MAGTF – the OPT is at the heart of the MAGTF's operational planning, supplemented by staff action and coordination.

Whether for business (IPT) or military (OPT) the emphasis is on the use of an integrated approach during the planning process. The focus is on consideration of capabilities and limitations of all other elements on the process. Because they are organized to be less hierarchical during planning they are able to bring all representatives together. Staff representatives must keep a two-way information flow going between the OPT and the staff and must avoid getting blind-sided by a principle staff officer during a brief to the commanding general.

One result of implementation of an OPT is an increase in situation awareness throughout the force. Results of implementing an OPT are generally better and faster decisions. Since MAGTFs fight as part of a Joint Task Force (JTF), the OPT is also linked to higher, adjacent, and other units through use of liaison officers (LNOs). Therefore, the entire plan has considered all the capabilities and limitations of the JTF across the warfighting functions and throughout the Joint Area of Operations (JOA). Everyone concerned will know the capabilities and limitations of logistics and the combat service support element (CSSE), which will ensure maximizing the combat power of the force. An OPT offers benefits that are analogous to those provided by IPTs, that is, all aspects of the (design) process will be represented so all these elements can be considered early and produce a better system or plan.

An OPT is normally formed around a core of planners from either Future Plans or Future Operations and draws members from both FOPS and COPS. The OPT is completed with representatives from various other staff sections and organizations that can provide SMEs required to address mission requirements. An advantage of an OPT is a focused group of SMEs approaching the problem in an integrated manner, however the division of responsibilities between the OPT and the principal, or designated staff ("battle staff") may become confused. A common misconception is that an OPT is viewed as a substitute for normal staff action and coordination. When this occurs, the staff tends to be disengaged from the planning effort, and the OPT is left unsupported in terms of staff estimates and guidance. The result is that the OPT may be unable to develop plans that are complete, supportable, and synchronized.

Frequently, an operational planning team – a task-organized team formed to conduct integrated planning for a specific mission – is formed by the MOC because it offers the advantage of a focused group of subject matter experts approaching the problem in an integrated manner. However, problems may be associated with their being somewhat isolated in situations that require the OPT to coordinate closely with the rest of the MOC. The OPT small group construct may lead to OPT isolation from the rest of the MOC staff despite being in a situation requiring close cross coordination with other staff in the MOC. In line with the theme of this year's symposium – The Evolution of C2 – this paper describes an experiment conducted to gain insight into the advantages and disadvantages associated with forming an OPT.

Hocevar and Owen (1998) identified critical issues that must be managed to achieve the desired outcomes associated with IPTs. They describe organizational-level factors, group-level factors, and individual factors. The business literature on large-scale change articulates that organizations are complex open systems and as such change must simultaneously address structure, technology, human resources, and tasks (Galbraith, 1989; Nadler, 1981). While teams provide a mechanism to increase flexibility of performance in the context of increasing environmental turbulence (Hocevar & Owen, 1998), decisions regarding whether and how to structure teams need to consider potential limitations that can result from the new structure. Structural changes require analysis of tasks and interdependencies as well as determination of appropriate integration mechanisms (Hocevar & Owen, 1998). Processes must be analyzed to determine what sets of activities have to be integrated with each other to provide increased value. In line with the goal of developing a better understanding of the conditions when standing up an OPT may produce undesired side effects, we are investigating one factor associated with formation of an OPT, namely how this structural change will impact task performance by virtue of OPT isolation.

METHOD

The objective of this experiment was to examine the potential problems that could arise when forming an OPT. The overarching *research question* seeks to understand how are emergent events best handled when resources must be shared among separate planning teams? For example when an Operational Planning Team is formed. The current study was designed to examine the efficiency and planning performance of two alternative organizational structures: (1) *Integrated* – where planning teams plan with a real-time view of others' resource planning and (2) *Isolated* – where planning teams operate in isolation, without the ability to directly view others' resource planning. The first experimental hypothesis was that "integrated teams create more effective plans than isolated teams due to their real-time awareness that enhances the interdependent solution. Our second experimental hypothesis was that isolated team member experience high levels of workload than integrated team members because their lack of real-time planning status requires more frequent status related communication in addition to collaborative effort. Our third experimental hypothesis was that isolated team members communicate more frequently in response to emergent events because isolated team members must communicate to learn how others alter plans in response to unexpected events.

Some MOCs form an OPT when a new crisis arises or a new unanticipated task needs to be accomplished. In these situations, some MOCs form an OPT, others do not. It has been observed during the Naval Staff Officers Course, that some OPTs tend to work in isolation, which can cause problems if their plans overlap – either in terms of the assets needed or operations – with the plans of the main body of the MOC. Our goal was to gain insight into performance differences for teams planning within a MOC where they planned with a sub-team of the MOC that either had full access to other planners' information, i.e., they were fully integrated, or the sub-team was isolated from the MOC. The isolated case was meant to serve as a surrogate for an OPT. The specific task entailed assigning resources to tasks and monitoring the effectiveness of task accomplishment and then replanning for the next day based on performance at the end of each day.

An experiment was conducted where the MOC planned in the condition where either the FOPS team (1) was supported by a decision aid/ planning tool that fosters coordination across planners or (2) planned with a planning tool with a reduced coordination capability. These FOPS planners were all planning for use of the same resources and all planning for mission task accomplishment at the same time, which was likely to cause conflict regarding asset availability when multiple people request the same Task Force to perform tasks. We hypothesized if the planners did not collaborate to coordinate asset assignments problems would arise.

Participants

Twenty-four students in the Graduate School of Operational and Information Sciences, at the Naval Postgraduate School (NPS), Monterey, CA, served as experimental participants during a ten-hour experiment conducted 1-12 March 2010. Their mean age was 33.4 years; services represented were Navy, 17, Marine Corps, 6, and Army, 1. Participants' rank ranged from 0-2 to 0-6. Six teams of four players participated in the experiment where each team consisted of four Future Operations (FOPS) players in line with the emphasis on planning at the operational level of war – the focus for Maritime Operations Centers.

Planning Task

Planning for the area of responsibility was divided among the four FOPS players. A player was responsible for planning in either Area A or Area B and was also responsible for planning for either the next day or two days into the future. This divided the planning tasks to make each person's task manageable. It also resembles the way planning is accomplished in a MOC, where the FOPS team segments plans for various plan phases. Each team was assigned to one of two experimental conditions: (1) the FOPS team members, when convened, had access to a planning tool that displayed planning progress on all tasks by all planners or (2) FOPS team members had a limited version of the planning tool that did not display planning progress for other planners.

