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Innovative Measures for the Evaluation of Command and Control Architectures

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Abstract

Several principles of warfare have been developed through experience over time. These principles provide a framework that can be used to assess model-derived command and control architectures from a military perspective. This paper will dis-cuss and present analysis of data collected on participants' ratings of three model-based archi-tectures on the principles of warfare to determine quantitative differences among the architectures. Comparisons of these ratings with critical dimen-sions used by modelers to optimize the architec-tures will be discussed, including feedback provid-ed during after-action reviews from military per-sonnel who operated under these organizational architectures when responding to computer-driven scenarios. The objective was to compare the advantages and disadvantages of the three model-derived architectures vis-à-vis military principles.

1. Introduction

Changes in military doctrine, as well as in operational and organizational concepts, are fund-amentally altering the character and conduct of future military operations. One of these changes involves the concept that the Navy's command and control (C2) processes should be capable of transitioning smoothly and effectively into Joint (i.e.,multi-service) or Coalition (i.e., multinational)

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operations: a basic premise is that naval doctrine must be seamless in its support of joint doctrine and joint operations. Another major reason for examining novel ways of organizing US military forces is that new military missions are consider-ably more difficult and complex than traditional missions in terms of C2 arrangements in several ways. The Institute for National Strategic Studies describes these differences, which include: (1) the compression of strategic, operational, and tactical decisions and processes; (2) the ad hoc nature of command, force, and sustainment arrangements: (3) the lack of unity of command or even purpose; and (4) the addition of a civil-military dimension [INSS, 1994].

The Adaptive Architectures for Command and Control (A2C2) research program is a multi-year, multidisciplinary effort to: (1) establish a body of knowledge in current and future joint command and control, and (2) develop and test theories of adaptive architectures. A guiding principle of the A2C2 program is that a practical knowledge of the interactions between the organizational and task (mission) structures is a precursor to the design of flexible organizations. Previous research has indi-cated that performance is higher when there is a match between the task and the organizational design or architecture [Levchuck *et al.,* 1996]. For all but a few cases, however, the dimensions and metrics for assessing the quality of the match have yet to be developed.

2. Model-Based Experimentation

A model-test-model research paradigm is being used to generate and test candidate organizational architectures and empirically evaluate them in experiments with military officers at the Naval Postgraduate School, in Monterey. The overarch-ing general hypothesis for a third experiment, conducted in November 1997, involved the trade-off between model-determined optimality and a team's subjective feelings of comfort with their initial organization when a decision to adapt is being made. This paper presents a portion of the results from this third experiment that is described in Benson *et al*. [1998] along with additional details on the background and objectives of the A2C2 research program. Results of other analyses are presented in Entin *et al*. [1998] and Hocevar *et al*. [1998].

2.1 Participants

Fifty-four military officers (O-3 to O-4) in the Joint Command, Control, Computers and Intelli-gence, Space Systems Operations, and Manage-ment Sciences curriculum were assigned to six-person teams representative of a Joint Task Force command structure.

2.2 Procedure

Nine teams responded to an initial scenario that simulated an amphibious assault mission in a six-node architecture. A trigger event was then introduced that involved the loss of approximately 30 percent of the available assets. At the end of a planning session teams were asked to choose from one of three architectures: (1) their former, six-node architecture with reduced assets, (2) a five-node architecture, that was similar to their original architecture, with assets somewhat better distri-buted for the mission, or (3) an 'optimal' four-node architecture, quite different from their original architecture, with assets specifically distributed for the mission's tasks. Each team then engaged in two additional scenarios, one in the architecture they choose and one in another, in a counter-balanced design. Additional details regard-ing the experimental procedure are presented in Entin *et al*. [1998].

A task/asset matrix was provided to guide participants regarding the type and number of assets required to accomplish the requisite mission tasks. Some tasks could be accomplished by the decisionmaker in a single node when he/she owned all the assets required for the specific task. Other tasks required an asset package that involved using assets from two or three nodes.

2.3 Organizational Architectures

Figures 1 and 2 depict the original A0 pre-trigger architecture and the A0 post-trigger (i.e., reduced assets) architectures, respectively. [Assets owned by the commander of each task group/ task unit are depicted for each node in the architecture. For example, "Flag" owns four fixed wing aircraft (VF), reconnaissance satellite (SAT), Tactical Air Reconnaissance Pod System (TARPS), and the carrier (CV).] A0 is the most traditional looking architecture as it was designed according to current procedures for organizing military forces, e.g., keeping sea-based assets in one node, etc. However, the scenario mission tasks were designed to require that assets from different nodes be used in order to stress the need for the participants to coordinate. Coordination is seen as a key factor in current and future opera-tions. Since more inter-nodal coordination was required under the traditional, six-node organiza-tion—because assets from various task groups/ units were required to conduct a mission task—it was hypothesized that the post-trigger six-node architecture would result in increased workload (i.e., inter-nodal coordination) and reduced perfor-mance. Conversely, since autonomous operations were possible under the more task-organized four-node architecture it was hypothesized that inter-nodal coordination would be decreased and performance would be increased.

