12TH ICCRTS

"Adapting C2 to the 21st Century"

A Quantitative Model-Driven Comparison of Command Approaches in an Adversarial Process Model

Tracks: Modeling and Simulation, C2 Metrics and Assessment, Organizational Issues

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Abstract

In this research, we will demonstrate that for a given mission, certain Command Approaches[1] are more effective against other Command Approaches (e.g. Control Free *may* be more effective against Interventionist than Problem Solving). Lenahan[2] identified metrics and techniques for adversarial C2 process modeling. We intend to further that work by developing a set of adversarial process models that will allow us to "compete" Command Approaches (Control Free, Problem Solving and Interventionist) against each other. We will evaluate the conflict outcome, abstract process metrics[2] and resource utilization rates (materiel and human). The intent is that this work will quantitatively examine the effect of varying Command Approaches for a specific mission and lay the foundation for future work in the area of C2 process and organization research. In the future, we would like to develop hybridized or unique command approaches that are most effective for specific mission portfolios.

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Introduction

The United States spent the Cold War developing a strong, robust military force to cope with a symmetric opponent, the Soviet Union. The military force that was developed was optimized to perform a large, but not exhaustive set of missions, almost all of a directly military nature. Once the Soviet Union dissolved, the United States military began to become a victim of its own success. As was demonstrated in Operation Desert Storm, the United States easily destroyed the 4th largest conventional army on the planet[3]. After a demonstration like this, it became apparent that fighting the United States military directly and conventionally was not an efficient proposition. Consequently, many organizations altered their strategies to achieve their goals through asymmetric, non-military means. The United States faces nimble, opportunistic adversaries (from large countries to smaller non-state actors like Al-Qaeda) that threaten the United States in unpredictable ways. These adversaries threaten with two strategies they use to achieve their objectives. First, they conduct operations in a quick, decisive, unconventional fashion which challenges the conventional procedures that the military is optimized for. In this regard, they take advantage of their speed of command advantages. Second, they challenge the resource base of the military forces. Because their missions often require resources that the military does not have (potentially for cost reasons), they challenge the military's range of adaptability.

The United States faces two major issues in regard to how the US military conducts and manages operations. The first challenge comes from asymmetric, unconventional, terrorist style organizations like Al-Qaeda whose command approach differ greatly from the traditional enemies that our military was designed to counter. The second challenge comes from within. The United States military is no longer able to go it alone from an organizational standpoint. To be successful, they need the cooperation and participation of other organizations, most of whom they will not be able to give orders to. This work is planned to lay the foundations for addressing both issues.

Origins

In order to achieve the agility and adaptability required to succeed against these threats, the US military is re-evaluating its physical force structure (systems, platforms, networks, sensors, humans). The Chief of Naval Operations (CNO) Strategic Studies Group (SSG) is considering concepts like Force Effects Packages (FEPs) to increase agility and adaptability in the physical force structure. Additionally, initiatives including the Navy Littoral Combat Ship (LCS) and Air Force Unmanned Combat Air Vehicle (UCAV) are moving the Joint forces toward a smaller, more adaptable structure.

These technical solutions often are integrated into existing operational processes. The vast majority of current military assessments in the area of force transformation are focused on technology solutions to the problem of achieving agility and adaptability in non-traditional environments. As Adm Cebrowski pointed out at the inception of the NCW era, technology is important but the largest gains come from the new technology coupled with process innovation and change (see Figure 1).

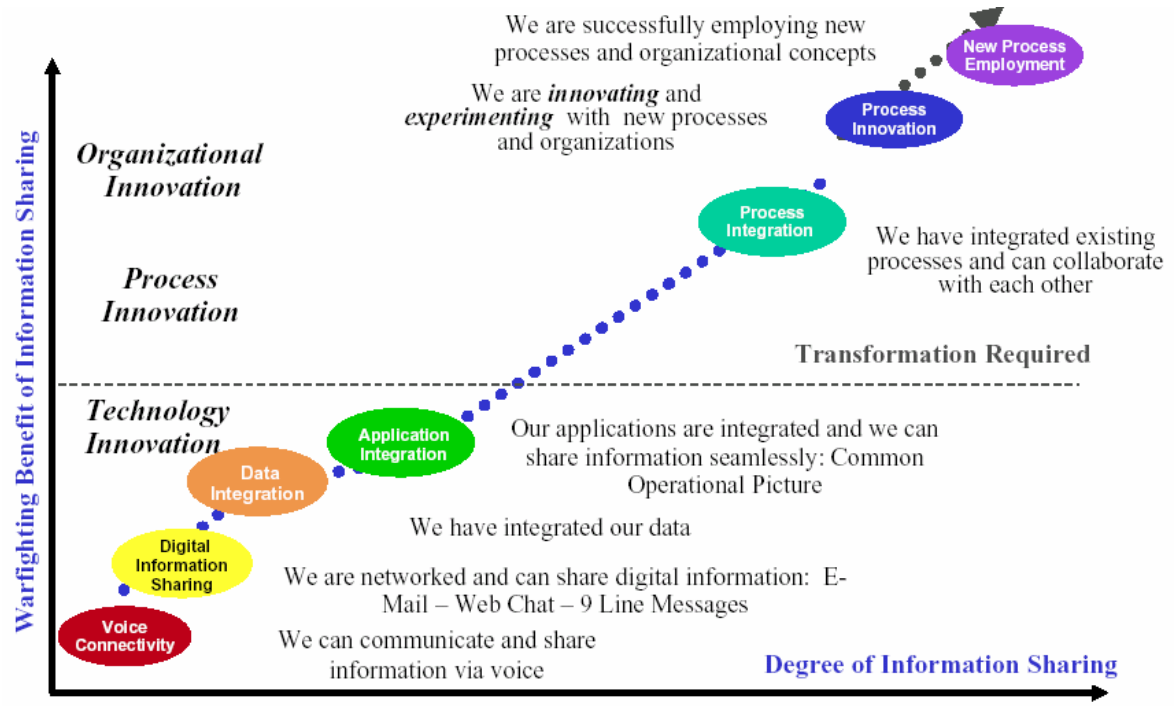


Figure 1: Garstka's Conception of the Benefit of Information Sharing[4]

The vast majority of current military assessments in the area of force transformation are focused on technology solutions to the problem of achieving agility and adaptability in non-traditional environments. Because the majority of C2 modeling has been performed with technical implementations in mind, a purely process oriented approach is necessary to understand which process is best for a given scenario. In a 2003 CCRTS paper, Jack Lenahan outlined a method for measuring the performance of a technology independent (abstract) C2 process[2]. This process was based on IDEF-0 process modeling and focused on how to improve the C2 process through improving metrics pertinent to the decision making process. The model structure and metrics used in this analysis is based on Lenahan's paper.

Another major influence for this paper was Dr. Alberts and Dr. Hayes 1995 paper, "Command Arrangements for Peace Operations"[1]. In this paper, they discuss the concept of a command arrangement which is a meta-process. Command approaches describe the rules to construct C2 processes for an entire organization. For the purposes of this experiment, a command approach has three major components. The first is a delegation/collaboration strategy. This is the policy that determines how the planning and work is delegated to other nodes in the organization. The second component is who does the work and their performance characteristics. The third component is the organizational structure.

Technical Description of the Problem

The technical problem under examination here is the issue of which command approach is best, if any. Quantitatively, traditional metrics for processes like latencies and utilizations only offer indirect insight into the quality of a command approach. The major problem in attempting to identify the best C2 approaches with traditional a C2 process assessment is threefold. First, they usually take technology into account and this skews the process (and command approach). Second, some modeling approaches use latencies and other metrics to indirectly evaluate the

performance of a command approach. This kind of measurement does not concretely identify which C2 process is better. Finally, some process modeling approaches use a single sided (blue only) model of the process in order to simulate and generate outcomes. Accurate modeling of the control aspect of C2 requires feedback from the engagement and only adversarial competition can demonstrate this.

To remedy these three issues, we've chosen to take advantage of Lenahan's abstract C2 process modeling concepts and his adversarial process modeling concepts[2]. These modeling techniques will be used to create a model that competes two command approaches. The outcome from the competition will be scenario specific results like blue accomplishes mission, red escapes, red succeeds. Additional metrics will also be collected.

The goal of this work is to demonstrate the initial framework for the type of analysis needed for command approach evaluation. This will be done by building C2 process models including human performance & decision models, competing them against each other, collecting metrics (outcome, latencies, information flow, utilization, etc) and finally using statistical analysis to determine if the command approaches have a significant impact on mission outcome in an example scenario. The proposed hypothesis is that it is possible to integrate and evaluate command approaches utilizing component factor models in a technology agnostic, adversarial process framework.

