GRC International, an AT&T Company

ANALYZING THE C4ISR CONTRIBUTION TO MILITARY OPERATIONAL EFFECTIVENESS

6th International
Command and Control Research and Technology Symposium:

COLLABORATION IN THE INFORMATION AGE

SYMPOSIUM TOPICS ADDRESSED:
C2 Experimentation
Modeling and Simulation

Gayla Dodd Horn
GRC International
1900 Gallows Road
Vienna, VA 22182
Tel. 703-605-5371
Fax. 703-556-4261
ghorn@grci.com

ANALYZING THE C4ISR CONTRIBUTION TO MILITARY OPERATIONAL EFFECTIVENESS

ABSTRACT

Two common themes are emerging from the transformation underway within DoD--Information Superiority and Network Centric Warfare. Current generation Modeling and Simulation analytic models are limited in their ability to represent reality and to discriminate among the Information Superiority and Network Centric Warfare options facing commanders in the 21st century. The Joint Warfare Simulation (JWARS), part of the next generation of Modeling and Simulation applications, is suitable for addressing these issues. It is designed to be a state-of-the-art, constructive simulation to support the Office of the Secretary of Defense, the Joint Staff, and the Unified Commanders in Chief to assist concept development, force structure analysis, acquisition assessments, and Course-Of-Action analyses. A 3X3X2 factorial design experiment will be conducted in the JWARS Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance domain and will examine the effects of manipulating three variants: Sensor Effectiveness, Common Operational Picture sharing and Command and Control behavior autonomy. The final reports will discuss insights gained from the development of the experiment, issues encountered in constructing the variants, and a description of the outcome landscape. A discussion of the current JWARS capability to perform this type of analysis will be included. Finally, possible modifications to the JWARS Command and Control analytic capability will be addressed.

1. PROBLEM

The Command, Control, Communication, Computer, Intelligence, Surveillance and Reconnaissance (C4ISR) System is a system of systems that delivers information to Command and Control (C2) decision makers and their supporting staffs. Senior decision makers within the Department of Defense (DoD) must make decisions about C4ISR investments; the mix of systems within the system; and the doctrine and processes for collecting, exploiting, and disseminating intelligence information. These decisions must be supported, based on solid analysis, and defended to Congress and others in order to obtain adequate resources for implementation. Analysis of this C4ISR system of systems, however, presents military operations analysts with a fundamental analytic challenge. The C2 process is dynamic and adaptive to human judgments, rendering it extremely difficult to model and support analytically. Individuals supporting and performing C2 decision-making continuously adapt their evaluation of the quality and timeliness

of the information that is presented to them. Individual intuition is brought to bear and influences the degree of adherence to both C2 processes and doctrine--because military operational success remains the foremost objective, decision makers will discard apparent dysfunctional doctrine or process and revert to personal intuition to arrive at a decision, which in their opinion, will result in operational success. These military decision makers and their staffs may alter doctrine and processes "on-the-fly" to ensure success.

While it is not possible to depict this type of intuitive process within an operational analysis, it is possible to craft limited changes to doctrine and process to the extent to which each is modeled in the tool being used to perform C4ISR analysis. This crafting of alternative doctrine and process is highly subjective. It must be accomplished carefully and with senior leadership oversight in order to ensure that the alternative doctrine is plausible and capable of implementation and is not simply a study-driven expedient.

A transformation is underway within DoD and common themes are emerging. Information superiority (IS) is the foundation of full-spectrum dominance envisioned by JV 2020, and Network Centric Warfare (NCW) translates IS into combat power. While Modeling and Simulation (M&S) applications support a wide variety of activities that are critical to the success of DoD transformation efforts, e.g., concept development and investment decisions, the current generation of M&S analytic models inadequately represents IS & NCW. They are limited in their ability to represent reality and to discriminate among the options facing commanders in the 21st century -- new approaches to C2, enhanced intelligence, surveillance, and reconnaissance (ISR) operations, and network centric warfare. The next generation of models needs to better depict these future options and to test NCW concepts and analyze NCQ relationships, e.g., determine effectiveness of NCW in providing increased tempo, lethality, improved survivability, and quicker victory.