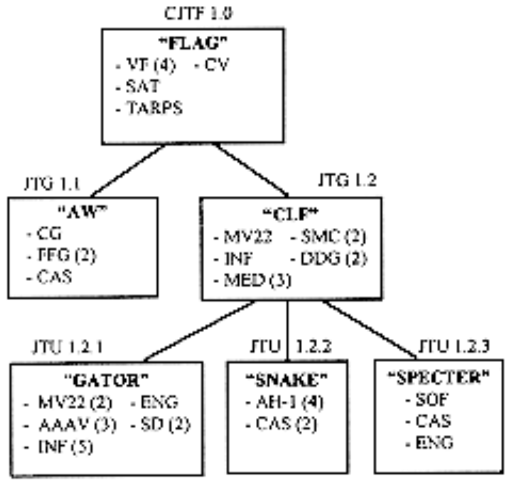

Figure 1. Architecture A0 Pre-Trigger

Figure 3 shows A1, the four-node architecture, designed to minimize the need to coordinate be-tween nodes for the use of assets. For A1, most tasks could be performed autonomously, i.e., with fewer coordination requirements because assets were grouped within the nodes where needed to accomplish mission tasks. Figure 4 depicts A2, the five-node architecture, designed as an inter-mediate architecture between A0 and A1, and pri-marily to minimize the number of tasks any one node would be involved in simultaneously.

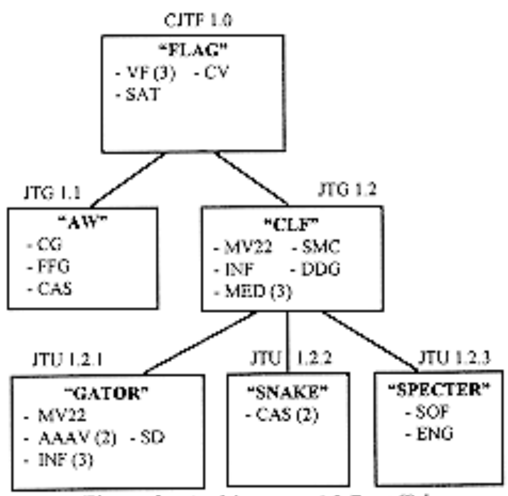

Figure 2. Architecture A0 Post-Trigger

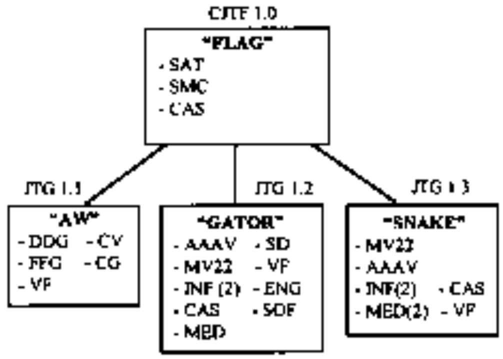

Figure 3. Architecture A1 Post-Trigger

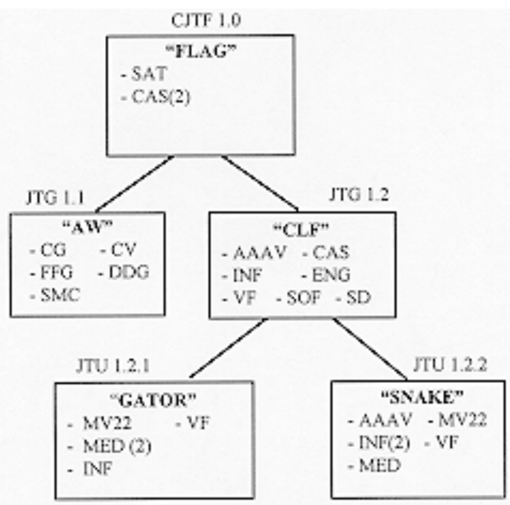

Figure 4. Architecture A2 Post-Trigger

3. Principles of War

Principles of warfare have been developed through experience over time and are documented in various joint military publications. [Joint Pub 3-0] Over the centuries, military practitioners and historians have attempted to comprehend the complexities of war; the result of these efforts were long complicated treatises that were not easily understood. Principles of war represent a distillation of the thinking of these works and have been in existence for nearly two centuries. During the last 55 years the principles of war have been a key element of Joint and Service doctrine to guide warfighting at the strategic, operational and tactical levels. It is noteworthy that these principles can also be applied to the business world, inasmuch as they provide a framework to structure thought processes in terms of crafting strategies, assessing plans, designing C2 architec-tures, and deriving insights from success or failure.