Analysis Approach/Solution Strategy

In order to perform this analysis objectively and with quantitative support, this research is based on a modeling and simulation analysis framework. The approach is to define and implement a baseline model of a current US military C2 process and organization. The model is then varied to represent alternative command approaches to determine relative efficiency and effectiveness. Recognizing that the adversary's C2 process and organization profoundly impact the results, a model of the Red process is included and cause-effect linkages between Blue and Red processes are defined. This research is technology-agnostic, assuming a constant system architecture. To illustrate the approach, the model is implemented for a single scenario, and experiments are designed based on C2 styles defined by Alberts and Hayes[1].

Assumptions

Because of the scope of any modeling effort attempting to tackle adversarial C2, restrictions had to be chosen due to time, funding and model fidelity issues.

- Scenario specific - Initial results presented in this paper are based on a single operational scenario to illustrate potential of the modeling and simulation solution strategy and selected Measures of Merit (MoM). Therefore, results and conclusion's validity will be highly specific to the selected scenario. Future work will explore sensitivity of results to modifications in scenario and solution spaces for new scenarios.
- Social and Political impacts – These impacts were not considered or modeled, although they do impact C2 processes.
- Technology agnostic – Technology has influenced the development of C2 process greatly and this may have limited process improvement. In addition, many other tools support technological performance evaluation.

- Limited option space – Because the option space of commander is only limited by his imagination, we were forced to narrow down their options at numerous points in the model. This is a modeling limitation.

The model is focused on C2 process and organization. Process activity delays are modeled based on human performance and decision models. We are assuming that supporting technology (i.e. C2 systems, communications, etc) are available and will not cause significant time delays in supporting the process. The idea here is that if a superior C2 process can be determined, subsequent technology models can be incorporated to either (i) set requirements for future technology to support optimal C2 structures or (ii) add technology constraints and re-run model to identify new optimal C2 structures constrained by current technology. The risks associated with this assumption include: a given systems architecture may better support one C2 structure over another. That is, a cyclic architecture may appear to be the best approach in a given situation. However, the communications architecture may not be there to support the extensive communication required between upper and lower CoC echelons. This technology constraint may demand a problem solving approach in cases where communications are unavailable.

Scenario

In order to maximize applicability to current day operations and test the hypotheses presented in a realistic environment, the scenario for this experiment includes a multiple mission environment with counter-insurgency operations. The following scenario was selected as it satisfies these requirements and was used by SSG XXV to support recommendations to the CNO in FY06. The scenario was originally developed using OPNAV tactical situation (TACSIT) processes and doctrine like Joint Pub 5-0[5].

The scenario developed for inclusion in the C2 Model is designed to exercise multiple layers of the Chain Of Command, and revolves around a struggling democracy which has experienced a recent increase in insurgent activity. The government has friendly diplomatic relations with the U.S., and has asked the U.S. to help stabilize the region by providing military assistance to their forces. The Combatant Commander has been directed by the National Command Authority to support the operation by deploying a Littoral Combat Ship (LCS) squadron, consisting of 3 LCS platforms, to the region for Peacekeeping and Humanitarian Assistance. Recent reporting from national sources indicates that the insurgent forces are now attempting to infiltrate weapons from a neighboring, neutral country via commercial shipping. This new threat requires a change in the operational situation and presents the LCS Squadron Commander with the requirement to simultaneously support Humanitarian Assistance, Counter Insurgency, and Counter Proliferation (HA/CI/CP) missions. See Appendix A for a full description of the scenario.

The operational scenario was then used to develop appropriate operational mission threads and associated IDEF models. These products were constructed using historical information derived from: current US Joint Doctrine[5], a study of German operations in Russia (Barbarossa) and Norway during WWII[6,7,8], Al Qaeda terrorist attacks[9,10], and Former Soviet Union C2 air defense actions during the shoot-down of the commercial airliner KAL 007[11].

Model

Model Design Strategy

The model design strategy is a very key aspect of this work. The strategy is to develop a process model of a mission and then integrate factor models as needed to improve fidelity. The process model is the central piece because it handles the information flow and dependencies between activities and resources. All actors' processes must be modeled as well and allowed to interact through an adversarial process interface. This process model acts as the backplane for higher fidelity individual performance models. Factor models like C2, human performance, decision must be added to test the performance of one command approach versus another.

Technical Methodology

The modeling framework proposed in this paper consists of end-to-end process models, personnel models and organization models. These models have been prototyped in the AnyLogic (XJ Technologies) modeling and simulation environment. The models have been designed to be as parameterized as possible so that the majority of model data can be captured in a database, and therefore varied, in an automated way.

Process Models

The model includes activity-based, discrete event process models for both blue and red, from planning through mission execution. The model is based on Lenahan's abstract C2 process model[2], where each activity is represented as a sequential process based on the IDEF0 framework, with inputs, outputs, controls and mechanisms (see Figure 2).

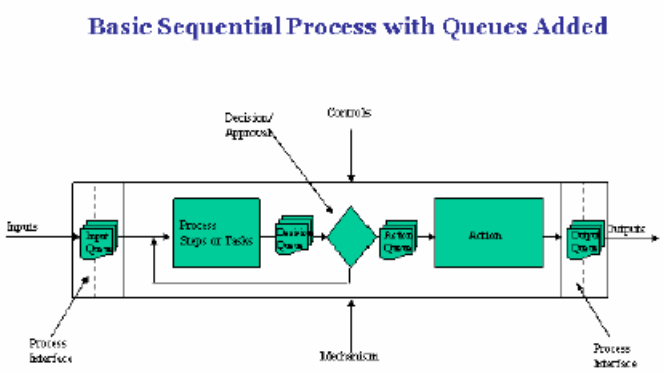


Figure 2: Basic Process Model Structure

Using AnyLogic's object-oriented framework, a generic set of process activities were modeled, then instantiated in a drag-and-drop manner for a majority of the activities in the mission thread. A subset of the mission activities required custom models to accurately reflect unique behaviors (i.e. course of action selection, target identification, etc). However, each of these custom objects can be re-used as appropriate in new missions. This approach provides flexibility in modeling complex missions, minimizes rework, and is easily extensible to new missions. Stimulation of the process model is message-based; that is, activity outputs are routed to become inputs or controls for other activities, thus tying the activities together into blue and red mission threads.

In order to observe the effect of command approach variations on mission outcome, the process model includes end-to-end processes for both the blue and red, including the interactions between them. The interface between the blue and red process models was implemented based on Lenahan's adversarial process model (see Figure 3)[2]. As described above, both the blue and red process models generate information (plans, orders, target information, etc) that is exchanged between process activities. The adversarial process interface defines how information from the blue process affects the red process, and vice-versa. The adversarial interface defines what information may be relevant to the adversary, the likelihood of interception of that information, and how that information would be used if intercepted.

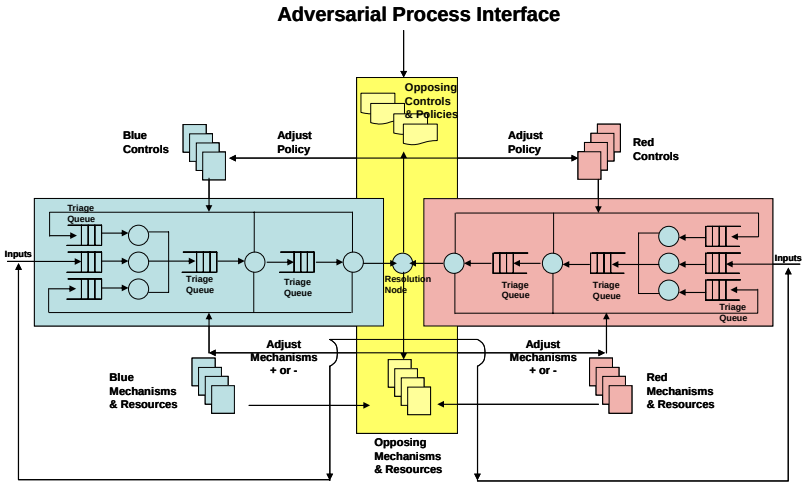


Figure 3: The Adversarial Process Model

To provide additional flexibility and ease experimentation, model attributes for each mission activity have been parameterized and stored in a database. Upon simulation initialization, activity attribute values are gathered via SQL calls from AnyLogic to a Microsoft Access database via an ODBC connection. These attributes include the list of inputs, outputs, controls and mechanisms for each activity, as well as processing and decision time distributions, and other activity attributes. These attributes are stored in a relational data model that includes command approach (Interventionist, Problem Solving, Control Free) as a field. This approach allows rapid, automatic reconfiguration of the model when the C2 approach is changed, and exposes a majority of the model parameters for easier model verification and validation.

