ASSESSING THE IMPACT OF C4ISR ALTERNATIVES WITH THE JOINT WARFARE SYSTEM

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Abstract

A new generation of Models and Simulations (M&S) gives increased capability and power to the analysis of Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance (C4ISR) issues. The Joint Warfare System (JWARS) is at the vanguard of this emerging set of tools. It is a state-of-the-art, constructive simulation that provides a multi-sided and balanced representation of joint theater warfare. Developed as a campaign-level analysis tool, JWARS has C4ISR as its basis and models many C4ISR concepts, such as sensors, the intelligence fusion process, and Command and Control (C2) decision making. This gives new capability to Department of Defense (DOD) joint warfare analysis--the exploration and testing of the dynamic and intuitive C2 process through enterprise modeling and business process analysis. Though JWARS is pre-IOC, its functionality is considered fairly mature.

An experiment was performed in the JWARS C2 domain to explore these issues and to assess model capability. A full factorial analysis of three C4ISR variants explored main and interaction effects. Traditional attrition measures of Red and Blue losses were examined, and then expanded through enterprise analysis. Results confirmed that manipulation of JWARS capabilities did produce quantifiable C4ISR effects and that a process analysis capability does provide a more robust understanding of results.

1. **Overview**

AT&T Government Solutions, Inc., formerly GRC International, was selected in 2000 to conduct the first operational experiment using JWARS as an analytic tool. JWARS, as part of the next generation of Models and Simulations, has been developed as a campaign-level analysis tool with C4ISR as its basis. The many C4ISR concepts modeled include sensors, the intelligence fusion process, and C2 decision-making behaviors. In contrast to the limited capability of current analytic M&S tools to represent options facing commanders in the 21st century, JWARS can use its C4ISR concepts to model and explore new approaches to C2, enhanced ISR operations, and network centric warfare.

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A study was conducted in the C2 domain in support of the Office of the Assistant Secretary of Defense (OASD) C3I CCRP. The overall analytic purpose of the experiment was to investigate the C4ISR contribution to military operational effectiveness and to support DoD efforts to exploit information superiority and network centric warfare. Specifically, AT&T research objectives were twofold: 1) To provide insights into the value of shared awareness; and 2) To identify potential modifications and improvements to JWARS in order to enhance its C4ISR analytic capability. The overriding research question was whether the JWARS pre-IOC capability was sufficiently mature to analyze complex questions related to C4ISR systems consistent with existing, *and alternative*, doctrine and process.

The study used a full factorial experimental design, which examined all possible combinations of three parameters, or "variants." ISR sensors were used to create an information advantage for friendly forces. A Common Operational Picture (COP) Sharing variant was used to explore effects of changes in shared awareness by controlling the timing and flow of information. Finally, C2 behaviors were manipulated to emulate increased decision-autonomy by commanders. Traditional strategic attrition measures of Red and Blue losses were examined, as well as tactical measures such as number of routs, numbers of sensor perceptions, numbers of fire support requests and fire orders, and assets killed per fire order. These tactical measures are of particular significance because their use requires an enterprise model with the capability to model and analyze individual processes. This is an important new analytic capability for the DoD theater warfare domain and it is uniquely provided by JWARS.

It is noteworthy that the work did produce quantifiable C4ISR effects, with outcomes generally following intuition. And, again, this was accomplished with a pre-IOC Version and existing model interfaces--no coding was required. Moreover, all modifications and enhancements to JWARS C4ISR constructs that were identified and suggested by the study team have already been incorporated into the new version by model developers, save one which is in development. Hence, model capability has already been expanded and improved, building on the AT&T work which successfully demonstrated the power and potential of JWARS C4ISR capabilities.

This report will examine the methodology and results of the experiment and will highlight the JWARS capabilities and potential revealed by the study.

2. **Methodology**

2.1 ***Variants***

The three concepts identified as relevant to this experiment were operationally defined as experimental variants. A Sensor Effectiveness variant, which models both ISR and tactical sensors, was used to create an information advantage. The effects of changes in shared awareness were simulated and explored by a COP Sharing variant. Increased decision-autonomy by commanders was simulated by a C2 variant. As JWARS models real-world intelligence systems, all actual system parameter (variant level) data values are Classified Secret and are not further discussed in this report.

2.1.1 ***Sensor Effectiveness***

Sensor systems in JWARS are assembled with three components: a detector, a collector, and a reporter. Varying the combination of these components enables representation of a large number of potential sensor systems with differing characteristics. Suitable sensor systems were identified for the scenario utilized and manipulated by altering detection capabilities. Expanded sensor capability should have a positive impact on ISR systems, and provide an improved COP.

This variant was examined at three levels. A Baseline case to which all modifications could be compared was established based on existing model capability. Though there are three principal parameters that characterize sensor functionality in the model--range, probability of detection, and probability of confusion--the model version used for the experiment allowed for the manipulation of the ISR sensor detection range only. Thus, it was used as a surrogate for full sensor capability. The Sensor Effectiveness variant was also examined at a Maximum level of performance achieved by extending sensor ranges in order to create an upper bound for sensor performance. Finally, a Degraded performance level, arbitrarily established at 25% of Baseline, was examined in order to gauge the extent of changes in perception.

2.1.2 ***COP Sharing***

The COP Sharing variant was used to examine the effects of varying shared awareness across the Common Operational Picture by manipulating the timing and flow of information. Increasing awareness of battlefield events should have an impact on the C2 behavior of subordinate units. The operational definition includes several factors--network load or capacity, transmission delays, and the intelligence fusion interval. The latter determines the update frequency of the commander's situation map, known as the JEF in JWARS parlance--JWARS Equipment and Forces--by specifying the fusion cycle of intelligence data.