2. RELEVANCE TO C2

Information technology will improve the ability to see, prioritize, assign, and assess information. The fusion of all-source intelligence with the fluid integration of sensors, platforms, and command organizations will allow a greater number of operational tasks to be accomplished faster. IS and NCW serve to integrate military operations providing opportunities to employ new C2 approaches and warfighting concepts. A network-centric force enjoying an information advantage will lead to better C2, better decisions, better plans, and a reduction of the fog of war.

The Joint Warfare Simulation, as part of the next generation of M&S, is designed to be a state-of-the-art, constructive simulation that provides a multi-sided and balanced representation of joint theater warfare. It will support the Office of the Secretary of Defense, the Joint Staff, and the Unified Commanders in Chief in assisting concept development, force structure analysis, acquisition assessments, and Course-Of-Action analyses. It has been developed as a campaign level analysis tool that uses C4ISR as its basis. Information-flows from a variety of sensors feed a correlation and fusion process resulting in a perception. The perception is used by Battle Space

Entity (BSE) C2 behaviors to perform decision-making. Decision making leads to BSE action, which updates the perception. The question for senior decision-makers is whether JWARS can be used to analyze complex questions related to C4ISR systems and processes, including C2 decision-making behaviors. An experiment in the JWARS C2 domain to determine the value of increased Sensor Effectiveness, Common Operational Picture sharing and C2 behavior autonomy will be valuable in demonstrating the ability of JWARS to perform analysis of C4ISR issues, and in learning how to make JWARS more useful for addressing these issues in the future, thereby supporting DoD efforts to exploit Information Superiority and Network Centric Warfare.

3. JWARS STUDY TEAM APPROACH

Objective

The ongoing experiment is being performed in support of the Office of the Assistant Secretary of Defense (OASD), C3I Command and Control Research Program. Its overall objective is to determine the utility of JWARS in addressing C4ISR issues which involve the value of shared awareness. Specifically, the goals are to, 1) Provide insights in the value of shared awareness, and, 2) Identify the potential modifications and improvements to JWARS that will further enable analysis of C4ISR issues.

Model Capabilities and Limitations

JWARS is a state-of-the-art, constructive simulation that provides a multi-sided and balanced representation of joint theater warfare in a realistic environment. While still under development, JWARS will simulate extensive C4ISR functions, when fully operational. Though it does not yet conduct dynamic intelligence collection synchronized with battle events, nor process and disseminate intelligence reports on a near-real-time basis, it does model intelligence assets at the national, theater, and tactical levels. This enables tracking of lead enemy divisions and detection of second-echelon units in accordance with collection plans for each scenario phase and state. JWARS also depicts the intelligence cycle and provides information necessary to support the friendly commander's actions. Analysts can modify selected entity performance parameters, the intelligence fusion and dissemination cycles and scenario components. And JWARS accepts stochastic inputs and allows run replication, data collection and post-run analysis.

Variants

Three variants were identified as relevant to this experiment; each varied across several levels. They are Sensor Effectiveness, a Shared Awareness variant termed Common Operational Picture (COP) Sharing, and a C2 Behavior variant which will examine increased decision autonomy by Commanders.

The **Sensor Effectiveness** variant will be examined at three levels. At the first level, sensors are modeled at their existing level of effectiveness in order to establish a baseline case to which all modifications will be compared. Sensors will then be examined at 100% effectiveness, that is, with perfect detection capability, in order to create an upper bound for sensor performance; and at a reduced level of effectiveness, arbitrarily established at 25% effectiveness.