Personnel Models

One of the key characteristics of the C2 approaches analyzed in this paper is the quality of the staff at the various levels of the chain of command. For example, control-free requires that the lower echelons are highly competent (via training, intelligence and experience), take advantage of their initiative and are trusted by the upper echelons, whereas in cyclic organizations, the lower echelons only needs to be able to follow clear orders provided by their superiors. In order to represent these differences, the model must account for the effect of human performance attributes. These attributes affect both the timeliness and quality of the activities and decisions performed through the course of the mission.

Human Decision Model Selection

One aspect of the human performance that was modeled was the human decision process. In determining the best means to model the human making a decision the following criteria were utilized:

- The model needed to be able to differentiate between different decision-makers in order to reflect the fact that changing the command approach will change the people making key decisions
- The decisions made and delay times incurred needed to be as realistic as possible
- The decision process needed to represent the way people make decisions when faced with the uncertainty and time pressures that exist in a warfighting mission

The class of decision theories called Naturalistic Decision Making (NDM) was identified as meeting the needs above, and the specific model called the Recognition Primed Decision Model (RPDM) was chosen to represent the decision process. Naturalistic Decision making was formed out of a desire by researchers to describe "naturalistic" environments where information is ambiguous, time pressures often exist, and the environment is dynamic[12]. Klein et al[13] developed the RPDM as a result of research looking into how fire ground commanders make decisions in difficult circumstances. In general the RPDM assumes that a person making a decision takes in available information, filters that information and matches it to available mental patterns of pertinent situations, and selects an appropriate action for that situation/pattern. Concepts are evaluated sequentially rather than comparing and contrasting several items at the same time. A process flow for the RPDM can be seen in Figure 4 below.

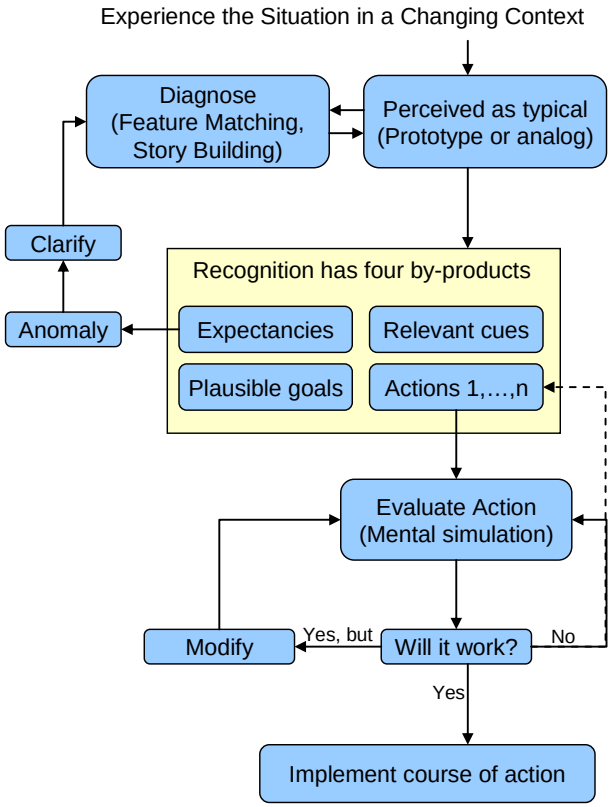


Figure 4: Recognition Primed Decision Model[14]

When a pattern is matched there are a set of 4 basic products that are results of the pattern match: cues – the pieces of information that are important to match the pattern, goals – the specific outcomes that the decision maker is trying to achieve, expectancies – the events that should or should not happen to confirm that the correct pattern was matched, and actions – the typical actions that can be undertaken to resolve the situation favorably[13]. Once an action is chosen, if time is available or if the decision maker has any doubts of the validity of the action a mental simulation is performed, running through the action to decide if it will result in the desired consequences. If the simulation turns up problems then the action can be modified or a new typical action can be chosen. In situations where a mental pattern cannot be quickly matched to the situation, then the model goes into a diagnose phase where the available information is examined and the decision maker attempts to develop a plausible understanding of the situation using knowledge of similar situations.

Human Decision Model Implementation

The RPDM was implemented in the overall model as a process object. The object had as inputs the patterns available for the decision, the cues/information available at the time of the decision, parameters used to describe human capability, and also had an input for the message type that would trigger the need to start the process. At the end of the RPDM process the message that triggered the process is updated with the action selected during the running of the process and then the updated message is output. This generic formulation of the RPDM model allows it to be used in multiple places in the overall C2 model. In this case it was used once in the blue model and once in the red in the positions where decisions needed to be made about the appropriate course of action to take given the available information about the adversary. It was assumed for this experiment that the patterns used in a given decision would be available to all different decision-makers. In the future, it would be an interesting to vary the available patterns based on the person making the decision.

The following parameters were used to differentiate between decision makers: Cognitive Ability, Experience, Training, and Risk Propensity. Although there are many other parameters that can have an effect on the human decision maker, these were identified through looking at available literature on RPDM and how different people make different decisions[14]. It was very difficult to determine the impact that each parameter should have on decision latency and the selection or rejection of a given pattern or action. Due to the context sensitive nature of human performance it might be that quantifying the effects that training or experience has on decision quality or latency is impossible to do in a manner that would cover all possible decisions. In addition, to quantify the differences in experience, training, etc between different humans, assumptions had to be made as to the difference in parameter values between different decision makers (an LCS Commander or the head of a CJTF). Once again, there was little information on this in the literature[12] and assumptions had to be made as to the levels of difference between these individuals.

Additional Personnel Model Implementation

The parameters used to differentiate between decision makers in the RPDM implementation described above were also used to impact the delay times associated with analysis and approvals used in other activities in the red and blue mission threads. Each resource type (CJTF commander or LCS Commander Staff) was given a set of parameter values for Cognitive Ability, Experience, Training, and Risk Propensity. These values were then used to moderately

shift the probability distributions for analysis and approval delays in the process activities. Higher parameter values were assumed to reduce the delay time and lower parameter values would increase the delay time. Average values would leave the delay constant. In addition to having the parameters vary based on the resource type the assumption was made that the command approach chosen would also affect the parameter values. For instance, it was assumed that lower ranked personnel would have higher training levels in a control-free approach than lower levels in the interventionist appproach. This is based on the statements made in Alberts and Hayes[1] that subordinate attributes such as professional competence and creativity/initiative would be high for control-free and moderate/low for interventionist.

Organization Models

One of the unique aspects of this modeling framework is the explicit representation of the organization's role in the end-to-end mission thread. The organizational nodes, their internal decision processes and their inter-nodal organizational connectivity (chain of command vice physical*) are explicitly represented in an organization model. Each process activity includes hooks to the organization model, which are implemented depending on the selected command approach. For example, the blue process activity "Select Course of Action" is performed by the COCOM staff but requires chain of command approvals from both the COCOM and President/SECDEF in the Problem-Solving command approach. These dependencies are explicitly modeled via information flows between the process activity and the organization model. This approach provides the flexibility to easily change the organizational structure and see the impact on the end-to-end mission.