The COP variant factors were defined at four levels. The Baseline Sharing level represents the current model capability of partial, time-lagged, peer-level awareness of other units' actions. An Intermediate Sharing level was established which slightly increases information sharing and slightly decreases the time element. A Maximum Sharing level was also examined in which we emulated complete peer-level awareness of other units’ actions occurring at or near real time. Although not originally considered, it became apparent late in the analysis that a Degraded level of COP Sharing would be of interest. This fourth level for the COP variant was added and incorporated into the final phases of the experiment. It provided a basis of comparison for the enhanced Sharing results, and in a sense, bounded the results. While it could also be considered to simulate sensor jamming, this interesting potential capability was outside of the scope of this project and will not be further considered here.

Changes were also made to the Local Surveillance Focus Area, which was expected to determine the proportion of JEF information made available to the Commander. However, we unexpectedly discovered that this capability was not yet fully functional and, as a result, had no impact on experiment results.

2.1.3 ***C2 Behavior***

The third variant is the C2 Behavior variant, which varies across two levels. Current C2 behavior relies on hierarchical decision-making with little autonomy. It was modeled as the Baseline case. Alternatively, the Modified C2 Behavior variant level attempts to emulate increased autonomy in decision making. Within JWARS, the C2 behavior of units is readily modified by changing their organization-type Command and Control function. This means we were able to reassign Division C2 behaviors to the Brigade entity, which provided the subordinate units, i.e., the brigades, with the C2 capability normally associated with higher level organizations, i.e., divisions, and, thus, greater independence. Although JWARS was not originally intended to provide this type of sophisticated capability, development is evolving towards this end.

The current JWARS C2 decision-making model at the battalion and brigade levels is based on a C2 component for each Battle Space Entity (BSE) that simulates thinking and decision making. This BSE C2 component bases its decisions on a perceived reality represented by a JEF entity. There is also a sensor component for each BSE which registers interest in specific sorts of items--tanks, for example--and signatures (electro-optical and IR emissions, radio transmissions, etc). This sensor component determines how the interaction between BSEs takes place and what information is collected. Assets within combat battalions are equally distributed over areas known as Fire Control Points (FCPs). It is the FCPs, not the assets, which are actually detected by enemy sensors and which get placed on a target list for direct and indirect fire. The BSE sensor then generates an implicit message, which is not subject to communications delay, requesting fire control or C2 decisions on BSE orientation for effective engagement posture. If the BSE C2 determines that its organic weapons cannot engage the enemy unit, it passes a Fire Support Request to its higher unit Fire Support Coordinator, which, in turn, assigns fire orders to available artillery units. The JWARS Adjudication Manager receives those fire orders and determines the attrition resulting from combat interactions among BSEs.

Division C2 functions a little differently because division units have more authority than brigade units. Division C2 receives Fire Support Requests and assigns fire orders to available artillery units and passes those orders to the Adjudication Manager. Also, division C2 messages are explicit, not implicit. This means they will have a direct impact on communications network flow and congestion. Further, Division C2 dictates a withdrawal distance after enemy contact greater than that guided by Brigade C2. These pertinent differences effect scenario outcomes when the Brigade C2 behavior is correspondingly modified and their impact is revealed in experiment results.

2.2 ***Design of Experiments***

Factorial experiment designs are suitable for these types of analyses--those with multiple multi-level variants in which interaction, as well as main, effects are of interest [Box, *et. al.*, 1978].
Hence, a full factorial design (3x4x2) was used for this project to explore the interaction and main effects of the three variants. Certain pathological cases--those that attempt to examine a capability for which there is no corresponding behavior--are excluded. They are those cases in which the current Baseline level of the C2 Behavior variant would have been combined with the

enhanced levels of the COP Sharing variant. By definition, current C2 behavior does not support alternative COP Sharing; there is no established doctrine or process for it. Accordingly, these cases are not of interest and were not considered.

*2.2.2 **Measurements and Hypotheses***

Traditional attrition measures of Red and Blue losses are examined, specifically, Loss Exchange Ratios and Force Exchange Ratios. In addition, other measures such as number of routs, assets killed per fire order, time to objective, numbers of sensor perceptions and numbers of fire support requests and fire orders are considered. These additional measures, enabled by the JWARS enterprise model and its process analysis capabilities, amplify our understanding about the simulation outcome landscape and give insight into the JWARS C4ISR process. Multiple replications were performed for each case to assess variance within the processes.

We hypothesize that these performance measures will improve when capability is enhanced and that they will decline when capabilities are decreased. In other words, we expect to encounter decreased attrition of friendly forces and increased attrition of enemy forces when we improve Sensor, COP and C2 capabilities. Generally, simulation outcomes confirmed these expectations.

*2.3 **Scenario Description***

The setting for the experiment is Southwest Asia in the year 2005. In order to focus more specifically on our objectives, the large and complex JWARS Microgold scenario was narrowed in scope. We used only two enemy armored divisions advancing in echelon against a U.S. armored division defending a small, friendly, Middle Eastern country. The U.S. division was tasked to conduct a delaying action. Robust intel assets were utilized, including air and space assets. Intelligence collection plans were built for the relevant simulation phases (Deter-Deploy, Halt Force Buildup, and Counteroffensive) and states (Pre-ambiguous, Ambiguous, Unambiguous, and Surprised). These plans designated priorities for each intelligence requirement, and the feasible and preferred sensor for each tasking. They also specified where the sensor would collect, what it would report, and how often.

*2.4 **Model***

JWARS Release 1.3 (R1.3), Service Release 1.09, was used as the basic simulation configuration for code and data sets.

3. **Findings & Results**

*3.1 **Analysis Tools***

The JWARS model collects and generates data through a set of output collectors called "Instruments." Various types of data were collected from the JWARS instruments and exported into spreadsheet and database tools in order to produce the measurements of interest. In addition, the JWARS "Rosetta" tool was used to translate the coded output into a more readable form.