A confederate played the role of a COPS member to simulate the exchange of information that occurs between COPS and FOPS. The COPS player sent situation reports (SITREPS) and casualty reports (CASREPS) via Chat over the course of the two-hour blocks to provide updates on execution of the plan. Information in these SITREPS and CASREPS had to be considered by the FOPS planners as it impacted the planning process.

Outline of Events

The experiment was conducted in four time blocks, spread over several days. Block 0 consisted of an introduction to the experiment, including a brief on the mission, and initial training and practice on their responsibilities. Following this, FOPS players were trained in their role as planners, practiced using their respective planning and monitoring tools, and communicating via Chat.

Block 1 comprised the first 2-hour set of the experimental task which began in Phase 1 (where time = today) with a pre-determined (i.e., “yesterday’s”) FOPS plan implemented in the distributed dynamic decisionmaking (DDD) simulation. The DDD is a simulation tool that was used to display locations of assets. The goal during Block 1 was to plan for Blocks 2 and 3. The plan for Block 3 was modified in Block 2 as well. FOPS obtained updated information from COPS throughout the experiment and planned for the next two Blocks. The FOPS planning update was briefed to the MOC Director and submitted as a new plan at the end of Block 1. The plan for Block 2 was implemented at the tactical level in DDD at the beginning of Block 2.

Block 2 was the second 2-hour set of the experimental task. Note: Block 2 began with the implementation of the FOPS participants’ plan produced in Block 1. FOPS planned for Blocks 3 and 4. The plan for Block 4 was modified in Block 3 as well. At the beginning of Block 2, an emergent threat was announced such that the MOC would be assuming responsibility for a second area of tasks, with no increase in resources to handle the load.

Block 3 comprised the third 2-hour set of the experimental task. The most recent Block 3 plans from FOPS were implemented to begin Block 3. FOPS planned for Blocks 4 and 5. Block 5 plans were not implemented in this experiment. A briefing with the MOC Director was held at the end of Block 3.

Block 4 was the fourth 2-hour set of the experimental task. The most recent Block 4 plans from FOPS were implemented to begin Block 4.

Commander’s Update Briefings: The MOC Director (played by an experimenter) presented the Commander’s Update Briefing at the beginning of each experimental session where he reviewed the scenario, including the Time-Phased Force Deployment Data (TPFDD) – the arrival schedule of forces into theater, and the task graph. Figure 1 presents a sample task graph used for the Commander’s update brief where days correspond to blocks. Commander’s guidance for task execution was given to indicate task priorities and key prerequisites for day T+1 (i.e., tomorrow) and T+2 (i.e., day after tomorrow) planning.

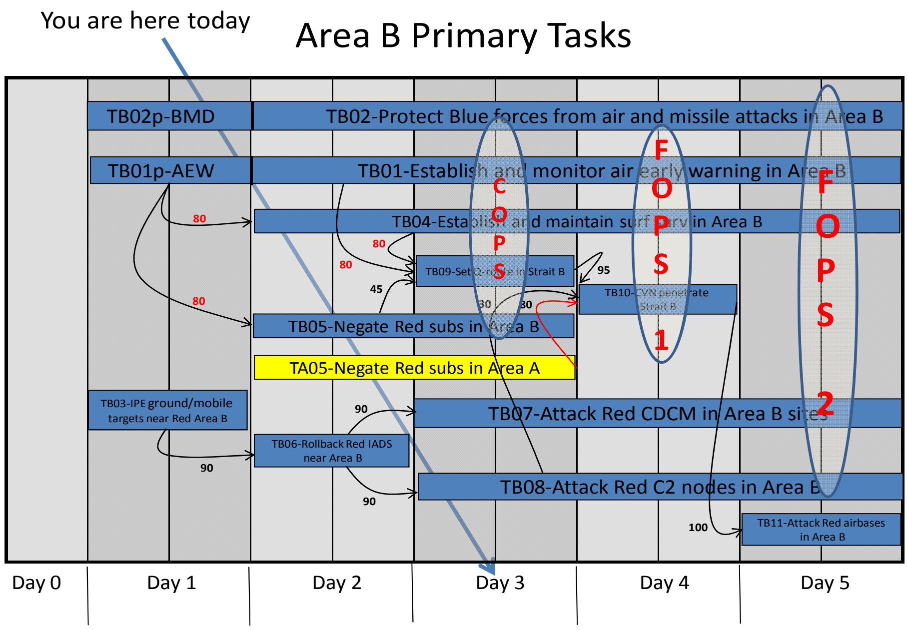


Figure 1. Sample Task Graph used for Commander's Update Brief.

Measures

Measures included performance-focused measures, measures of perceived workload, information need and availability, team process, and communication effectiveness. We report on several of these measures here. Additional analysis is ongoing and will be included in the presentation.

Experimental Design

Decision-aid tool availability was manipulated as our primary independent variable as the objective for this research is to gain insight into the advantages and limitations associated with integrated versus isolated planners. Decision-aid tool availability had two levels: (1) whether the FOPS team conducted planning using the full FOPS tool – where players could see planning progress on others' tasks, or (2) a reduced FOPS tool was used which did not facilitate coordination across planners, that is, the planner could only see his/her own tasks. In the reduced-tool condition, when planners submitted their plan to the subordinate task forces, via the agent included in the tool, the agent informed the planner of the asset-to-task mapping it would recommend, and indicated whether its earlier recommendations to other planners included those same assets. This condition subsequently required communication between planners to resolve asset-to-task conflicts before submitting a joint plan). [Note, the FOPS planning tool and the intelligent agent are described in the next section.]

Materials and Scenario

A number of scenario injects were crafted in the form of casualty reports (CASREPS) and situation reports (SITREPS) to cause changes regarding the planning tasks over the four time blocks. These included changes in asset availability that occurred over the course of the scenario to reflect real-world situations, e.g., a catapult on the carrier goes down, an aircraft system incurs a problem, or a missile launcher is temporarily reduced to 50% capability. All information arrived on an a-periodic basis, at various time intervals.

Updates were sent by COPS (played by a confederate, or the white cell) and passed to FOPS regarding the following: (1) performance on individual tasks (accuracy and percentage completed) for that day and (2) reports on asset capabilities, such as, when systems were back up to full capability.