Sensor systems in JWARS are assembled with three components: a detector, a collector, and a reporter. Since each of these three components may have a number of specific versions defined, there are a large number of potential sensor systems with varying characteristics that can be represented using different sets of components. The experiment team has altered the properties of selected sensors were altered by changing their detection and reporting parameters during a series of preliminary runs. Output is being examined to determine if a correlation exists between sensor effectiveness and number of enemy units detected and destroyed by friendly forces. The team is studying JWARS output--Perception Reports, Direct/Indirect Fire Killer-Victim Scoreboards, Unit Enemy Contact Reports and Unit Enemy Fire Reports. This output provides information about scenario events and outcomes, including the time of detection of enemy units, the identification of enemy units (ground truth and perceived), the location of enemy units (ground truth and perceived), the strength of enemy units (ground truth and perceived), targeted and attrited enemy units, the time of contact between friendly and enemy units, the time at which units come under fire, and battle duration.

The **COP Sharing** variant will be used to examine the effects of varying shared awareness across the Common Operational Picture. This variant will be examined across the continuum of possible awareness sharing, from No Sharing, that is no peer-level awareness of other units' actions (the baseline case); to Partial Sharing in which there is partial time-lagged peer-level awareness of other units' actions; to Complete Sharing in which there is complete peer-level awareness of other units' actions occurring at or near real-time. Note that this variant incorporates a time index.

Increasing awareness of battlefield events should have an impact on the C2 behavior of subordinate units, thereby changing the COP. COP sharing will be defined and simulated by manipulating several factors. Under consideration are the modification of the connectivity, capacity, and processing of information along selected communications networks; changing the update frequency of the commander's situation map (known as the JEF in JWARS parlance--JWARS Equipment & Forces), thereby effecting the fusion cycle of intelligence data; and finally, varying the quantity of information from the JEF made available to units.

The third variant is the **C2 Behavior** variant, which will vary across two levels. Current behavior relies on hierarchical decision making with little autonomy. This represents the Baseline case. Alternatively, modified C2 behavior will reflect increased autonomy in decision making.

The C2 behavior of subordinate units (i.e., brigades) is readily modified by changing their organization-type C2 function. This change provides subordinate units the C2 capability normally associated with higher-level organizations (i.e., divisions) and, thus, greater independence.

In summary, the variants and their levels are:

1. Sensor Effectiveness Variant
    a. Current Effectiveness = given current sensors; the Baseline
    b. 100 Effectiveness = perfect detection by all sensors
    c. 25% Effectiveness = reduced detection by all sensors.
2. COP Sharing Variant
    a. No Sharing = no peer-level awareness of other units' actions; the Baseline
    b. Partial Sharing = partial peer-level awareness of other units' actions, time lagged
    c. Complete Sharing = complete peer-level awareness of other units' actions, near real-time
3. C2 Behavior Variant
    a. Current C2 Behavior = hierarchical decision making, with limited autonomy; the Baseline
    b. Modified C2 Behavior = increased autonomy in decision making.

The experiment team will address research questions, or Essential Elements of Analysis (EEAs), associated with each variant:

- Is the model sensitive to changes in sensor effectiveness?
- What is the impact of varying the level of shared awareness?
- What is the impact of varying C2 decision autonomy?

Experiment Design

A 3x3x2 factorial design will be used, reflecting the three variants and their respective levels (see Figure 1). This enables consideration of all possible variant combinations, i.e., cases. However, those pathological cases which attempt to combine mutually exclusive events will be excluded. Specifically, in cases 3, 5, 9, 11, 15, and 17, the Current level of the C2 Behavior variant is combined with the Enhanced levels of the COP Sharing variant. Since, by definition, current C2 behavior does not support alternative COP sharing, these cases are of no interest and will not be considered. A hypothesis and the number of runs will be established for each case.