*3.2 **Attrition Analysis***

The traditional set of measures for campaign analysis are those that deal with attrition. We considered three such measures, the Initial Force Ratio (IFR), Loss Exchange Ratios (LERs) and Force Exchange Ratios (FERs). These measures were calculated for all cases and replications in the study. They were computed from JWARS data and mapped during post-processing into the so-called "Big Four" ground systems--Armored Personnel Carriers (APC), Artillery (ARTY), Infantry Fighting Vehicles (IFV), and Tanks. The "Other" category was not used since counts of personnel and support equipment (trucks, for example) would skew results. These items are important, but are not yet well represented in JWARS, or, for that matter, in most legacy models. Neither the assets nor the categories were weighted in this analysis. Note that in the future, consideration can be given to tracking C4ISR assets as a separate category as the degradation of networks and ground stations will be explicitly modeled in upcoming JWARS releases. The IRF in our scenario is 0.88, near a parity of 1.0, giving a slight advantage to Blue. See Figure 1.

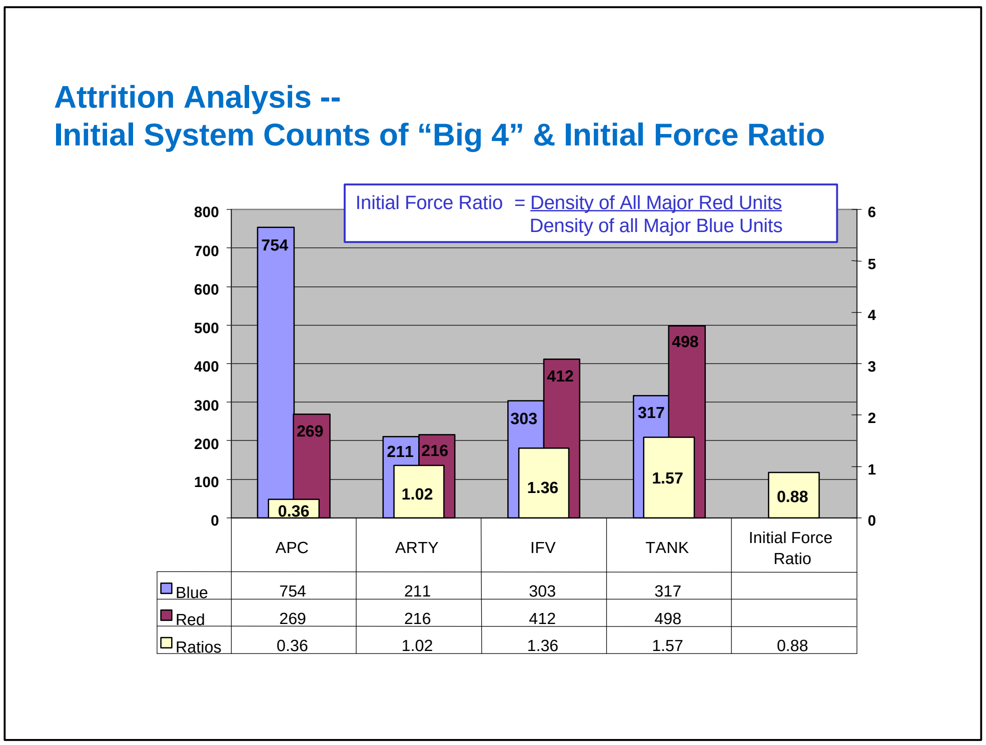

Figure 1. Initial System Counts

Figures 2 and 3 show the loss data for Blue and Red by Case for each of the four categories of land assets. Note that only those cases in which the Sensor Effectiveness variant was set at

Baseline level are presented as results showed little variation across Sensor levels for this measure. This was most likely a function of the JWARS model capabilities and limitations (which have been fully expanded in newer releases). In R1.3, we could craft only limited changes to sensor attributes, and, moreover, the Land C2 functionality was not fully mature. This meant that, though some changes to sensors could be made, they could not be exploited or leveraged. This result might also be attributed to the scenario circumstances--there was no air or deep strike attack, the battle was fought close-in, and the short simulation period (10 days) may not have allowed the increased intelligence capability to shape the battle.

These two charts provide an initial synthesis of the raw JWARS attrition output, which consists of thousands of records listing losses by system, by time, and by individual replication. The values represent an average across all replications for a given case. In Figure 2, Blue Losses, we see that friendly losses are greatest in the cases in which COP Sharing was Degraded. In contrast, when we examine Maximum COP Sharing, we see that Blue losses are at, or close to, their absolute minimum levels.