These principles provide a framework that can be used to assess the model-derived architectures from a military perspective. Participants ratings of the architectures on the principles of warfare were analyzed to determine quantitative differences among the three architectures. The principles of war include: unity of command, unity of effort, economy of force, simplicity, and span of control. The objective was to highlight the advantages and disadvantages of the three architectures from the warfighter's perspective. This perspective in-cludes how well the architectures support the users in accomplishing their mission tasks in terms of supporting the underlying concepts embodied in the principles of war.

Differences among the architectures will be discussed in terms of the modeling efforts to optimize the architectures on critical dimensions from a theoretical perspective. Discussion of these comparisons will be supplemented by comments from participants, regarding the pros and cons of operating in the different architectures, recorded during the after action-reviews that were conducted after each of the experimental sessions.

3.1 Unity of Command

Unity of command states that all efforts must be directed and coordinated towards a common objective under one responsible commander. This means that all forces should operate under a single commander (but not necessarily the same) for each objective. Unity of command would lead to, or be an enabler for, unity of effort.

3.2 Unity of Effort

Unity of effort refers to the number of tasks a unit is involved with simultaneously. Unity of effort is defined as "all effort being directed toward the achievement of common aims." Unity of effort requires coordination and cooperation among all forces toward a commonly recognized objective, although they are not necessarily part of the same command structure. Unity of effort is an essential element of unity of command.

3.3 Economy of Force

Economy of force states that in order to ensure that overwhelming combat power is avail-able, minimal combat power should be devoted to secondary objectives. This refers to the judicious employment and distribution of forces. It is the measured application of available combat power to such tasks as limited attacks, defense, delays, deception, or retrograde operations in order to achieve mass elsewhere at the decisive point and time.

3.4 Simplicity

Simplicity states that the commander should prepare clear, uncomplicated plans and clear, con-cise orders to ensure thorough understanding. The commander, at all echelons, should avoid unneces-sary complexity in organizing, preparing, planning and conducting military operations. Simplicity contributes to successful operations by minimiz-ing misunderstanding and confusion.

3.5 Span of Control

Span of control refers to the span of authority; this may be less than full command exercised by a commander over part of the activities of subor-dinates or other organizations. Span of control is the control exercised by commanders over their allocated forces to accomplish the mission.

4. Measurement Instruments

A measurement instrument was designed to obtain quantitative data on the three post-trigger architectures for each of the five principles. This form included the definition for each principle and a seven-point Likert-type scale with labeled an-chors. Participants were asked to read the defini-tion and then indicate how they would rate the de-gree to which each of the three architectures sup-ported each of the principles. This measurement instrument was administered to participants after they had completed their first post-trigger run.

To obtain a more detailed assessment of the architectures three subject matter experts (SMEs) rated the architectures with the instructions to assess each architecture, on a task-by-task basis, for each principle, i.e., down to the lowest level node/s responsible for accomplishing each mission task. A rating of was "1" was given when any task could be completed by one node (i.e., full support of the principle being rated), a "2" when the architecture supported accomplishing the task somewhat, but the principle was not fully adhered to, and a "3" when there were major departures from the principle in question.

In addition to the subjective evaluations of an architecture's adherence to the principles of war (for a given mission and environment) by subject matter experts, we are developing objective mea-sures that, ideally, can be incorporated in the models used to design architectures according to specified optimization criteria. One such measure has been developed for the principle of unity of command. It can be used directly for architectures, missions and environments developed for simula-tion on the Distributed Dynamic Decisionmaking (DDD)-III [Kleinman, et al., 1996] and we are investigating extending it to the general case.

After-action reviews were conducted after each scenario run. The following structured set of items were discussed by the team in a round-table format: workload distribution, coordination issues, strategies, organizational structure, teamwork, and individual and team performance. These discus-sions were tape recorded and pertinent comments were extracted from the recordings.

5. Results

Participants' ratings of the architectures on the degree to which they supported the principles of war were analyzed separately. Subject matter experts (SME) ratings of the architectures on the principles, on a task-by-task basis, were also examined. An objective measure for the principle of unity of command was developed and results were compared with ratings by the SMEs. Finally, after-action review comments were examined to gain insight into the effectiveness of the three architectures and the underlying concepts used to develop them.

5.1 Participant Ratings of Architectures

A Kruskal-Wallis non-parametric one way anova procedure was used to analyze the data from the participants' ratings of how well the architectures supported the principles of war. Significant differences were found among the three architecture means for all five principles. This non-parametric test was repeated pair-wise to determine the source of the differences for each one of the principles of war. Architecture A0 (post-trigger) was rated significantly higher than both A1 and A2 on all five principles ($p \leq .03$). Architecture A2 was rated significantly higher than A1 on unity of effort ($p<.04$) and economy of force ($p<.01$). Figure 5 depicts the mean ratings for unity of effort which were representative of the overall pattern of results. This overall pattern of A0 being rated highest, and A2 being rated higher than A1 was found for all five principles across the three architectures.