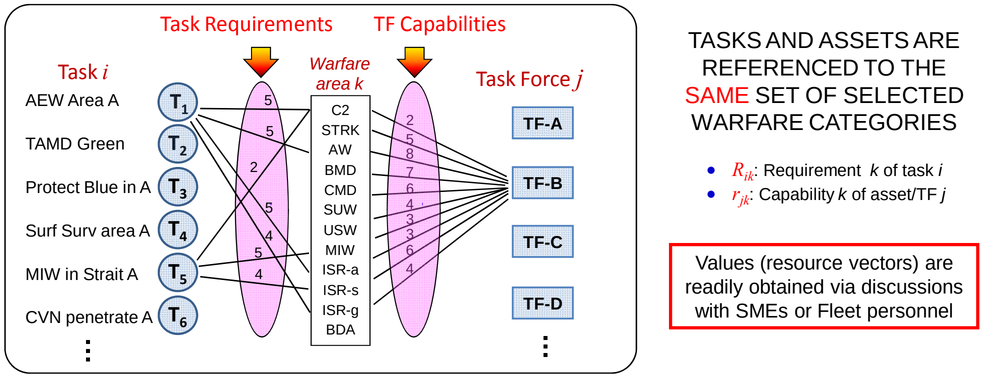
Future Operations (FOPS) Planning Task

FOPS planners were charged with translating the mission and selecting a course of action (COA) to instantiate a plan for that mission. They considered available forces, to request support for execution of the mission tasks for which they were responsible (from subordinate task forces either as the primary task force responsible for execution of the task, or as in a secondary role as a supporting task force). Then they determined how they could meet their planning needs within the next 24 hours, and 48 hours, and assigned task forces as either primary or supporting for the given tasks. FOPS also monitored the information received in the CASREPS and SITREPS to ascertain the implications of this new information.

FOPS Planning Tool

A planning tool developed to facilitate the planning process was provided to all four FOPS players. Our MOC-2010 experiment utilized analytical models in a relatively new and expanded manner by embedding analytical models within an on-line decision aid for asset allocation and planning. This decision-aid module was developed and implemented by the University of Connecticut (Mandal, Han, Pattipati, & Kleinman, 2010; Han, Mandal, Bui, Martinez, Sidoti, Pattipati, & Kleinman, 2010). This work presents a step forward in the design of decision aids (and agents) for human-in-the-loop planning activities.

Figure 2 depicts the modeling formalism used to match tasks to assets. This was accomplished by quantifying the amount of warfare capabilities required to accomplish each of the tasks in the scenario and quantifying the amount of warfighting capability provided by each Task Force. For example, in Figure 2 we see conducting Task T1, air early warning (AEW) in Area A, requires 5 units each of C2, air warfare, and ISR-air, and 4 units of ISR-ground capability. Similarly, the amount of each of the warfighting capabilities provided by each Task Force is specified. (These values were obtained through discussions with subject matter experts.) FOPS planners assigned each task to a Task Force, and also specified performance goals and priorities for accomplishing each task. These requirements were then “submitted” to the subordinate Task Forces by entering them into the tool. The Task Forces then determined, via the agent, how best to utilize their assets to meet the specified performance goals.



- TF LEVEL CAPABILITIES ARE ROLL-UPS OF THE INDIVIDUAL ASSET CAPABILITIES

	C2	STRK	AW	BMD	CMD	SUW	USW	MIW	ISR_a	ISR_s	ISR_g	BDA
CVN-1	6	6	5		2	6	2	1	**4**	**6**	2	6
CG-1	3	4	8	7	6	4	4	3	6	5		
DDG-1	2	5	8	7	6	4	3	3	6	4		
DDG-2	2	5	8	7	6	4	3	3	6	4		
FFG-1	1	1	4		2	2	4	3	2	4		
Total TF-A	**14**	**21**	**33**	**21**	**22**	**20**	**16**	**13**	**24**	**23**	**2**	**6**

- FOPS ASSIGNS EACH TASK TO A TF, with PERFORMANCE GOALS and PRIORITIES
  - One **primary** TF, with others assigned as **supporting** in one or more warfare areas
  - **The TFs** determine how to best utilize their assets to meet performance goals

Figure 2. Modeling Formalism: Matching Tasks to Assets.

The FOPS planning tool is an interactive computer-based tool that provides the ability for the planner to assign mission tasks to subordinate task forces. Players were given a set of constraints they needed to consider during the planning process. These constraints included the following: (1) no subordinate task force (STF) can have primary responsibility for more than four concurrent tasks, (2) a STF can have a supporting role for no more than two concurrent tasks, and (3) there can be no more than two supporting TFs on any given task. Once a FOPS planner had designated STFs, as either supported (primary) or supporting (secondary) for all tasks for which he/she was assigned responsibility, the plan was "submitted." An agent-based Task Force algorithm was then run to determine assignments based on the expected performance levels designated by the FOPS players for all tasks, similar to the way planning is conducted at the operational level of war.