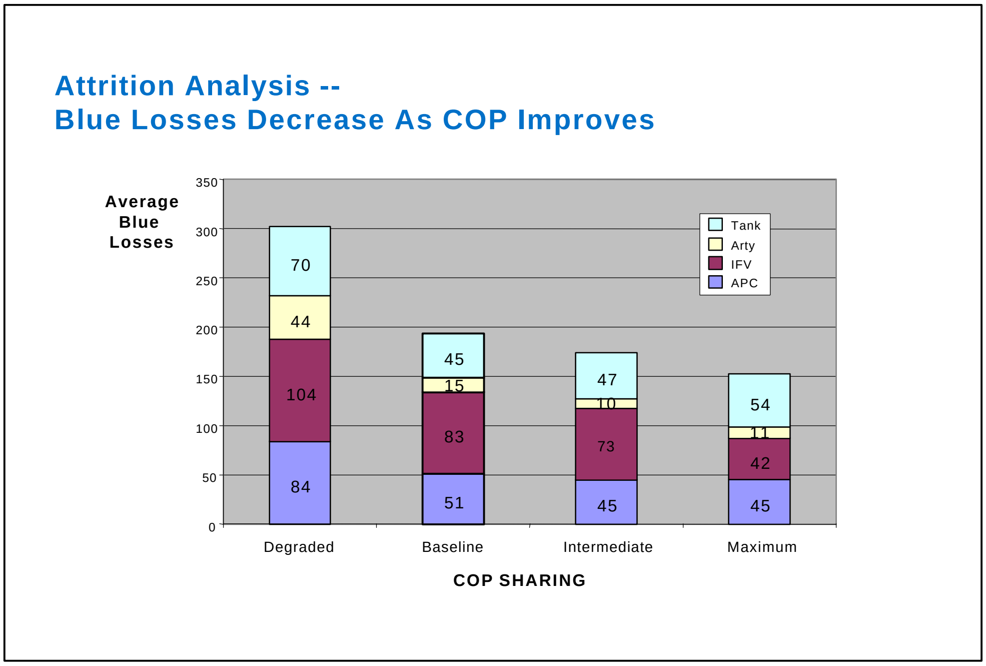

Figure 2. Blue Losses

Regarding Red Losses (Figure 3), it is noteworthy that as COP Sharing improves from Baseline, Red losses increase. The implication is that COP Sharing does have an effect in JWARS and in the direction we would expect. However, we also note that Red Losses increase when COP Sharing is degraded from Baseline, a result which was not expected. By using a new JWARS capability, video playback, we were able to explore this occurrence by actually watching the interaction of forces during the warfight. Through it, the movements of Blue forces--whose COP Sharing was degraded and C2 behavior modified--were revealed to be extremely erratic. We determined that Blue Brigades enabled with Modified, i.e., Division, C2 withdrew to a greater distance than those with Baseline C2 (10km. vs. the 5km. brigade withdrawal distance), resulting in significantly increased contact between the forces. This increased interaction resulted in more Blue fire orders and, in turn, more Red losses. The chaotic and violent fight seen in this scenario case will impact other aspects of the analysis and will be explored further later.

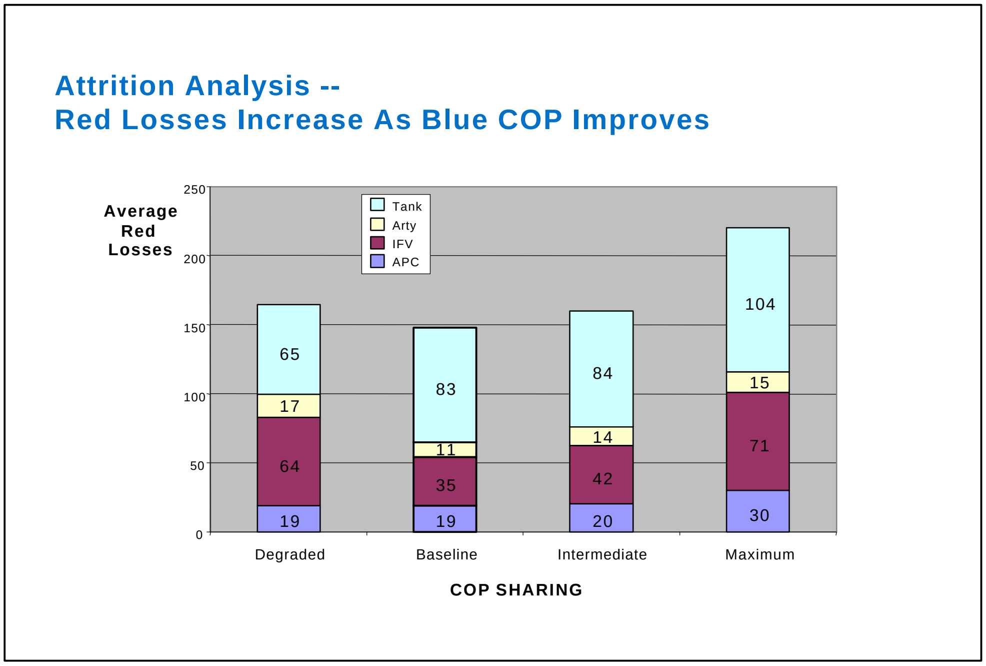

Figure 3. Red Losses

*3.2.1 **Exchange Ratios***

The Loss Exchange Ratio (LER) and the Force Exchange Ratio (FER) further synthesize JWARS output. They are typically considered to be the best measures for simple attrition analysis. Of the two, the LER is conceptually easier to grasp since it is a simple comparison of Red system losses to Blue system losses. The FER is a more subtle indicator; it represents the intuitive expectation that the side with the bigger force will have an advantage. The FER compares the IFR to the LER. For both LERs and FERs, ratios of 1.0 imply parity, and ratios greater than 1.0 are favorable to Blue.

The LERs (Figure 4) were computed for all cases and all replications. Though JWARS is a stochastic model, our scenario essentially consisted of a ground campaign and ground attrition is modeled deterministically in JWARS. As a result, there was little to no variance across the replications for each case (standard deviations were essentially zero). We see that the LER is most favorable when COP Sharing is maximized, in the mid-range for Intermediate COP Sharing, and least favorable when it is Degraded. This confirms our expectation that increasing COP Sharing will effect attrition favorably.