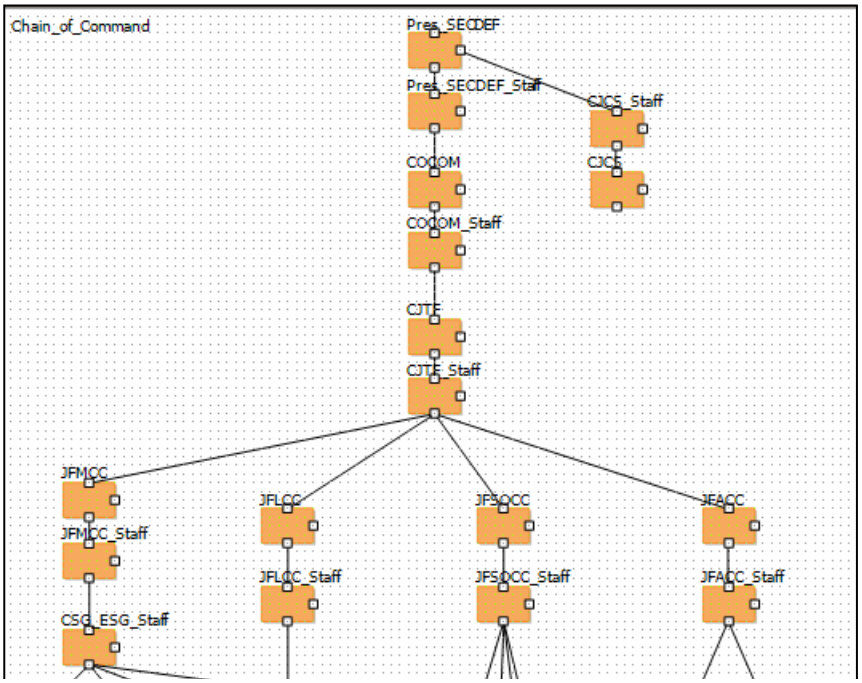


Figure 5: A Section of the Blue Top-Level Organization Model

Experiment

Experimental Methodology

A factorial experiment was performed to analyze the effectiveness of the various command approaches against one another. The goal of this analysis is to determine whether there is a statistically significant difference in mission outcome when command approach is varied. Two factors, blue and red command approach, are evaluated at three levels (Interventionist, Problem Solving, Control Free), requiring 3^2 combinations. The set of command approaches was limited to 3 from the original 6 for time's sake. Each command approach is represented by a set of independent variables in the model (described below). The response variable measures mission outcome on an ordinal scale. The nature of this problem requires the use of nonparametric statistics to handle the ordinal response values.

Independent Variables

The command approach is represented by the following independent variables in the model: resource allocation, personnel performance levels and collaboration/delegation strategy. The collaboration/delegation strategy defines when and how the organization model is exercised in a given mission thread. This corresponds to the number of approvals required through the course of the mission and well as the level of approval required.

> **Control Free -** This command approach utilizes a distributed command structure with subordinates expected to use all assets at their disposal, and to operate independently to complete assigned missions. Higher echelons do not monitor the battle in detail, and lower echelons are trusted implicitly by higher echelons. This command approach requires a highly competent and highly trained force with initiative and creativity.
> **Problem-Solving -** Missions and objectives are developed by each echelon for two levels of subordinates. Substantial guidance is promulgated by higher echelons on how objectives are to be completed, but considerable room for creativity and initiative is allowed. Subordinates are heavily reliant on upper echelons for key resources (lift, intelligence, and logistics). Higher echelons monitor the battle in detail. There is also a heavy reliance on technology and Command and Control infrastructure.
> **Interventionist -** This command approach places heavy reliance on central authority, with higher echelons requiring very detailed information on the battlespace, and continuous and specific reports from subordinates two layers down. Rigid Tactics, Techniques and Procedures (TTP) and extensive pre-planning processes are also attributes of this approach.

The operational scenario was then used to develop appropriate operational mission threads and associated IDEF models. These products were constructed using historical information derived from current US Joint Doctrine, a study of German operations in Russia (Barbarossa) and Norway during WWII, Al Qaeda terrorist attacks, and Former Soviet Union C2 air defense actions during the shoot-down of the commercial airliner KAL 007 (references 5 through 11 apply). The model also assumes that the process (set of end-to-end activities required for the mission) does not change as the command approach changes.

Control Variables

The controls in the experiments include the scenario, the warfighting process and the nominal process execution time.

Assumptions regarding the scenario (defined in appendix A), including the scenario option space, are held constant as the command approach is varied. The "best" C2 approach for a given situation will clearly be dependent upon the scenario; however, the primary goal of this paper is to show a *methodology* for selecting an optimal C2 approach for a given scenario. The results presented in this paper are specific to the selected scenario and may be highly sensitive to modifications in the scenario (one of the recommendations for further research).

In order to maximize applicability to current day operations, the scenario for this experiment includes a multiple mission environment with counter-insurgency operations. The scenario is based upon work done by SSG XXV to support their FY06 recommendations to the CNO. See Appendix A for a full description of the scenario. In addition, the nominal process execution time is held constant (it can still be varied from the nominal value as a result of poor personnel performance).

Random Effects

Each of the blue and red process activities contain delays that are represented as time distributions. The distribution parameters for the example scenario were obtained through operational subject matter experts and research into Navy Mission Essential Task List (NMETL) threshold and objective times. The overall impact of these individual activity time variations on the mission outcome is significant, due to the number of activities in each thread (modeled from planning through execution) and the intricacies of the blue/red interactions via the adversarial interface.

As described in the Model section of this paper, one of the parameters in the adversarial interface model is the likelihood of interception of adversary information. This [0,1] probability is evaluated against a random number draw to determine whether a given piece of adversary information is available to the mission thread. For example, certain activities in the red planning phase of the mission have a nonzero probability of interception by blue, especially those activities that require interaction between echelons in the red chain of command structure. When blue intercepts red information during their planning stage, as opposed to execution, blue forces have more time to organize and prepare and the impact on outcome is significant.

As discussed, several activities in the model require custom models to account for specific behavior. Most of this custom behavior is managed by probability distributions. For example, depending on the course of action selected, the "Develop COAs" activity in blue planning may require a change in the rules of engagement, thereby looping back to an earlier "Approve Supplemental ROE" activity. Because most command approaches require approval from the upper echelons in the COC to approve ROE modifications, this occurrence may have a significant impact on blue planning delay. These custom activity probabilities lead to significant variation in mission outcome, which aligns with the dynamics in a real world scenario.

Response Variables

The following variables were measured during the course of the experiments. This resulted in vast amounts of data, most of which is only summarized here. As a result, the raw data can be provided upon request.

1. Mission Outcome – measured on an ordinal scale as described in Table B.1..
    a. Blue Interdiction
    b. Blue Strike
    c. Red Abort
    d. Red Delivers Arms Cache
    e. Red Delivers Arms Cache and Initiates Conflict with Blue
2. Latencies – These are primarily taken from Lenahan[2].
    a. Data Latency
    b. Analysis Latency
    c. Decision Latency
    d. Action Distance
3. Resource Utilization
4. Information Flow Patterns
5. Decision Patterns

Lenahan[2] defines Action Distance as the sum of all the latencies in a given process set. For each process activity in the model, these latencies are gathered and recorded for analysis. Data Latency is defined as the amount of time required to gather all of the data required to perform the process activity, and includes time waiting for inputs, controls or mechanisms, including waiting time for human and materiel resources. Analysis latency is defined as the amount of time required to perform the activity, not including time to get approval if required. Decision latency is the total amount of time required to get a decision on the activity, including time up and down the chain of command. These latencies are rolled up to the mission phase level (planning, execution) and to the overall ETE mission level for both Blue and Red.

Resource utilization is defined as the proportion of time each resource is engaged in some activity over a defined mission time segment [t1, t2]. Resource utilization was sampled over two hour increments. Resource utilization serves as a quantitative measure of how efficient the process is with respect to resources. Resource utilization peaks reveal where bottlenecks in the organization are hindering mission performance. Low resource utilization rates may indicate areas where staffs may be reorganized to busier nodes to optimize the organization.

Table 1: Model Variable Classification

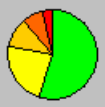
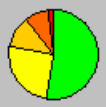
Independent Variables	Control Variables	Random Effects	Response Variables
Resource Allocation, Personnel Performance, Collaboration/Delegation Strategy	Scenario, Warfighting Process, Nominal Process Execution Time	Activity Times, Adversarial Information, Custom Activity Outcomes (ie Pd, Pk, etc)	Scenario Outcome, Action Distance, Resource Utilization

Results

As mentioned above, a 3^2 factorial experiment was selected to represent this problem. Due to the primary interest in varying two factors, blue and red command approach, and analyzing the impact on the response variables, and due to the limit of 3 levels for each factor, the nine combinations are a manageable in a full-factorial experiment. The factorial representation allows us to test the significance of the C2 approach on mission effectiveness, and the dependence and interaction between the various blue/red command approach pairs.

Literature research did not reveal a methodology for determining sample size in a factorial experiment with ordinal outcomes. Most examples found in our research settle on a minimum of 5 replications per cell. Because of the random effects in this experiment (described above), in order to ensure that the experiments account for variability, the sample size for each treatment combination (replications per cell) was selected to be 100, for a total of 900 simulations. The only constraints on sample size are computational (approximately 100 model runs/hour on a 2GHz processor). Table 2 shows the observed outcomes by red and blue command approach.