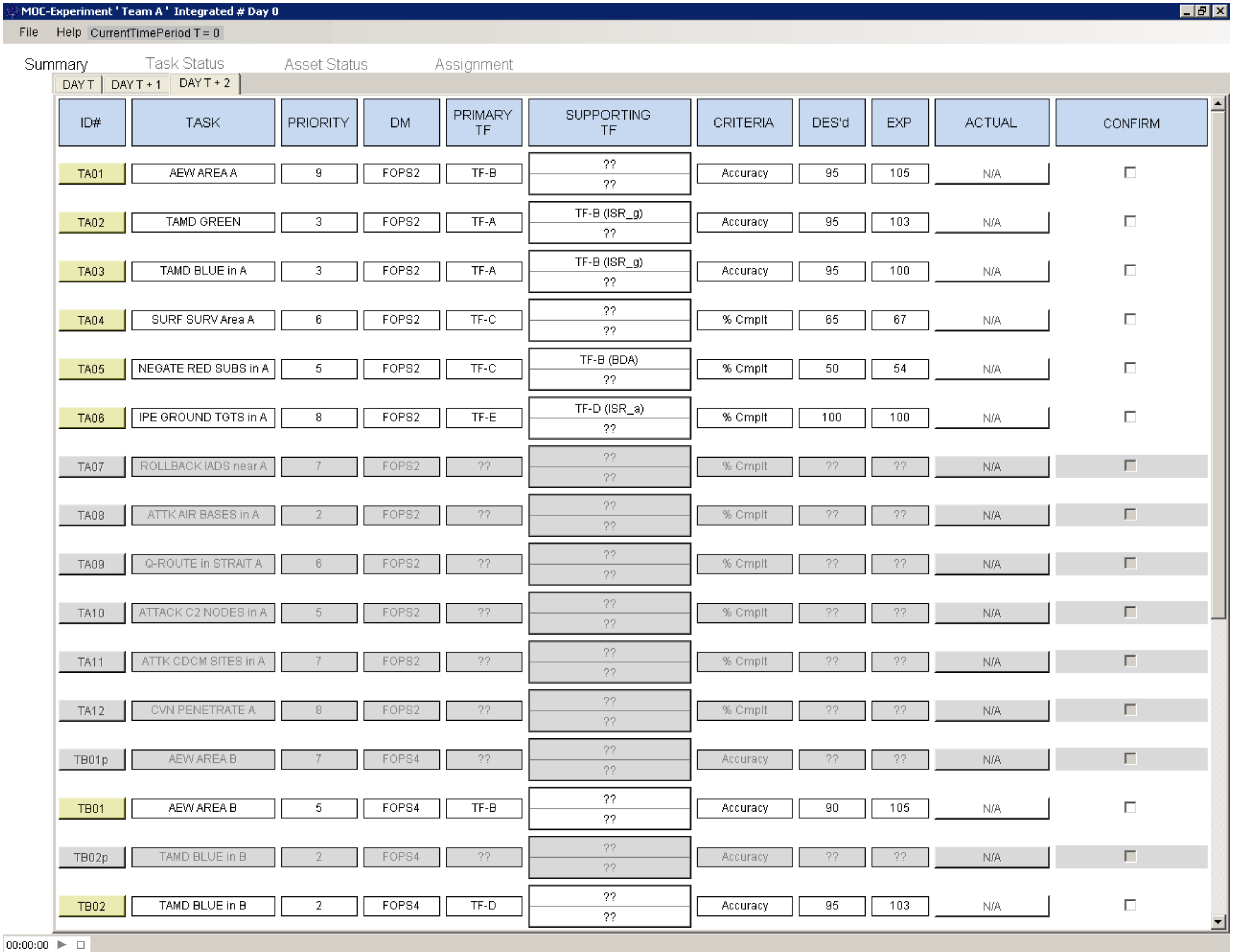
Additional details of the FOPS planning tool are described in Appendix A. Figure 3 depicts the *Summary* screen that is one of several displays included in the FOPS planning tool. All known tasks are shown on this *Summary screen*, including those that have ended or are not yet doable or begun. Those tasks that are not relevant for that day are shaded out. It was known a priori when tasks would begin and (nominally) when they would end. The *Summary* screen provides functionality for the following processes: (1) submitting a preliminary plan to the subordinate Task Forces (TFs) for their review; (2) finalizing the plan that will be briefed to the MOC commander at the end of the day; and (3) alerting a FOPS player when new (asset) information has arrived.

Finalizing the plan. Finalize means to send out the actual operational orders to the TFs. *Finalize* is only valid for day T+1 and T+2 and was done by FOPS only at the end of the lab session. The plan for today (day T) is already being executed, and so no changes were allowed by FOPS.

Alerting a FOPS planner when new information has arrived. When any asset parameters have changed, COPS pushed information to FOPS planners via CHAT. The FOPS planner used the *Asset Status* screen to import this new information on assets. When asset capabilities had changed, the results that have been provided by the agent models may no longer be valid. Thus, the players needed to resubmit the plan to the TFs for adjustment, taking into account the changed asset capabilities.

Assignment Screen. The *Assignment* screen, depicted in Figure 4, is the main screen that individual planners used to perform their job of assigning tasks to primary and supporting TFs on specific days (T+1 and T+2). Tasks were assigned one at a time. In using this screen the relevant task was first selected via a drop-down list, where only the relevant tasks for the day in question were on this list. (A user could also reach this screen by clicking the Task-ID button on the Summary screen wherein the selected task would be brought up directly.) Associated with the selected task is shown the (fixed/ given) task priority, and the decision maker (DM) responsible for planning that task on the relevant day. The desired performance goal/target for the day is input/changed by the players via a drop-down list. The *Expected by TFs* performance numbers is provided via the TF agent models *only* after an overall plan has been submitted to the TFs for review (via the Summary screen).

Assigning a task involves: (a) selecting a primary TF, and (b) selecting up to two supporting TFs – each one possibly supporting in up to two warfare areas. Selecting a primary TF is via a radio button, so that there can only be a single primary TF. A primary TF can apply any or all of its warfare capabilities to the task, depending on the allocation decisions reached by the agent models. Any TF not designated as primary can be a supporting TF. The selection of up to 2 *supporting* warfare areas per supporting TF is via a drop-down list that contains all of the warfare areas as well as “none”.



MOC-Experiment ' Team A ' Integrated # Day 0

File Help CurrentTimePeriod T = 0

Summary | Task Status | Asset Status | Assignment

DAY T | DAY T + 1 | DAY T + 2

ID#	TASK	PRIORITY	DM	PRIMARY TF	SUPPORTING TF	CRITERIA	DES'd	EXP	ACTUAL	CONFIRM
TA01	AEW AREA A	9	FOPS2	TF-B	?? / ??	Accuracy	95	105	N/A	
TA02	TAMD GREEN	3	FOPS2	TF-A	TF-B (ISR_g) / ??	Accuracy	95	103	N/A	
TA03	TAMD BLUE in A	3	FOPS2	TF-A	TF-B (ISR_g) / ??	Accuracy	95	100	N/A	
TA04	SURF SURV Area A	6	FOPS2	TF-C	?? / ??	% Cmplt	65	67	N/A	
TA05	NEGATE RED SUBS in A	5	FOPS2	TF-C	TF-B (BDA) / ??	% Cmplt	50	54	N/A	
TA06	IPE GROUND TGTS in A	8	FOPS2	TF-E	TF-D (ISR_a) / ??	% Cmplt	100	100	N/A	
TA07	ROLLBACK IADS near A	7	FOPS2	??	?? / ??	% Cmplt	??	??	N/A	
TA08	ATTK AIR BASES in A	2	FOPS2	??	?? / ??	% Cmplt	??	??	N/A	
TA09	Q-ROUTE in STRAIT A	6	FOPS2	??	?? / ??	% Cmplt	??	??	N/A	
TA10	ATTACK C2 NODES in A	5	FOPS2	??	?? / ??	% Cmplt	??	??	N/A	
TA11	ATTK CDCM SITES in A	7	FOPS2	??	?? / ??	% Cmplt	??	??	N/A	
TA12	CVN PENETRATE A	8	FOPS2	??	?? / ??	% Cmplt	??	??	N/A	
TB01p	AEW AREA B	7	FOPS4	??	?? / ??	Accuracy	??	??	N/A	
TB01	AEW AREA B	5	FOPS4	TF-B	?? / ??	Accuracy	90	105	N/A	
TB02p	TAMD BLUE in B	2	FOPS4	??	?? / ??	Accuracy	??	??	N/A	
TB02	TAMD BLUE in B	2	FOPS4	TF-D	?? / ??	Accuracy	95	103	N/A	

00:00:00

Figure 3. Summary Screen in FOPS Planning Tool.