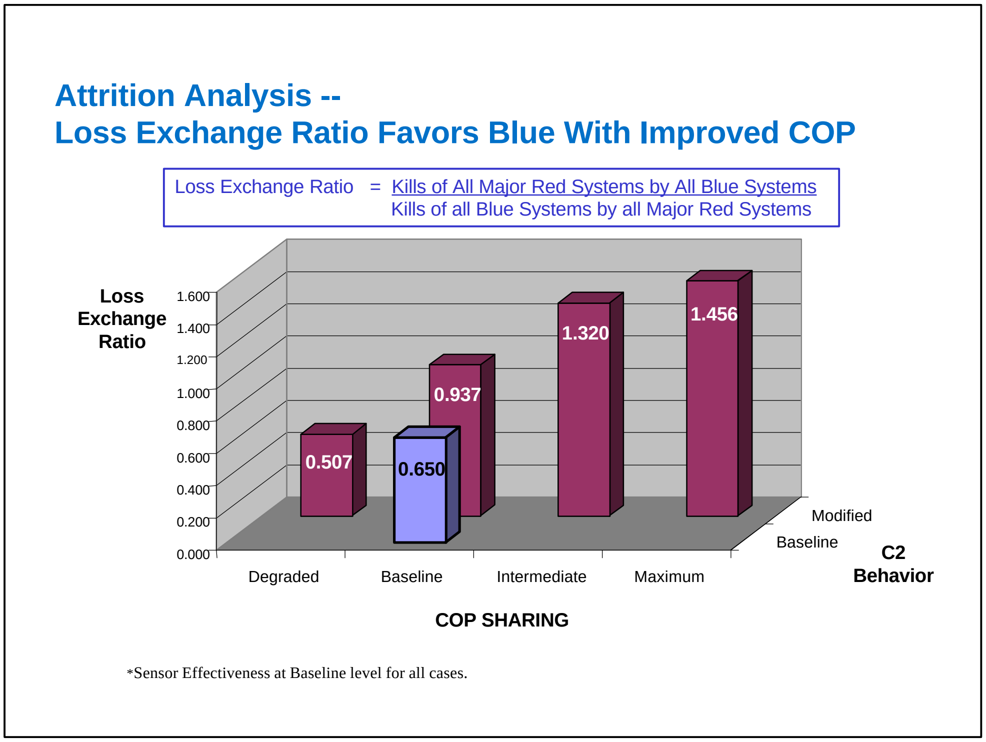

Figure 4. Loss Exchange Ratios

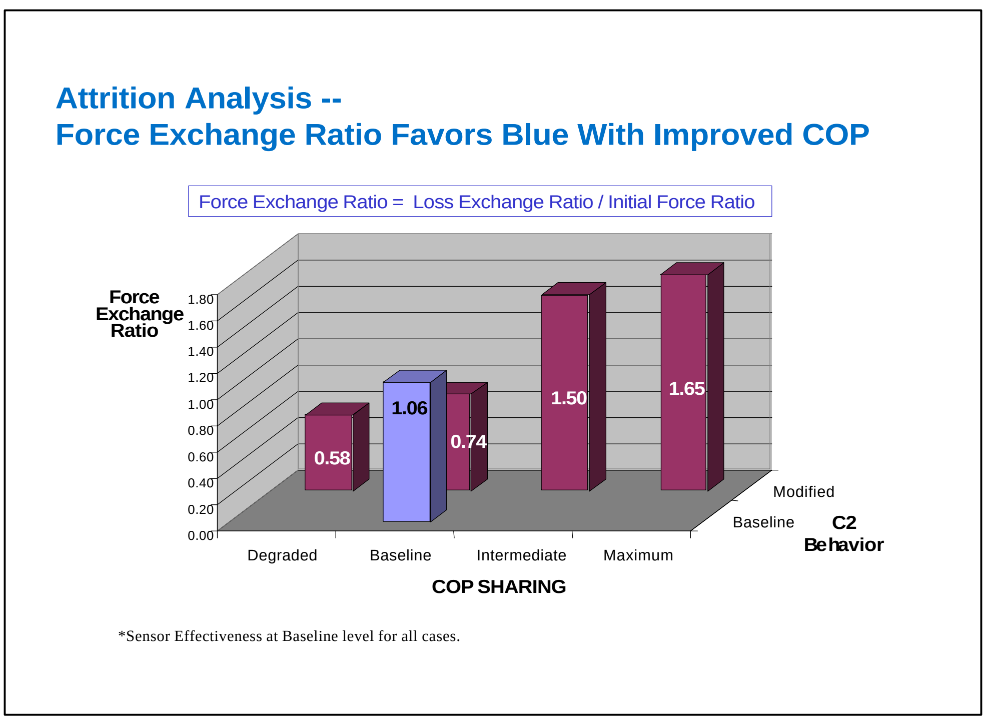

Figure 5. Force Exchange Ratios

The FER, shown in Figure 5, reflects the same trend as the LER, but is based on more information than just losses, making it a better indication of the outcome than the LER alone. It compares the Loss Exchange Ratios to the Initial Force Ratios and thus normalizes losses to the force ratio position at the onset of the engagement. FER is essentially an indicator of whether a side is winning or losing. Ratios greater than one are favorable for Blue because they indicate that Red is sustaining losses at a greater rate than blue, and in a battle of attrition, will consequently deplete their forces earlier.

As with the LER, we see a pronounced effect in cases of Maximum COP Sharing and of Degraded COP Sharing. However, note that the FER drops off when C2 Behavior is modified at Baseline levels of COP. This is most likely explained by the greater distance to which Blue Brigades enabled with Modified, i.e., Division, C2 withdrew (Section 3.2). Second echelon units were thus exposed to direct fire for an increased amount of time, resulting in increased attrition. We also detected an increase in message traffic over the brigade nets with Modified C2 Behavior, which, through process analysis, we determined was caused by two things. First, many of the messages that had been passed implicitly with Baseline C2 Behavior (e.g., situation reports and movement orders) were communicated explicitly with Modified C2 Behavior and were thus subject to communications delays. Second, even with the increased sovereignty associated with Modified C2 Behavior, brigade-to-division reporting requirements did not diminish. The erratic behavior mentioned above led to more enemy contact, which produced even greater numbers of situation reports, calls for fire, and movement orders.