Table 2: 3^2 Factorial with Responses and Totals – Pie Charts

		Red Approach			
		Control Free	Problem Solving	Interventionist	TOTALS
Blue Approach	Control Free				
	Problem Solving				
	Interventionist				
	TOTALS				

Blue Interdicts
Blue Strikes
Red Aborts
Red Delivers
Red Engage

Analysis

When the response variable in a factorial experiment is ordinal, differences between values are not directly interpretable (i.e. Mission Outcome = 3 (red aborts) is not necessarily three times worse than Mission Outcome = 1 (blue interdicts)). Research in this area concludes that the

standard parametric statistical methods do no apply, summarized well in the following quote by Shah and Madden[15]:

> "Means based on these value labels cannot be interpreted in the same sense as the means of observations measured on a continuous scale. Parametric methods of analysis using statistics based on means, or differences between means (such as ANOVA) are thus, strictly speaking, inappropriate for analyzing data on an ordinal scale"

This type of problem requires the use of non-parametric statistics, which do not require the normality assumptions of their parametric counterparts. "Nonparametric tests are often more conservative tests compared with parametric ones. This means that the test has less power to reject the null hypothesis."[16] Initial literature research did not reveal an appropriate non-parametric test for more than one factor. The Kruskal-Wallis test based on ranks is the non-parametric equivalent of the one-way ANOVA test, and will be applied here to test the significance of each command approach. Shortfalls of this approach include the need for more hypothesis tests (a total of six, shown below), and the inability to directly test for interactions of effects. Future research will continue to explore more robust methods for analyzing ordinal data. The Kruskal-Wallis test is used here to determine whether there exist significant differences in mission outcome across three command and control approaches. Because a two-way ANOVA is inappropriate, the problem is divided into six sub-problems, defined in table 3.

Table 3: Hypotheses Under Test

Test ID	Hypothesis	Constant Assumptions
A	H_O: $u_{Blue\ CF} = u_{Blue\ PS} = u_{Blue\ IV}$ H_A: $u_{Blue\ CF}, u_{Blue\ PS}, u_{Blue\ IV}$ not all equal	Red Approach = Control Free
B	H_O: $u_{Blue\ CF} = u_{Blue\ PS} = u_{Blue\ IV}$ H_A: $u_{Blue\ CF}, u_{Blue\ PS}, u_{Blue\ IV}$ not all equal	Red Approach = Problem Solving
C	H_O: $u_{Blue\ CF} = u_{Blue\ PS} = u_{Blue\ IV}$ H_A: $u_{Blue\ CF}, u_{Blue\ PS}, u_{Blue\ IV}$ not all equal	Red Approach = Interventionist
D	H_O: $u_{Red\ CF} = u_{Red\ PS} = u_{Red\ IV}$ H_A: $u_{Red\ CF}, u_{Red\ PS}, u_{Red\ IV}$ not all equal	Blue Approach = Control Free
E	H_O: $u_{Red\ CF} = u_{Red\ PS} = u_{Red\ IV}$ H_A: $u_{Red\ CF}, u_{Red\ PS}, u_{Red\ IV}$ not all equal	Blue Approach = Problem Solving
F	H_O: $u_{Red\ CF} = u_{Red\ PS} = u_{Red\ IV}$ H_A: $u_{Red\ CF}, u_{Red\ PS}, u_{Red\ IV}$ not all equal	Blue Approach = Interventionist

To apply the Kruskal-Wallis test, each ordinal outcome is first translated into a rank value. Where there are ties, the ranks are replaced by the average rank over tied ordinal values. The Kruskal-Wallis test statistic, H, is then calculated using MATLAB's statistical toolbox, and matches calculations derived from a statistical text[17]. The results are shown in Table 4.

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Table 4: Kruskal-Wallis H statistic per Test

Test ID	Test	H	Chi	Result
A	Ho: Equal Blue Means over Red CF	0.645631338	5.991	accept Ho
B	Ho: Equal Blue Means over Red PS	6.893422972	5.991	reject Ho
C	Ho: Equal Blue Means over Red IV	2.566774857	5.991	accept Ho
D	Ho: Equal Red Means over Blue CF	1.211454434	5.991	accept Ho
E	Ho: Equal Red Means over Blue PS	0.582166192	5.991	accept Ho
F	Ho: Equal Red Means over Blue IV	0.8966099	5.991	accept Ho

Table 4 shows that only one of the six tests, Test B, shows a significant difference in mission outcome. Therefore, the conclusion is that that Blue command approach has a significant impact on mission outcome when the opponent is using a Problem Solving command approach (for this specific scenario). However, when Red is using a Control Free or Interventionist approach, the difference between outcomes when Blue approach is varied is not significant with a 95% confidence level. Further tests to determine which of the Blue approaches differ within Test B indicate that Control Free is significantly different than Interventionist, but there is not enough evidence to reject that the Problem Solving outcomes are different from either Control Free or Interventionist.

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This test confirms the pattern that is revealed in the pie charts in Table 2. Looking across the columns (Red approaches), the pie charts do not appear to vary significantly. However, reading down the rows (Blue approaches), clear patterns emerge. For example, when Blue assumes an Interventionist approach, there appear to be many more successful Interdictions than when Blue is Control Free or Problem Solving. However, when Blue is Interventionist, we also see more successful red arms deliveries (outcomes 4 and 5). When Blue is Control Free or Problem Solving, there are less Interdictions, but many more Strike outcomes (which is still a positive outcome for Blue), and many more cases where Red aborts the mission (not a positive Blue outcome, but preferred over outcomes 4 and 5).

In cases where there is not a significant difference in mission outcome when command approach is changed, it is expected that the effects of varying command approach are being dampened out over the course of the end-to-end mission due to the complexity of the mission. The data calculated at the mission phase level shows more variability when command approach is changed. The following table shows the average time to complete each phase of the mission for both Blue and Red, over the various command approaches.

Table 5: Average Time by Mission Phase

Blue Approach	Red Approach	Mean Blue Planning Time (mins)	Mean Blue Interdiction Time (mins)	Mean Blue Strike Time (mins)	Mean Red Planning Time (mins)	Mean Red Arms Delivery Time (mins)	Mean Red Engagement Time (mins)
Control Free	Control Free	5189.65	1476.47	270.51	7633.32	6924.96	3.70
Control Free	Interventionist	5108.79	1158.20	261.50	8343.61	7573.47	
Control Free	Problem Solving	5197.41	1120.14	277.75	8957.63	7579.15	6.05
Interventionist	Control Free	5186.38	1605.18	478.04	7675.44	8044.18	5.84
Interventionist	Interventionist	5051.90	1154.65	486.83	8021.57	7487.18	9.83
Interventionist	Problem Solving	5109.82	1532.94	426.50	8872.84	7138.32	6.85
Problem Solving	Control Free	5319.77	1390.74	298.51	7545.16	6765.55	
Problem Solving	Interventionist	5250.68	1055.69	315.66	8545.04	8998.46	
Problem Solving	Problem Solving	5053.77	1055.62	311.78	8529.47	7224.16	9.86

This data meets the requirements for two-way ANOVA analysis, which was performed using MATLAB's statistical toolbox to determine if any of the approach pairings have a significant impact on mission phase time. Appendix B shows screen captures of the outcomes of each of these six two way ANOVA tests for significance. Two of the tests found significant differences: Red Planning Times are significantly different over Red approaches and Blue Strike Times are significantly different over Blue approaches (see Appendix B,). Neither result is particularly

surprising; however, they do show that the command approach does have a significant impact on time at the mission phase level.

As described in the variables section above, data, analysis, and decision latencies were also recorded for each message in the model, for each experiment. The following table shows the average Blue latency values for the various approach pairings. There appear to be subtle differences in Blue data and analysis latencies; however, the one very obvious difference occurs over Blue decision latency, when Blue is Interventionist. This supports the observations made up to this point and will be further explored using resource utilization values.