The Total capabilities lines present the following, by warfare area: Possibly (potentially) applicable is the total of (1) all capabilities in the *Available for this task* line for the primary TF, plus (2) all capabilities *in the selected warfare areas* for every supporting TF as given in their *Available for this task* line. Clearly this is an optimistic assessment as it does not consider other DMs' actions.

These numbers change on-line as the DM makes changes to the task assignment. *Last Allocation by TFs* is the amount of different resource capabilities that the agent models last assigned to this task, across all TFs. These numbers will only change after a new plan is sent to the TFs for review. *Shortage* is the difference between the *Last Allocation by TFs* line and the *Estimated task requirements* line.

There are a number of constraints that must be satisfied in the *overall* task-to-TF assignments. These constraints require DMs to collaborate in their distributed task planning and assignment actions include the following: (1) a TF cannot be primary on more than three tasks on a given day; (2) a DM cannot select *any* supporting TFs on a task until a primary TF has been selected; (3) a TF cannot be supporting on more than three tasks on a given day; (4) there can be no more than two supporting TFs on any given task; and (5) some primary assignments of a TF are fixed and cannot be changed: a) for T+1 *any* task that had been assigned in the prior day's T+2. b) for T+2 *any* task that is still ongoing from the previous day – i.e., if a TF was primary on day n it must continue to be prime on day n+1. Basically, primary assignments once made on a task cannot be changed. But any supporting assignment can be changed as needed.

The tool checked and verified (using information as currently posted on the *Summary* page) that all constraints as noted above were satisfied and then placed the new task assignment (performance goals, supported-supporting relations) into the table on the *Summary* page. If some constraints were not satisfied, a pop-up window will advise the DM of the problem.

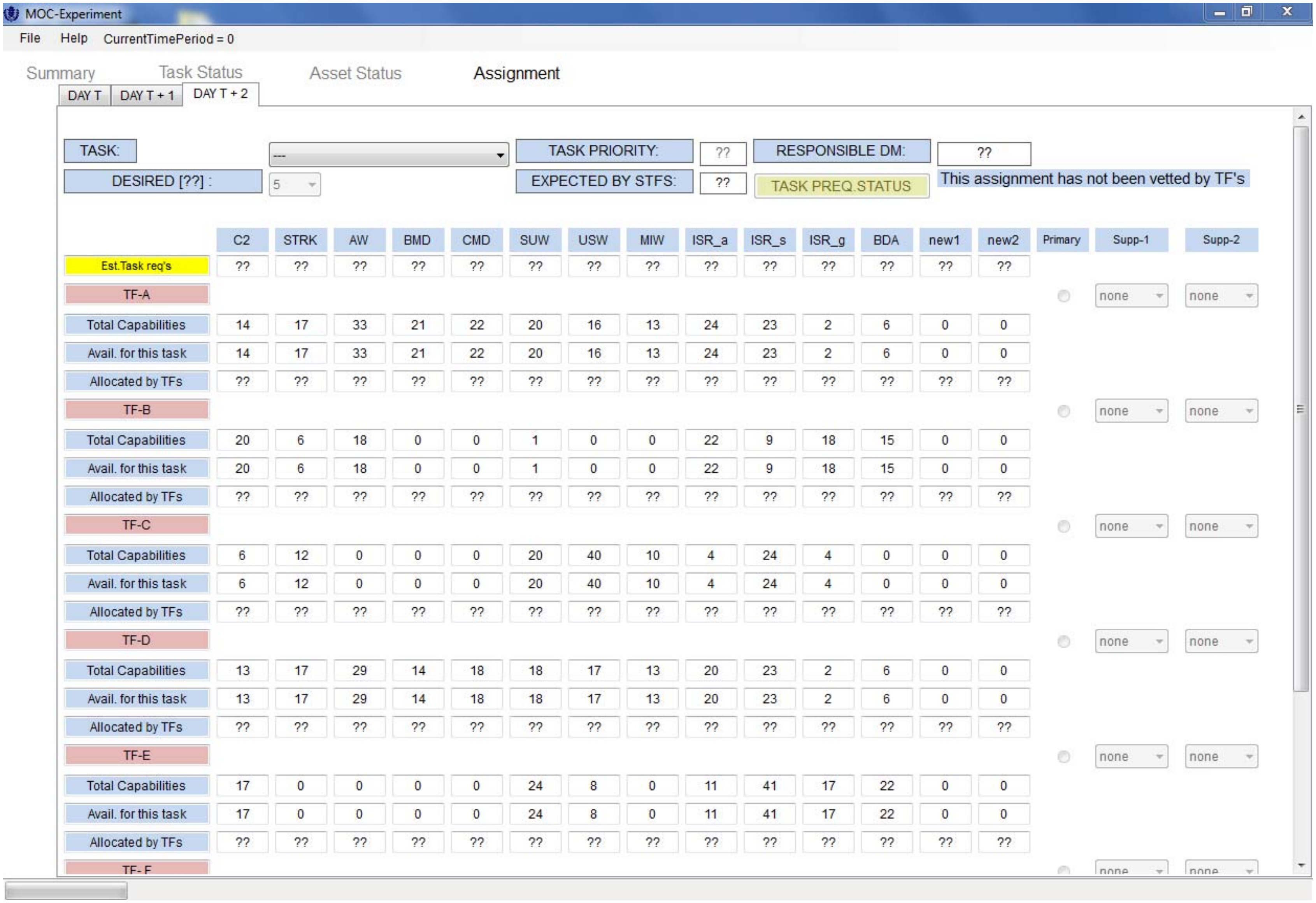


Figure 4. Assignment Screen in the FOPS Planning Tool.

RESULTS

Each of six teams engaged in four (4) two-hour sessions (i.e., blocks) of the experiment, discussed here in relation to the fictional days of the experimental scenario (i.e., Days 0, 1, 2, and 3). Days 0 and 1 consisted of training the participants to use the operational-level planning software with guidance from experimenters. Days 2 and 3, considered the *performance periods*, provided greater autonomy to participants in their efforts to develop plans for Future Operations (FOPS). The experimental goals in these two performance periods were to investigate differences in plan quality (performance), workload, and communication between experimental conditions that differ with regard to shared situation awareness.

Teams in the *integrated* condition used planning software that enabled full situation awareness regarding the assignment of task forces (TFs) to tasks in both primary and supporting roles. While each of the four team members who was responsible for a unique set of tasks in a specific planning area (Area A or B) during a specific timeframe [Time T+1 (tomorrow), or T+2 (day after tomorrow)], all members in this integrated condition were cognizant of the current planning allocations by everyone within the team.