3.2.2 ***Friendly Routs***

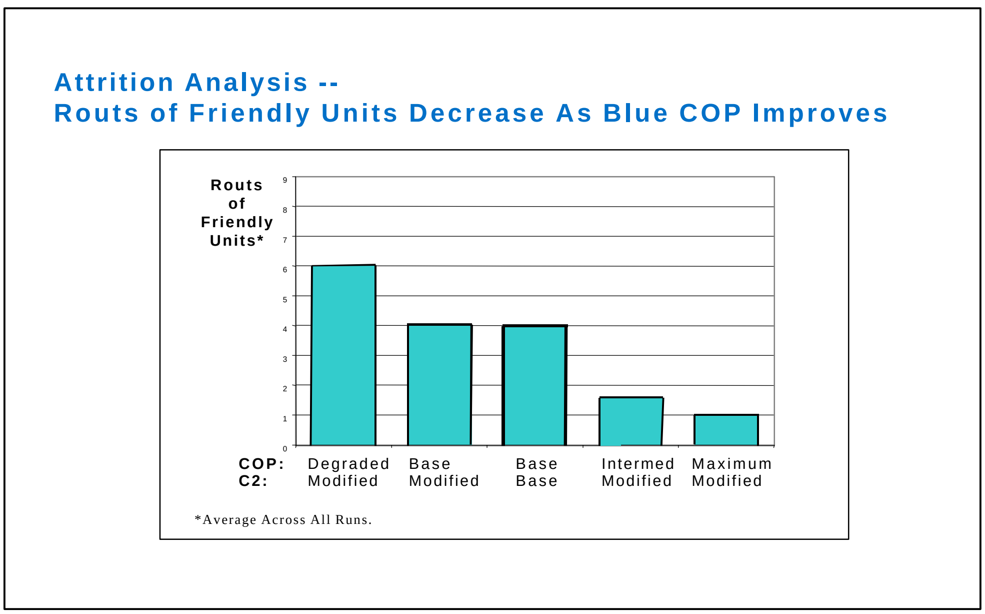

Figure 6. Routs of Friendly Units

Figure 6 illustrates that Blue forces with enhanced COP Sharing experienced a reduced number of routs, perhaps because they were able to pass information more quickly and react in near real-time to enemy movements. In contrast, note the extreme results with a Degraded COP where Blue units were more likely to be routed by an advancing enemy. This was probably due to the erratic behavior of the Blue brigade itself, which resulted in more contact, less effective fires (as revealed in the targeting analysis discussed below), and heavier casualties (as indicated by the Attrition results). Analysis of the instances of enemy units being routed was inconclusive and is not discussed here.

*3.3 **Measures of Effectiveness***

We considered several other measures in order to amplify our understanding of the simulation outcome landscape and give insight into JWARS C4ISR processes. These process analyses were enabled by JWARS enterprise model capabilities.

*3.3.1 **Sensor Perceptions***

This measure examines the effectiveness of the Sensor Effectiveness variant. Though model capability was, at that time, limited in this functional area, we were able to manipulate ISR sensor ranges and observe the effects of those manipulations. We tabulated the total number of perceptions of key enemy units, i.e., the headquarters unit of the single enemy corps in the

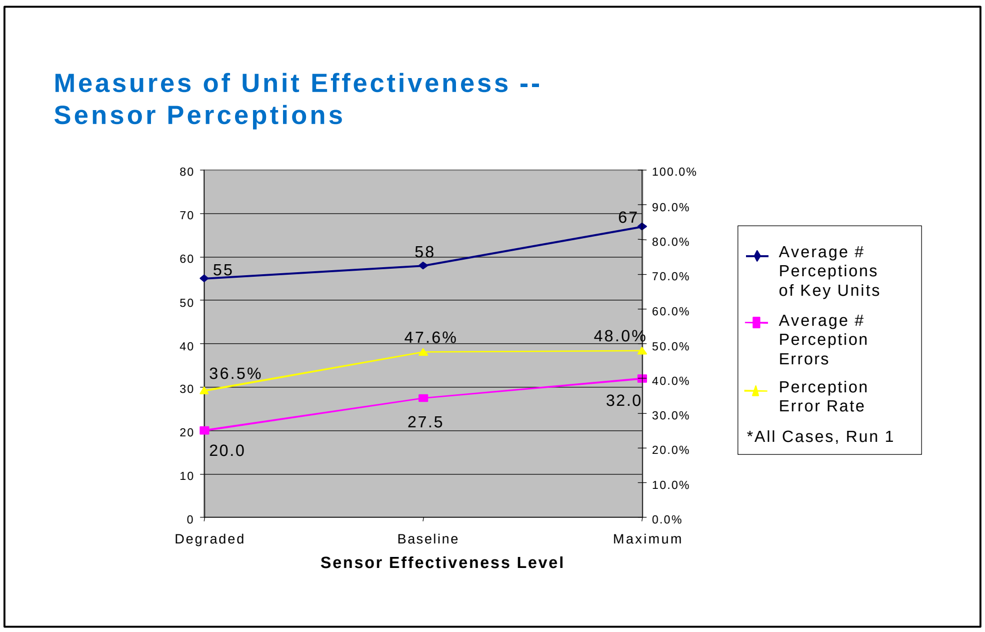

Figure 7. Sensor Perceptions

scenario, and then computed the average number of perceptions for run #1 across all cases for each Sensor Level. Figure 7 shows that the number of perceptions increases as the sensor range expanded. The perception error rate, defined as a perceived location deviating from its ground truth location by 100+ meters, was constant across Baseline and Maximum Sensor levels, though the total numbers of perceptions and perception errors increased. Note the counterintuitive drop-off in the error rate at the Degraded Sensor level. This may be explained by the extensive close-in contact of the conflict and the limited opportunities for ISR sensings in that chaotic environment.