Table 6: Average Latencies by Blue/Red Command Approach Pair

Blue Approach	Red Approach	Average Data Latency (mins)	Average Analysis Latency (mins)	Average Decision Latency (mins)
Control Free	Control Free	2.31	200.00	3.21
Control Free	Interventionist	1.78	195.52	3.22
Control Free	Problem Solving	1.27	194.51	3.19
Interventionist	Control Free	0.85	196.74	7.35
Interventionist	Interventionist	0.72	195.96	7.49
Interventionist	Problem Solving	1.32	194.24	8.20
Problem Solving	Control Free	1.28	191.77	3.71
Problem Solving	Interventionist	1.46	199.37	3.70
Problem Solving	Problem Solving	1.78	195.11	3.61

The high degree of variability in mission outcome observed when Blue is Interventionist can be attributed to the requirement for multiple chain of command approvals on several mission activities, especially during Strike execution. This requirement creates the possibility for activities to get stuck in the approval process. This occurs because there are several nodes in the chain of command with limited resources that are supporting multiple activities in the mission. When these limited staffs are required to either make a decision or pass information up or down the chain of command for these critical activities, there is potential for information gridlock, especially when multiple approvals are required and one or more of these approvals fail (requiring re-work and additional approvals).

The following two charts show resource utilization for the Blue organizations over the course of the mission. Figure 6 shows an experiment when Blue is Interventionist and Red is Problem Solving. In this model run, Blue does not detect the arms delivery in time to execute an Interdiction mission and is forced to do a Strike mission beginning around 18000 time units. The eventual outcome is Red success with engagement (outcome 5). This chart shows that during initial planning for the peacekeeping mission (t ~ [0, 4000]), several organizations reach very high utilization values (i.e. COCOM, SCC, President/SECDEF). Shortly after peacekeeping planning ends, the royal blue line indicates the LCS activity supporting peacekeeping (t ~ [7000, 18000]). After peacekeeping begins, there are three additional spikes in activity. The first occurs around t = 8000, when Blue gets early intelligence that Red is planning the arms delivery. This peak is characterized by increased utilization at most of the chain of command nodes. The second peak occurs around t = 13,000, when Blue gets additional intelligence. The final peak occurs around t = 18,000, when Blue detects the arms carrier arriving at its destination port. There is not enough time for an Interdiction at this point, so a Strike mission is selected. The amount of chain of command activity required to execute the Strike is obvious around this last peak in activity and the delay caused by these required approvals results in Red being able to finish offloading arms and counter-engage Blue before the Blue strike is able to complete.

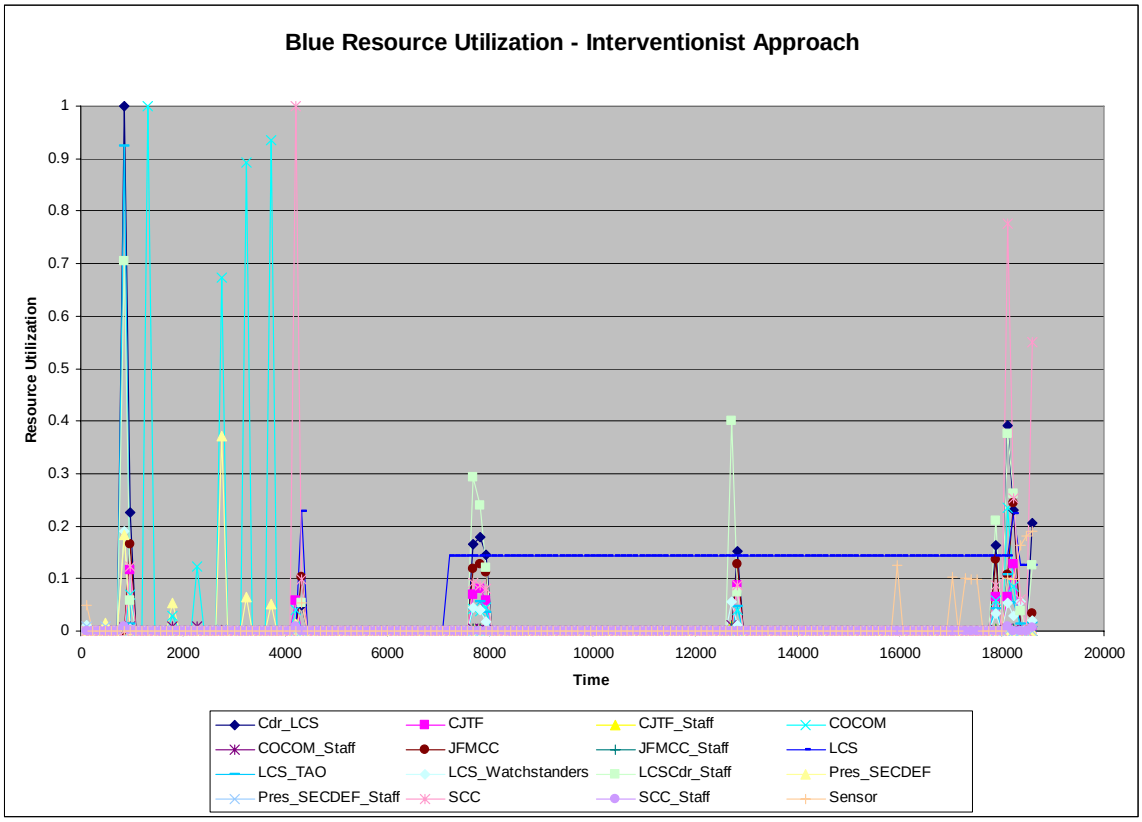

Figure 6: Blue Resource Utilization (Interventionist Example)

Figure 7 shows the same information for a different model run when Blue is Control Free. A very different pattern appears here. The first thing to notice is the relative simplicity of the initial planning phase. The only node showing any significant utilization during this period is the CJTF, as opposed to the upper echelon activity observed during the Interventionist version. Blue also picks up on Red arms delivery planning in this experiment; however, we don't see the clear peaks that we see in the previous chart. Here, the LCS Cdr staff is trusted with analyzing and acting on this information without higher level approval required. Therefore, the same peaks in activity (t ~ 10,500 and t ~ 12,500) are barely noticeable on the utilization chart. Around t = 15,000, the arms carrier is detected during its delivery, a single approval is required from the JFMCC, Interdiction is initiated and executed quickly and successfully.

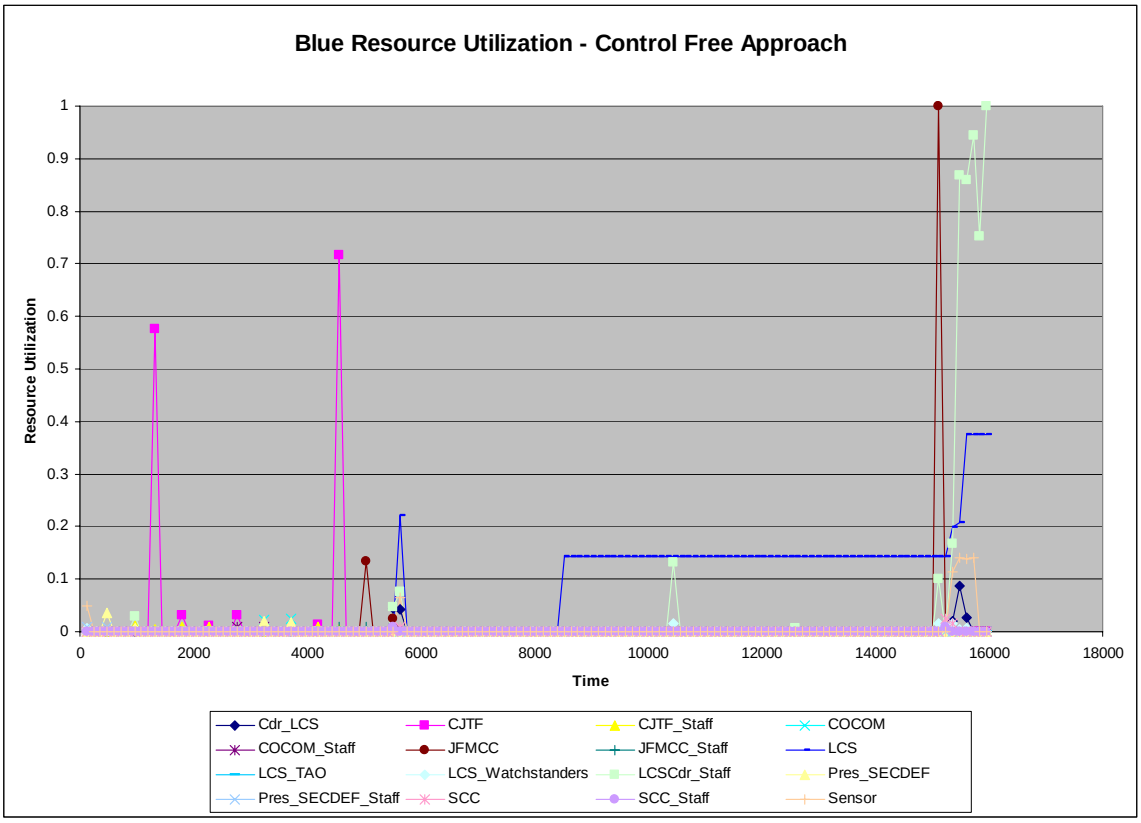

Figure 7: Blue Resource Utilization (Control Free Example)

To explore this further, the following charts show which nodes in the chain of command are processing the most information, and which nodes are making the most decisions, for the Interventionist and Control Free command styles (for the two experiments summarized above). The most glaring difference between the two charts is the amount of information processed by each node. It is clear that the Interventionist approach requires a significantly larger amount of information and decisions than the Control Free approach. Also notice that the only long bars in the right chart (Control Free) correspond to lower echelons in the chain of command, while the left chart (Interventionist) shows long bars across the levels of the chain of command.