In contrast, teams in the *isolated* condition used a limited form of this planning software, in which situation awareness was limited to only those tasks for which the individual team member is responsible. Thus, the task force allocation information readily available to integrated team members is not visibly available to isolated team members, and must be obtained through computer chat-based communication. Results from between-condition analyses are described throughout the remainder of this section.

Performance

Performance in this experiment was defined as the quality of the plan produced by participants in the role of Future Operations (FOPS) planners. Four specific plans were submitted at the end of each two-hour performance period: plans for timeframes T+1 and T+2 in both Areas A and B. Measures of planning quality, or *performance*, were calculated as the average weighted score for each task (across Areas A and B, within a specified timeframe – either T+1 or T+2). Task scores contain the ratio of expected plan quality levels (either accuracy or percent complete) to those values requested by Commander's Intent, and weighted by the priority of the task in relation to other tasks (2 = low priority; 10 = high priority).

It was expected that teams in the integrated condition would produce higher quality plans than the isolated condition due to the enhanced shared situation awareness provided by the planning software. Results from a repeated measures analysis of variance (ANOVA) supported this hypothesis (see Figure 5), as the quality of plans provided by the integrated teams (M = 106.75, SE = .73) was significantly greater than plans developed by teams in the isolated condition (M = 103.67, SE = .73) during the final two performance periods [$F(1, 22) = 8.91$, $p < .01$].

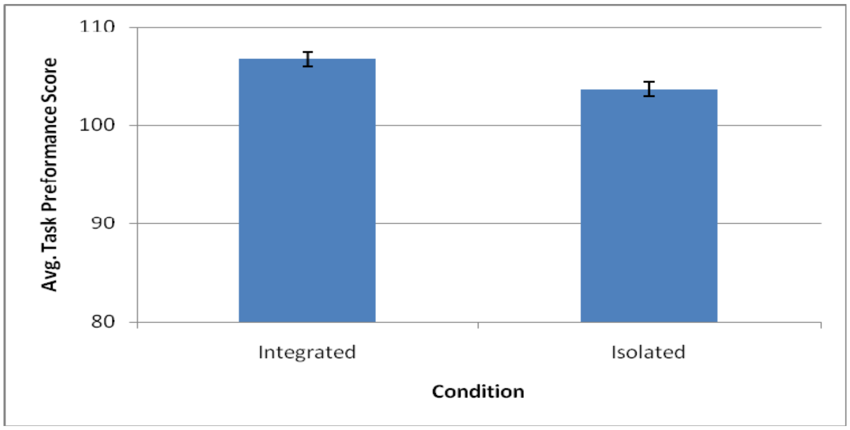


Figure 5. Average performance between conditions across the two final performance periods.

Additional ANOVA analyses indicate that this significant pattern of differences between conditions exists with T+1 (tomorrow) planners [$F(1, 10) = 6.95$, $p < .03$], but only a marginal difference exists among T+2 (day after tomorrow) planners [$F(1, 10) = 3.40$, $p < .10$]. While the integrated teams scored consistently higher than isolated teams for both T+1 and T+2 planners (see Figure 6), there was a greater degree of variance among T+2 planners ($M = 107.17$, $SE = 1.34$) than among T+1 planners ($M = 106.33$, $SE = .72$).

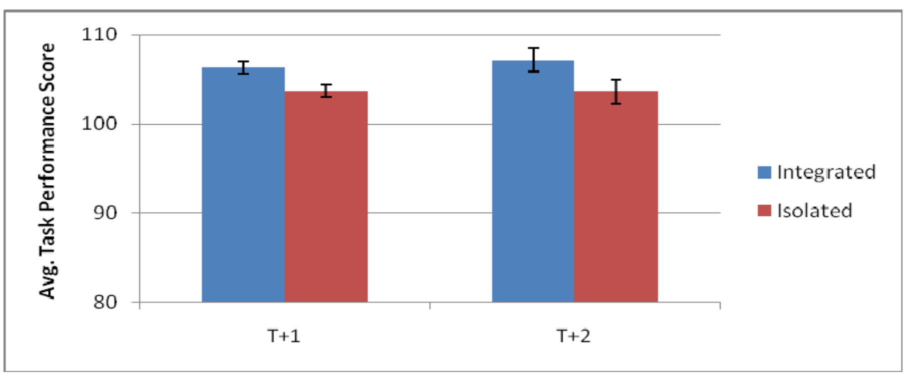


Figure 6. Average performance between conditions for T+1 and T+2 planners.

Workload

Workload was assessed using an adapted version of the TLX Workload Scale (Hart & Staveland, 1988), in which workload is measured on a self-report 10-point continuous rating scale in each of five distinct dimensions: *mental*, *time pressure*, *performance*, *effort*, and *frustration*. This measure was issued at the close of each experimental session (four times per team), and demonstrated sufficient internal consistency ($\alpha = .87$).

It was expected that workload would be greatest for teams in the isolated condition, as the lack of shared situation awareness provided by their planning tool necessitates an increase in the amount of explicit (communication-based) status updates and coordination required to succeed on this interdependent task. Workload was also expected to increase as the experiment progressed from Days 0-3, as injects that limit one's available resources increased in complexity over time.

As expected, results of a condition (2; Integrated vs. Isolated) by session (4; Days 0-3) between-within-subjects ANOVA (see Figure 7) indicate that the average overall workload reported by isolated team members (*M* = 42.89, *SE* = 3.75) was significantly greater than workload reported by integrated team members (*M* = 33.69, *SE* = 3.75) across all four experimental sessions ($F(1, 22) = 3.01$, $p < .05$, one-tailed).

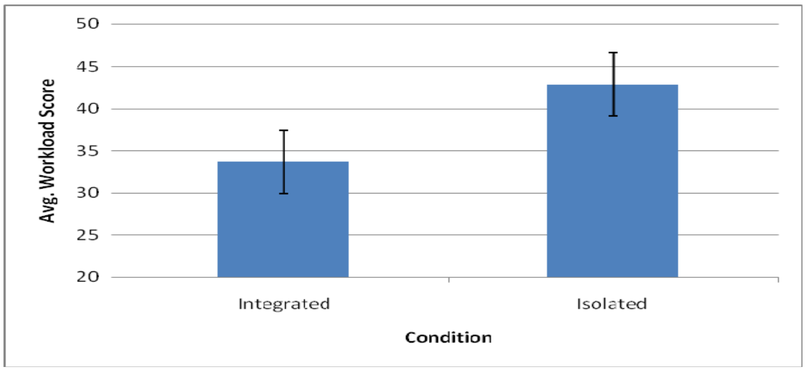


Figure 7. Average workload scores between conditions across all experimental sessions.