3.3.2 Fire Support Requests, Fire Orders

The data for this analysis reflect an increase from Baseline in the number of fire support requests (FSRs) for both Intermediate and Degraded COP Sharing while the number of such requests for Maximum COP Sharing actually drop off slightly from the Intermediate level. This drop-off is probably a result of more timely and effective communications reducing unit reaction times and numbers of enemy contacts. The optimal level of COP Sharing could be identified through a sensitivity analysis. In the particular case of Degraded COP Sharing, there was a significant increase in message traffic over the fire support net at the time of (and is probably explained by) that very erratic behavior of one Blue brigade. Also, fewer fire missions were generated with Maximum COP Sharing, but those that were generated were passed more quickly to friendly artillery units.

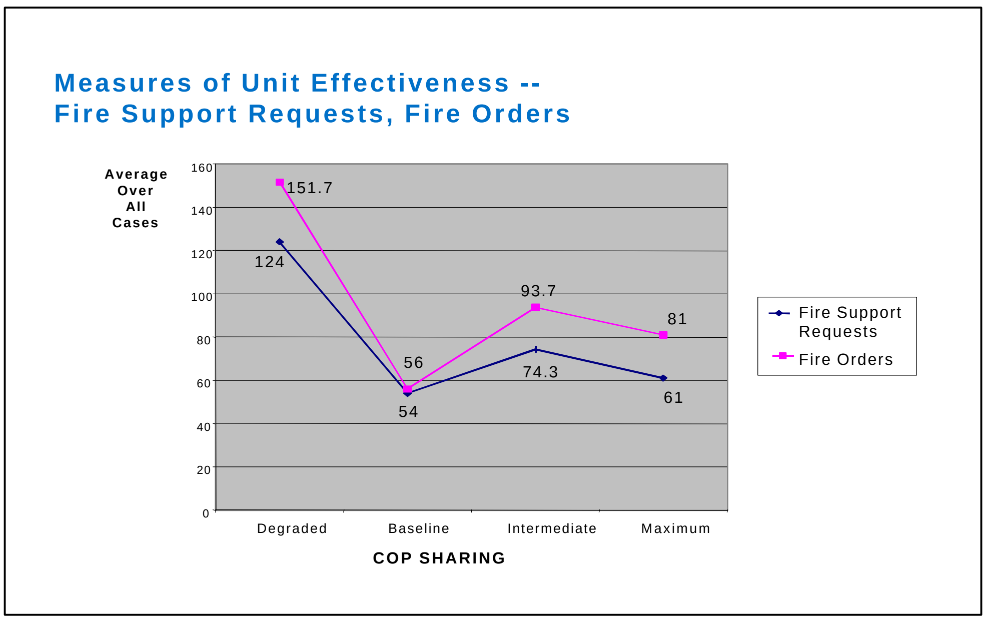

Figure 8. Fire Support

A detailed examination of the actual message content revealed that fire requests and resulting fire orders (FOs) were delayed by as much as three hours when the COP was Degraded, compared to Baseline delays of approximately five minutes. Delays of such magnitude rendered target data nearly obsolete. As a result, enemy units had often moved out of range when the firing units received the orders to fire. Blue fire control units were thus forced to serially poll all available Blue artillery units to determine which ones were within range, significantly increasing the amount of traffic over the brigades' fire support nets and delaying their effective response.

3.3.3 ***Targeting Analysis***

An effort was undertaken late in the project to explore and link sensed, engaged and killed targets. The results are displayed in Figure 9 and are considered exploratory--only one run per case and a very narrow time slice of the battle were examined due to time constraints. Hence, they are not as robust as those for the previous Fire Support Request and Fire Order analysis. But they are important because they reflect emerging concepts and because the effort again demonstrates the application of process analysis within the JWARS model and its impact on the enterprise or domain. It thus merits our attention.