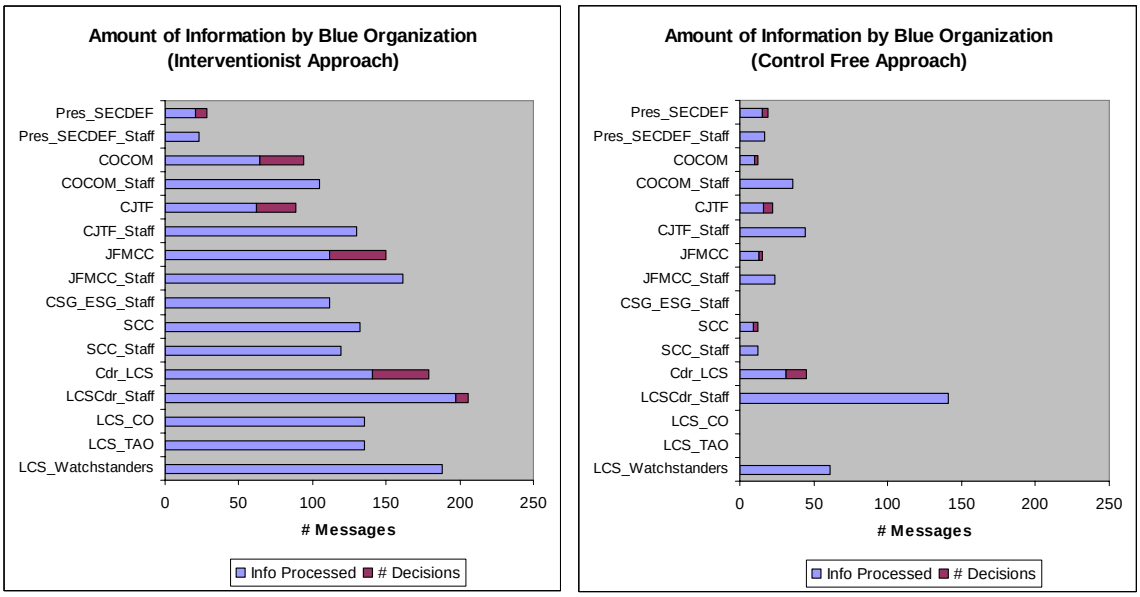

Figure 8: Blue Message Traffic by Organization

The outcomes of these experiments show that there is no clear winning command approach. Even if there had been a clear winner, it would be improper to draw conclusions based on a single scenario.

Conclusion

The proposed hypothesis is that it is possible to integrate and evaluate command approaches utilizing component factor models in a technology agnostic, adversarial process framework. This experiment has shown that the hypothesis is true. First, the factors were integrated into the model and the model approximated a command approach. Second, we measured aspects of the model including outcome, latencies, utilization, information flow and showed significant differences between command approaches.

The model included C2, human performance, human decision and organizational components whose attributes were varied by command approach. The integrated model competed three command approaches against each other for a specific scenario. Although only a single scenario was modeled, important patterns were revealed which characterize each command approach. For example,

- When Red is Problem Solving, Blue command strategy has a significant impact on mission outcome. In this case, Blue Interventionist has a significantly better mean outcome than Blue Control Free.
- Although Blue Interventionist leads to more successful Interdictions than Blue Control Free, the control free command approach had significantly reduced latencies during the strike phase
- Blue interventionist generally experienced a larger percentage of red success due to the difficulty in executing strikes as an interventionist organization.

- Interventionist organizational nodes generally gather/receive more information than their counterparts in other command approaches.
- Interventionist is dramatically more resource intensive from a utilization perspective. Control free utilization is lower on average, however the peaks are much more intense at the lower echelon of the organization.
- Interventionist had notably longer decision latency than the other command approaches.
- Red planning time is significantly impacted by Red strategy. When Red is Control Free, the amount of time it takes to plan is much lower.

The model demonstrated a subset of the differences between command approaches. The design strategy of an adversarial C2 process model integrated with multiple factor models appears to be able to model behavior of command approaches.

The hierarchical organizational structure of most militaries has emerged from the processes that they use to fight battles. The need to repeatedly subdivide the troops into more logically manageable groups (from a command perspective) has generated the hierarchical command structure. Over history, the tree structure's branches have changed. For example in the US military, the inter-service rivalry that existed during Vietnam had caused problems. Under the Goldwater-Nichols act, the Congress changed the process and stripped the service chiefs of operational control of their forces. Once this process changed, the US chain of command changed followed suit.

The US organization has emerged from the large number of processes that the US military follows. From the set of all processes (including military operations, procurement processes, public relations, recruitment, etc) that the US military executes, the US organizations evolved. Across the entire range of processes, this organization has been a successful one. However, for specific, individual operations it is non-optimal and potentially performance limiting.

Based on our observations, it is apparent that the optimal organizational model is strongly dependent on the mission being executed, and as such should be an emergent result of the processes that the organization undertakes. Static organizations (i.e. JTF organization) are guaranteed to be sub-optimal across a subset of missions. The only guarantees for optimal mission organizational structure occur when the organization emerges out of the process requirements.

Future Work

This work has demonstrated the foundation of a framework to build on for C2 experimentation. Tremendous amounts of work remain in the realm of C2 modeling. These are some of the areas that it would be beneficial to tackle.

- Plan Model – Explicitly model mission plan, have it determine mission execution, can reflect quality of plan.
- Policy Model – The effect of policy on processes has not been fully implemented at this time. In the future, it is envisioned that ROE will be modeled and have an impact on planning and tactical execution.

- Multiple Scenarios – Single scenario models are not rich enough to make definitive statements about the quality of command approaches, so a portfolio of scenarios needs to be examined.
- Factor Performance Models – This model includes human performance, human decision and C2 models. These component models can be refined while new factor performance models can be added.
- Sensitivity Analysis - Future work will explore sensitivity of results to modifications in scenario and solution spaces for new scenarios.
- In the future, we would like to develop hybridized or unique command approaches that are most effective for specific mission portfolios.
- Reverse engineer human performance attributes as requirements. For example, if Blue assumes a control free command strategy in this scenario, what levels of training, experience, etc are required at what nodes in the chain of command, to achieve the desired mission outcome.
- Statistical Sophistication Future research will continue to explore more robust methods for analyzing ordinal data.
- Evaluate optimal organizational structure across a portfolio of missions.

Further work must be done to integrate the other aspects of a command approach, specifically Policy models and Plan models in order to more completely represent the characteristics of a command approach. Once this work is complete, the model should be able to fully act as a command approach experimentation platform.

Appendix A – Operational Description of Scenario

The scenario revolves around Country "X," which has experienced a recent increase in insurgent activity. Country X's military forces have suffered serious setbacks and believe the insurgents are taking advantage of the country's vast waterway system. Country X's government has asked the U.S. to provide military assistance to their forcers in order to help stabilize the region. The U.S. Government has directed the DoD to provide assistance and a JTF has been established to conduct SSTR operations. Due to Country X's vast coastline and waterway system, the JTF was assigned to Naval forces.

The JTF Commander has deployed a squadron of LCS and riverine craft to support JTF objectives. The riverine craft are patrolling waterways along with support from Country X's military. The LCS squadron is off shore providing ISR support using a combination of sensors. While conducting waterway reconnaissance, numerous villages are observed that have been affected by the fighting. Medical services, clean water, and food are needed by local residents, so the original Counter Insurgency mission now includes Humanitarian Assistance (HA) operations.