Workload was also compared between integrated and isolated conditions in a one-way between-subjects ANOVA, showing similar significant support for increased workload in the isolated condition [$F(1, 94) = 5.61$, $p < .03$]. Results of a MANOVA comparing conditions across the five dimensions of workload showed a significant difference between conditions [Wilks' Lambda = 0.167, $F(5, 90) = 90.01$, $p < .001$]. Subsequent univariate analyses showed the workload ratings of *mental pressure*, *performance,* and *effort* to each be significantly greater for isolated team members ($p < .01$).

Results also supported the hypothesized increase in workload as the experiment progressed (see Figure 8). Specifically, workload ratings provided on session Day 0 (*M* = 29.08, *SE* = 2.48), Day 1 (*M* = 36.21, *SE* = 3.63), Day 2 (*M* = 41.52, *SE* = 3.67), and Day 3 (*M* = 46.37, *SE* = 4.85) were significantly different [$F(3, 66) = 5.86$, $p < .01$], and increased linearly [$F(1, 22) = 8.50$, $p < .01$].

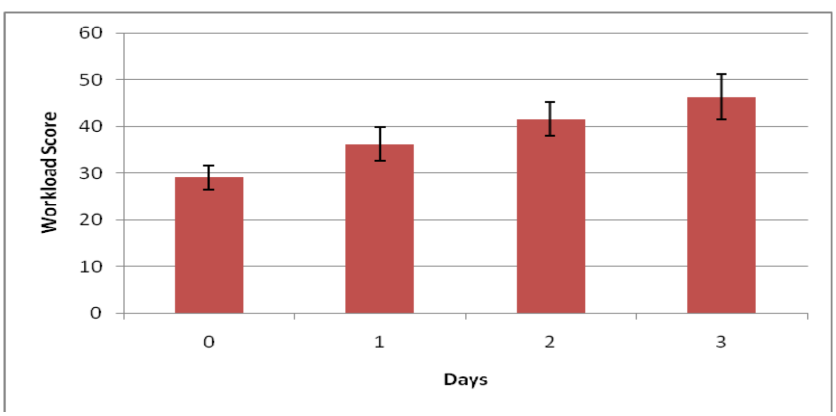


Figure 8. Linear increase in workload throughout subsequent days of the experiment.

In addition to the main effect for session shown above, isolated teams reported greater workload than integrated teams in each block (see Figure 9). Combined with the findings noted above, these results suggest that as the scenario builds and the interdependence between task areas A and B becomes more complex, integrated team members perceive less mental workload and demonstrate more effective performance than isolated team members. Thus, providing additional status-related situation awareness can increase planning performance and decrease workload for interdependent planning teams.

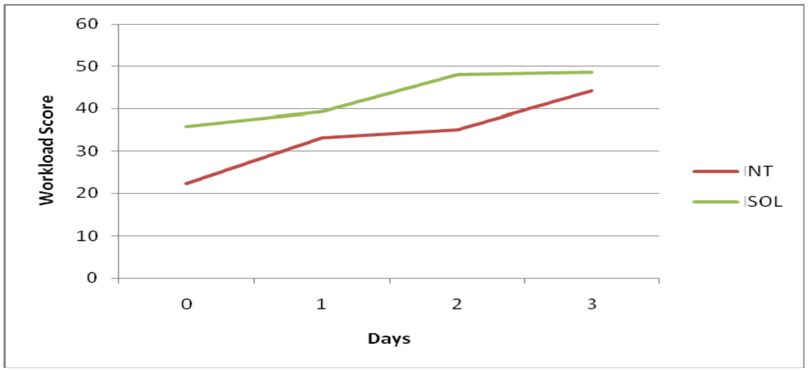


Figure 9. Greater workload for isolated vs. integrated team members.

Communication

All Chat messages sent during an experimental session were captured electronically. To analyze the chat the chat-file for each experimental session was printed to expedite coding. First all acknowledgement messages (e.g., roger, solid copy, confirm) were removed. The primary metric was the percent of collaborating messages to total messages sent. Percent collaborating messages was analyzed using a Condition X Days between-within-subjects ANOVA. As we can see from Figure 10, the percent of collaborative messages to all messages increases almost linearly from day 1 to day 3 for the teams in the isolated condition, whereas the percent collaborative messages for the teams in the integrated condition falls below the isolated level by day two and remains below the isolated level on day 3. This interaction was significant, $F(2, 8) = 4.36$, $p <= .05$. It would appear that the need to discuss the collaborative effort increases constantly for those in the isolated condition. But, for those in the integrated condition once they establish collaborative patterns the need to collaborate falls off considerably.

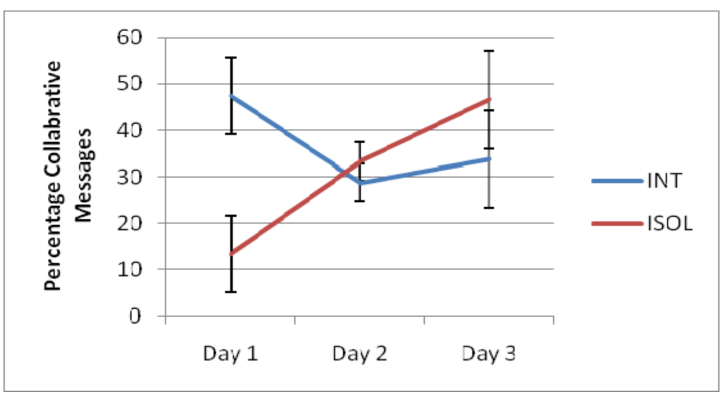


Figure 10. Percentage of collaborative chat messages by condition and day.

Additional analyses are being conducted and a complete discussion will be included during the presentation.

APPENDIX A: Details of the FOPS Planning Tool

Summary Screen

The *Summary* screen shows the task assignment actions of all co-acting and interacting players on a task-by-task basis. It was used by FOPS to iterate a plan with the (subordinate) Task Forces for either day T+1 (today plus 1 day) or T+2, and then to finalize the plan. [Note: FOPS used the *Assignment* screen for the actual planning of asset allocation for all tasks.]