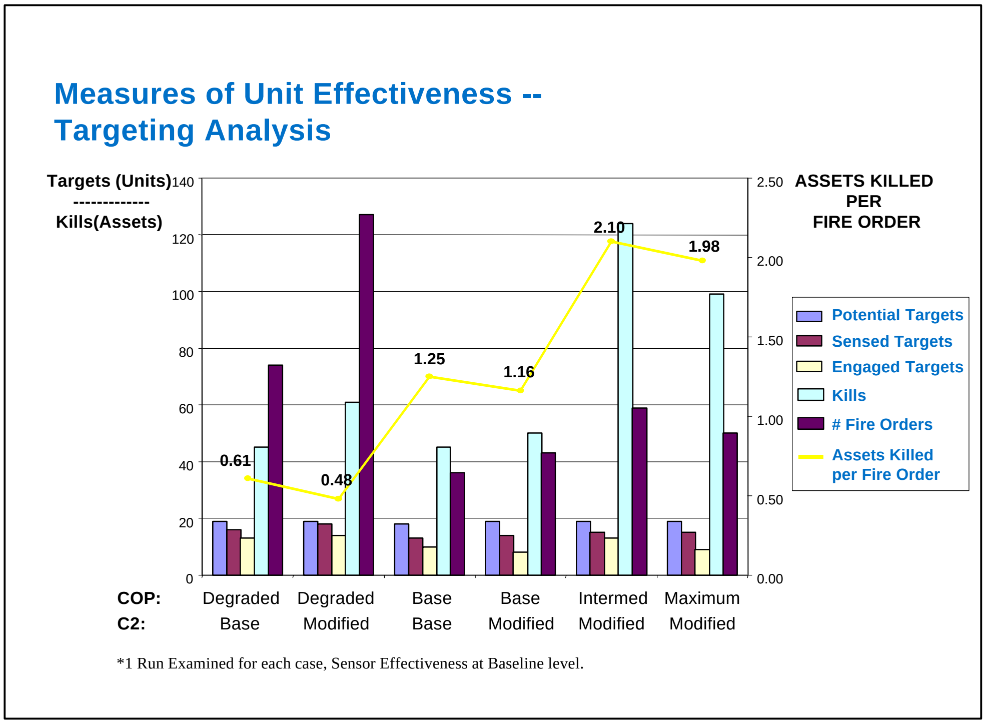

Figure 9. Targeting Analysis

The issue of interest is the relationship between particular FSRs/FOs and particular targets. Note that targets are defined as units while kills refer to assets. Thus, the relationship between them must be established by tracking two separate processes. It is possible to do so with current model capability, but it requires a custom code snipper and extensive reviews of message logs (a tedious task, at best). While we do know that there were many repeat FSRs--Blue fire control units serially polled blue artillery units to determine which were in range--we cannot be certain which FSRs and FOs are unique and which are repeats. This is critical for establishing cause and effect between friendly and enemy actions and responses. Accordingly, the capability to determine this linkage should be improved.

The raw numbers of potential, sensed, and engaged targets and kills are depicted in the figure, and the number of assets killed per fire order overlays that data. We observe that this measure improves as COP Sharing improves but drops off at Maximum COP Sharing. This effect is related to the FSR/FO analysis discussed above; the optimal level of COP Sharing could be refined with sensitivity analysis. Finally, the lowest value of this measure occurs with a degraded COP and suggests that a more violent battle is not necessarily a better managed one.

3.4 Summary Results

3.4.1 Value of Shared Awareness

Attrition analysis confirmed the COP Sharing variant had a pronounced and favorable impact on unit effectiveness. Enhanced COP Sharing resulted in effective friendly fires against enemy forces (maximizing Red losses) and near minimum amounts of friendly losses and Blue routs. On the other hand, with Degraded COP Sharing, Blue fire support was least effective, Blue suffered maximum losses, and Blue units were routed most often.

For the Sensor Effectiveness and C2 Behavior variants, the outcomes were pronounced but less conclusive. Overall, improved sensors did not have much of an effect, though this seems to be a function of existing JWARS model capabilities (which have been significantly expanded since that time). However, expanding sensor capability did result in increased detections of high-priority units. Moreover, unit behavior did change dramatically when C2 was altered, though not with cohesive impact. The modified C2 Behavior variant produced mixed results with respect to loss and force exchange ratios, and was linked to enemy forces reaching their objectives somewhat sooner, indicating that increased autonomy does not always guarantee enhanced combat effectiveness.

3.4.2 JWARS C4ISR Capabilities

Nearly all of the modifications and enhancements to JWARS C4ISR constructs that we identified and suggested during the course of the study were accepted and incorporated into the model before our study was even completed. We detected and fixed several problems with JWARS sensors. First, we found that a good portion of the sensor data was notional and not based on actual (and classified) sensor range data. We replaced the notional data with the more accurate, classified data. Next, we discovered problems with sensor ranges, which were corrected by the appropriate software engineers. We also recommended that the Ground Composite Sensor be enhanced to better depict tactical unmanned aerial vehicles (UAV) and ground-based signals intelligence (SIGINT) operations (and this is under development). We unexpectedly discovered that the JWARS capability to provide intelligence "pull-down" support to subordinate units was not fully functional in R1.3. However, this oversight will be corrected in the upcoming JWARS release. Finally, we discovered that with modified C2 Behavior, brigades exhibited erratic behavior by withdrawing too far to the rear after contact with the enemy, and thereby demonstrated the inherent problem in changing capabilities without adjusting doctrine. That withdrawal distance is now modifiable; changes should be made in concert with exploring alternate doctrine.

Other relevant model improvements which will more fully power C4ISR analysis are on the horizon. A land commander concept is being developed which will enable the wargaming of different courses of action based on current perceptions. It will consist of a knowledge base and a logic engine involving backward chaining and fuzzy rule sets which select a best course of action from those being simulated. Also, a new intelligence planner will assist the Land Commander by providing reports on enemy status and likely enemy courses of action.

4. **Study Recommendations**

This analysis could be improved in a number of ways, most of which are tied to emerging functionality within the JWARS model. The attrition analysis could be improved by tracking C4ISR entities as assets; this requires the capability to explicate model network and ground station degradation within the JWARS model. It is under development and will greatly leverage JWARS' already considerable C4ISR analytic capability. The targeting process analysis should be expanded to include all cases and runs and to identify the optimal level of COP Sharing. Improvements in C2 capability, i.e., the development of the Maneuver Planner, should be exploited to further explore shared awareness. New model capabilities in intelligence processing, intelligence pull-down and dynamic collection can be leveraged to better assess the impact of manipulating C4ISR concepts. Finally, variant definitions should be refined and a different Design of Experiments should be considered to better isolate main effects, which were convoluted because of the exclusion of the pathological cases.

5. **JWARS Doctrine Modeling**

This work convincingly demonstrates that JWARS can model and analyze individual processes. The ability to analyze the effectiveness of a process is termed process analysis. It requires an enterprise or domain modeling capability and JWARS has it. The power of this concept is that, while the ability to examine traditional strategic outcomes (e.g. attrition) is maintained, an entirely new ability to breakout and inspect tactical outcomes, processes that were buried in the larger action as a small part of the larger whole, has been created. This potential has additional powerful application in the use of doctrinal issue analysis and doctrine development. It is an important new analytic capability for the DOD M&S theater warfare domain.

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