Recent reporting from national sources indicates that the insurgent forces are now attempting to infiltrate weapons from neighboring, neutral country "Y" via maritime shipping. Country X has coastal forces, similar to the U.S. Coast Guard, but is not capable of performing this mission alone. The current operational situation now requires the LCS Commander to support simultaneous Humanitarian Assistance, Counter Insurgency, and Counter Proliferation (HA/CI/CP) missions.

Blue Forces are on station in Country X territorial waters, conducting Peacekeeping Operations in the Joint Operating Area (JOA). Blue riverine Forces are upriver, conducting HA/CI patrols, with LCS squadrons providing surveillance of the JOA. All required communication links have been established; the Link 16 network is fully operational, and with all platforms as participating units.

At this point in the vignette, National source Indications and Warnings (I&W) are received, via satellite communications channels, that a Red Counter Proliferation threat (arms carrier) is scheduled to sail from a Neutral Country 'Y' port city in the next 24 hours; the platform is currently unidentified. The LCS Commander detaches two LCS platforms to support the CP mission, initiated by I&W of potential CP threats. At this point, Blue has the ability to support all three mission requirements (HA/CP/CI).

Appendix B – Experimental Data

Table B.1: Mission Outcome Possibilities

Response Variable Value	Mission Outcome
1	Blue successfully interdicts Red arms delivery. This is the most desirable outcome because the arms delivery is thwarted without significant use of force by Blue.
2	Blue successfully strikes Red prior to completion of arms delivery. This outcome is still considered a Blue success as the arms delivery does not complete; however, it requires a strong use of force by Blue, which implies greater risk to Blue forces, potential negative media impacts, collateral damage to white shipping, etc.
3	Red aborts the mission before Blue can successfully interdict or strike. This outcome is negative for both Blue and Red. The arms are not seized by Blue, nor are they delivered to their destination to re-supply the local insurgency.
4	Red successfully delivers arms cache to insurgency. This is clearly a negative outcome for Blue.
5	Red successfully delivers arms cache to insurgency and initiates hostile action against Blue (Blue suffers materiel and/or human casualty in the process of attempting to disrupt delivery). This is the most negative outcome for Blue because the insurgency receives their arms shipment, and Blue suffers some loss*.

*Subsequent Blue response (i.e. additional strikes) is not modeled in this scenario.

Table B.2: 3^2 Factorial with Responses and Totals

		Red Approach			
		Control Free	Problem Solving	Interventionist	TOTAL
Blue Approach	Control Free	Blue Interdicts: 53 Blue Strikes: 29 Red Aborts: 8 Red Delivers: 9 Red Engage: 1	Blue Interdicts: 44 Blue Strikes: 35 Red Aborts: 16 Red Delivers: 4 Red Engage: 1	Blue Interdicts: 45 Blue Strikes: 35 Red Aborts: 13 Red Delivers: 7 Red Engage: 0	Blue Interdicts: 142 Blue Strikes: 99 Red Aborts: 37 Red Delivers: 20 Red Engage: 2
	Problem Solving	Blue Interdicts: 52 Blue Strikes: 26 Red Aborts: 18 Red Delivers: 4 Red Engage: 0	Blue Interdicts: 50 Blue Strikes: 24 Red Aborts: 14 Red Delivers: 10 Red Engage: 2	Blue Interdicts: 49 Blue Strikes: 25 Red Aborts: 19 Red Delivers: 7 Red Engage: 0	Blue Interdicts: 151 Blue Strikes: 75 Red Aborts: 51 Red Delivers: 21 Red Engage: 2
	Interventionist	Blue Interdicts: 63 Blue Strikes: 15 Red Aborts: 4 Red Delivers: 12 Red Engage: 6	Blue Interdicts: 70 Blue Strikes: 10 Red Aborts: 3 Red Delivers: 10 Red Engage: 7	Blue Interdicts: 63 Blue Strikes: 16 Red Aborts: 3 Red Delivers: 13 Red Engage: 5	Blue Interdicts: 196 Blue Strikes: 41 Red Aborts: 10 Red Delivers: 35 Red Engage: 18
	TOTAL	Blue Interdicts: 168 Blue Strikes: 70 Red Aborts: 30 Red Delivers: 25 Red Engage: 7	Blue Interdicts: 164 Blue Strikes: 69 Red Aborts: 33 Red Delivers: 24 Red Engage: 10	Blue Interdicts: 157 Blue Strikes: 76 Red Aborts: 35 Red Delivers: 27 Red Engage: 5	Blue Interdicts: 489 Blue Strikes: 215 Red Aborts: 98 Red Delivers: 76 Red Engage: 22

Blue Planning:

Figure 1: N-Way ANOVA

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Analysis of Variance

Source	Sum Sq.	d.f.	Mean Sq.	F	Prob>F
X1	1.27274e+006	2	636367.8	0.52	0.5927
X2	2.17251e+006	2	1086255.2	0.89	0.4096
X1*X2	3.02934e+006	4	757334.4	0.62	0.6462
Error	1.08326e+009	891	1215774.6		
Total	1.08973e+009	899			

Constrained (Type III) sums of squares.

Red Planning:

Figure 1: N-Way ANOVA

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Analysis of Variance

Source	Sum Sq.	d.f.	Mean Sq.	F	Prob>F
X1	2.60719e+006	2	1.30359e+006	0.31	0.7362
X2	2.06914e+008	2	1.03457e+008	24.32	0
X1*X2	2.25009e+007	4	5.62524e+006	1.32	0.2599
Error	3.79106e+009	891	4.25484e+006		
Total	4.02308e+009	899			

Constrained (Type III) sums of squares.

Blue Interdiction:

Figure 2: N-Way ANOVA

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Analysis of Variance

Source	Sum Sq.	d.f.	Mean Sq.	F	Prob>F
X1	6.33402e+006	2	3167010.6	0.93	0.3953
X2	1.14769e+007	2	5738474.1	1.68	0.1866
X1*X2	3.24136e+006	4	810339.2	0.24	0.9169
Error	1.63495e+009	480	3406137.6		
Total	1.65625e+009	488			

Constrained (Type III) sums of squares.

Red Arms Delivery:

Figure 4: N-Way ANOVA

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Analysis of Variance

Source	Sum Sq.	d.f.	Mean Sq.	F	Prob>F
X1	865882.2	2	432941.1	0.13	0.8823
X2	8466779.9	2	4233389.9	1.23	0.2997
X1*X2	17747655.7	4	4436913.9	1.29	0.2844
Error	231199790.7	67	3450743.1		
Total	257604452.2	75			

Constrained (Type III) sums of squares.

Blue Strike:

Figure 3: N-Way ANOVA

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Analysis of Variance

Source	Sum Sq.	d.f.	Mean Sq.	F	Prob>F
X1	1067885.9	2	533943	123.91	0
X2	7710.2	2	3855.1	0.89	0.4103
X1*X2	32519.8	4	8129.9	1.89	0.114
Error	887684.8	206	4309.1		
Total	2088053.6	214			

Constrained (Type III) sums of squares.

Red Engagement:

Figure 5: N-Way ANOVA

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Analysis of Variance

Source	Sum Sq.	d.f.	Mean Sq.	F	Prob>F
# X1	0	0	0	0	NaN
# X2	0	0	0	0	NaN
# X1*X2	0.777	1	0.777	0.28	0.606
Error	44.914	16	2.80712		
Total	118.681	21			

Constrained (Type III) sums of squares. Terms marked with # are not full rank.

X1: Blue Approach Effect
X2: Red Approach Effect

Figure B.1: Two-Way ANOVA Outcomes for Mission Phase Times

Appendix C - Acronyms

ANOVA – Analysis of Variance
C2 – Command and Control
CCRTS – Command and Control Research and Technology Symposium
CI – Counter Insurgency
CNO – Chief of Naval Operations
CoC – Chain of Command
COCOM – Combatant Commander
CP – Counter Proliferation
FEP – Force Effects Package
HA – Humanitarian Assistance
I&W – Indications and Warnings
IDEF – Integrated Definition
LCS – Littoral Combat Ship
MoM – Measures of Merit
NCW –Network Centric Warfare
NDM – Naturalistic Decision Modeling
NMETL – Navy Mission Essential Task List
ODBC – Open Database Connectivity
OPNAV – Naval Operations
RPDM – Recognition Primed Decision Modeling
SCC – Strike Combatant Commander
SQL – Structured Query Language
SSG – Strategic Studies Group
SSTR – Security, Stability, Transition and Reconstruction
UCAV - Unmanned Combat Air Vehicle

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