The columns on the *Summary* screen for each task will be described from left to right. *ID number* (e.g., TA01) – this button, when clicked, will take the decision maker to the *Assignment* screen for that task for the particular day in question, including day T. *Task* is the name of the task the information on this row describes. *Priority* is the priority assigned to the task, ostensibly by elements external to FOPS (that is, the battlegroup commander). *Decision Maker* (DM) is the FOPS DM who is responsible for planning the task (set by the experimenters). Note that any one FOPS DM only had responsibility for a *subset* of the overall tasks, and this could vary from day to day. *Primary TF* is the unique primary Task Force assigned to conduct the task. *Supporting TF* is where the FOPS planner designates up to two supporting Task Forces for that task along with specifying those warfare areas in which they are to provide support.

Criteria refers to the desired performance criteria associated with this task, which is specified either in terms of accuracy/ coverage desired or percentage of task complete at the end of the day. Typically, a task that persists would have an accuracy or percent coverage assigned with it, such as having enough aircraft up to cover 75% of the area of operations for a surface surveillance task. The task-specific criterion is fixed in the scenario, i.e., whether accuracy/ coverage or percent complete at day's end is the correct criterion for a given task. *Desired Performance* specifies performance desired for this task by FOPS in terms of either accuracy or percent complete. (These numbers are entered via the *Assignment* page.) *Expected Performance* is the expected accuracy or percent complete which is calculated by the Task Force intelligent agent. The Task Force agent models provided these numbers once the overall plan had been submitted to the TFs for review.

Actual performance is relevant only for day T (i.e., today), in that this provides feedback to all players on the *actual* performance on the task. This information came via COPS, who passed information to FOPS, in the form of SITREPS that informed FOPS on execution of the mission. *Confirm Assignment* – Since different FOPS players had responsibility for planning separate subsets of the overall tasks, this checkbox was used to synchronize player's actions before the composite plan was submitted to the TFs. If any change was made to the task assignment (as saved via the assignment page) this box became unchecked. Only the DM responsible for the task could check this box. Before a plan could be submitted to the TFs or finalized, *all* confirm boxes must be checked.

Submitting the plan developed by FOPS to subordinate Task Forces (TFs) for their review means to "ask" the TFs how they would instantiate the composite plan. This instantiation was done by the agent models. All relevant tasks for the day in question had to have a primary TF designated (in the Prime STF column), with a priority greater than zero, *and* a *desired* performance number in order to be included in the plan. The (new or revised) performance numbers in the *expected* column were returned from the agent model. These performance numbers were calculated for expected accuracy for tasks having "infinite" duration, *or* expected percentage completion for tasks having finite time duration. Submitting the plan is like a pushing a "what if" button to see what kind of performance can be achieved given all the competing demands on limited resources.

If any change was made to any task within the overall plan (including priority, desired performance, expected performance, etc.), the plan had to be resubmitted to the TFs. Players had indications when a change was made to a task assignment via: a) the confirm box for that task became unchecked and b) the expected performance for that task showed "??". If *Submit* had been clicked, further clicking of this button (as well as the *Save* button on the Assignment screen) for the particular day was *disabled* until the agent algorithms finished and returned their results, or a minimum (fixed) time has passed.

Task Force Agent Modal Processing

Agent algorithms were designed to represent the TF planning cells at each TF level for each TF. A vector contains information on what the task needs based on the latest intelligence and when the COPS player receives new intelligence he/she will provide updates to this list of task requirements based on these inputs. This list of task requirements provides the best information available to planners on what is needed to accomplish the tasks. Based on the assumption that the individual TFs are coordinating with each other, the agent receives the plan as submitted by the FOPS players in the MOC regarding primary and secondary assignments of TFs to specified mission tasks. The agent algorithm determines how to best assign individual assets (such a CG-1, UAV-4, aircraft-6) in order to best meet desired performance levels specified by the MOC. This is accomplished by minimizing differences between task accuracy (or performance completed) as a ratio of applied resource capability to the estimated task resource requirements. The algorithm minimizes the difference between what is thought to be needed to accomplish the task and desired performance as a weighted sum of overall tasks, where weight equals the priority assigned to each task.

A vector is produced to show how much capability will be provided by the primary TF and the supporting TFs to each task. This vector is presented to the FOPS players to show which individual assets within each TF are assigned to which task and how much of that asset's capability is available for a given task. This includes how much a primary TF provides to each task (a primary TF can support up to four tasks at any time) and how much a secondary TF provides to each task. Agents do not override what was designated by FOPS planners; they merely make decisions about which of the assets to apply to each task. For example, DDG-1 will use two units of C2 on task x, and two units of C2 on task y. (Note: FOPS does not receive this level of detail when the agent presents the results to the FOPS planners. But this information is sent to the DDD so it can show which assets have been assigned to which TF.)

Assignment Screen

The resource vectors shown (across task and TF warfare areas) are the following: The *Estimated task requirements* is the current "best guess" as provided via intelligence or COPS regarding the capabilities that must be brought to bear on the task in order to achieve the desired performance goal. These numbers were calculated by the software from stored task values for each play session. They will not be dependent on any player actions. However, they will change on-line if the FOPS planner makes changes to the desired performance goals, e.g., if a player increases the desired percent complete by end of day (or increases the desired accuracy) for that task.

For each specific TF, the *Total capabilities* numbers are taken *directly* from the summation line on the *Asset Status* page. Thus, it behooves the players to continually update their local TF capability data. The *Available for this task* line is the previous line less *all* resource allocations – *as last made by the TF agents* – to tasks *other* than the currently selected task. If no composite plan has ever been sent to the TFs for review (via the *Summary* page) then this line will equal the total line. An "x" in a resource category means that the particular TF is out of range for applying that resource (warfare area) to the selected task.

The *Allocated by TFs* line shows the amount of resource capability that the TF agents *last allocated to the task*. Nominally these numbers will approximate the prior line in those warfare areas relevant ($\neq 0$) to the selected task. If no composite plan has yet been sent to the TFs for review all entries will be "??". Also, if the DM made *any* change in the assignment of the task to TF-X this line will either show all "??" or be shaded out.

The Task prerequisite Status button is only needed for days T+1 and T+2 – *and only for those tasks that are scheduled to begin on the day in question.* When clicked it pops up a window that lists, on a line-by-line basis, all of the prerequisites for the selected task. A given line shows: a) the required prerequisite performance criterion (in percentage), and b) the (actual or expected) performance numbers for the prior day. Thus, for tasks starting on day T+ 1 we show the actual performance of the prerequisite as pulled from the *Summary* page (if no entry exists yet use the estimated performance value and display in italic). For tasks starting on day T+2 we show the estimated performance from the day T+1 *Summary* page. If that value is "??" we show "TBD" in the pop up window. If a task has no prerequisites, or is not scheduled to begin on eitherT+1 or T+2, the button is shaded out. The user must close the pop-up window before any other actions can be taken.

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