Case	Sensor Effectiveness (3 Levels)	COP Sharing (3 Levels)	C2 Behavior (2 Levels)	Notes
1	Current	No Sharing	Current	BASELINE[1]
2	Current	No Sharing	Modified	
3	Current	Partial Sharing	Current	*Excluded*
4	Current	Partial Sharing	Modified	
5	Current	Complete Sharing	Current	*Excluded*
6	Current	Complete Sharing	Modified	
7	100%	No Sharing	Current	
8	100%	No Sharing	Modified	
9	100%	Partial Sharing	Current	*Excluded*
10	100%	Partial Sharing	Modified	
11	100%	Complete Sharing	Current	*Excluded*
12	100%%	Complete Sharing	Modified	
13	25%	No Sharing	Current	
14	25%	No Sharing	Modified	
15	25%	Partial Sharing	Current	*Excluded*
16	25%	Partial Sharing	Modified	
17	25%	Complete Sharing	Current	*Excluded*
18	25%	Complete Sharing	Modified	

Figure 1. Case Matrix

Simulation Runs

A JWARS Run is defined as the association of a Run Definition with a specified Scenario data set and the subsequent execution of one or more replications of the simulation. A JWARS Run Definition is a set of control parameters which can be applied to sets of replications. The control parameter information includes: user specified simulation control data, including instruments activated; number of replications; random number generator and seed; simulation duration; pauses; and, execution modes. The Instruments functionality refers to software methods designed to capture a set of data elements (output) according to particular trigger events within JWARS. The analyst determines whether to activate an instrument or not, thus causing the associated data elements to be captured or ignored.

Scenario

The JWARS Full and MicroGold scenarios were modified to accommodate specific experiment requirements. Scenarios were narrowed to bound the project--the Blue Plan is held constant and

[1] The baseline case, or set of control group data.

Red attacks Blue. The setting is near-future (2005) in southwest Asia. Two enemy armored divisions advance in echelon against a U.S. armored division which is defending a small, friendly middle Eastern country.

Key Definitions

The C4ISR Model. The C4ISR Model includes the representations of the COP, the BSE ISR systems that feed the COP, and the communications infrastructure.

The C2 Model. The C2 Model is the sum of the command and control decision-making behaviors of a BSE.

The Blue Plan. The Blue Plan is the information that defines the Blue objectives and how they will be achieved.

Metrics

Some metrics, or measures, have been tentatively identified for performance assessment: the number and proportion of Enemy units not detected by time interval, Blue losses (attrition), Red losses (attrition), and battle duration from attack to disengagement. "Measures" are grouping concepts found in JWARS. They typically consist of numerical counts of collections, or lists, of instrument outputs. Measures are useful in the collection and aggregation of output data for post-processing. Examples are system exchange ratios and loss exchange. Generally, performance measures are expected to improve when capability is enhanced and to decline when capabilities are decreased. "Improve" is operationally defined as decreased attrition of friendly forces and decreased battle duration. In order to establish meaningful measures which will provide insight into one or more of the EEAs, the team is currently varying scenario inputs in preliminary runs and analyzing the JWARS outputs.

4. RESULTS

Preliminary results indicate that JWARS standard output can provide the data necessary to assess the value of shared awareness. When complete, the experiment analysis will include an examination of the experiment process itself. A discussion of insights gained from the developmental process and of issues encountered in constructing the variants will be presented. The analysis will also include a description and discussion of the outcome landscape reflecting the effects of altering variant levels and variant interactions. This summary analysis then will inform an assessment of the current JWARS capability to perform C4ISR analysis and lead to recommendations about possible JWARS modifications and additions which would result in an improved C4ISR analytic capability.

Beyond the time horizon of this experiment, the ultimate activation of a planned Maneuver Planner module in JWARS should enhance these C4ISR capabilities. Additionally, planned intelligence improvements will enhance JWARS' ability to realistically depict the intelligence cycle and analyze the impact of increasing shared awareness. For example, a collection capability which automatically evolves with the dynamic tactical and operational situations and with the immediate fusion of intelligence reports on select high-value targets is desirable because it is more realistic than the current static capability.

REFERENCES

JWARS R1.3 with Documentation

BPA 549-00-6, DO 333 and Statement of Work

GRCI CCRP Project Management Plan

GRCI CCRP Study Plan