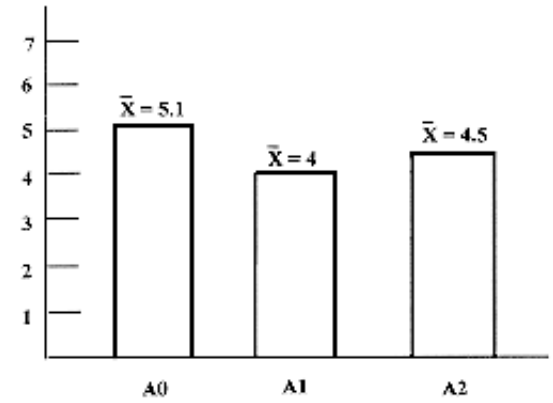

Figure 5. Mean Ratings for Three Architectures on Unity of Effort

5.2 Subject Matter Expert Ratings of Architectures

Table 1 presents the results of the SMEs analysis and shows the pattern of results is quite different from the pattern that emerged when experiment participants made their ratings. Archi-tecture A1 was rated significantly better on both unity of command ($p<.03$) and unity of effort ($p<.03$). There were no significant differences among the architecture means for economy of force, simplicity, and on span of control.

PRINCIPLE	ARCHITECTURE A0	A1	A2
Unity of Command	2.4	1	2.1
Unity of Effort	2.1	1.1	2.1
Economy of Force	1.7	2.2	1.9
Simplicity	2.1	2.1	2.1
Span of Control	2.3	3	2
Overall Means	2.11	1.86	2.0

5.3 After-Action Review Comments

Many salient points were made during discus-sions of the experience of responding to the scen-arios under the three architectures. Issues included difficulties encountered, successful versus unsuc-cessful strategies, and the effect of the architec-ture's structure on the team's ability to perform the tasks.

5.3.2 Architecture A1

Both positive and negative comments were voiced regarding architecture A1. Positive com-ments included: "the best architecture is the one that provides the commander in each node with the assets required to accomplish that comman-der's mission tasks;" this architecture provided greater autonomy to accomplish the tasks at hand, it required less coordination with other nodes, and workload was more evenly spread across the players. Negative comments included: "biggest problem was the number of assets, having the ground commander control the special operations forces (SOF) was not logical, and it was difficult to control so many tasks.

5.3.3 Architecture A2

Coordination issues were noted in terms of problems between Snake and Gator in coordi-nating their attacks and coordinating close-air-support assets that belonged to someone on another communication net. Distribution of tasks and assets was noted as a problem in terms of (1) decisionmakers being responsible for diverse areas, e.g., a ground task and air defense simultaneously; (2) not owning the assets to accomplish an assign-ed mission, (3) an uneven distribution of assets, or (4) the rationale for distribution of assets was not apparent. Workload was thought to be too high in terms of there being too much to do or that accom-plishing some tasks was cumbersome, e.g., it required three people to process one aircraft from the time it was detected to engaged.

5.4 Objective Measures of Principles

The DDD simulation software calculates an accuracy score each time an enemy asset (task) is attacked. Each task has a requirements vector that lists the friendly capabilities (each capability is a component in the vector, e.g., ground assault, fires, etc.) that must be brought to bear simultan-eously for a fully successful attack. Similarly, each friendly asset has a vector with the same compo-nent structure that lists the capabilities of that asset. The capabilities of all assets used in the attack are summed, and the resulting vector is compared component by component to the task requirements vector. Excess capabilities and zero requirements are ignored, and the proportion of the requirements present in each component is calculated. These values are squared and averaged to produce the accuracy score.

This same procedure was used to calculate unity of command scores for the three post-trigger architectures. The six mission tasks (two beaches, hill, port, airfield and bridge) were initially select-ed for assessment. Next, due to their interdepen-dence, the north beach and hill were combined into a single task. The encounter tasks (mines, armor and SAMs) on the roads from the beaches to the port and airfield were then aggregated to form one task for each road. Next, for each node, the capability vectors of all assets belonging to the node were summed to form a single vector. Finally, an assignment of nodes to tasks was made that best matched capabilities to requirements. Temporal requirements of the mission were honored (e.g., north beach and the hill were attack-ed at the same time so they required different assets, but the north beach and port could be attacked sequentially reusing the same assets) and a unity of command score was calculated for each task. These scores are displayed in figures 6 and 7. These objective scores match the results of the SME assessments for the architectures overall. Architecture A1 is clearly superior in both assess-ments and architecture A2 is rated better than A0.

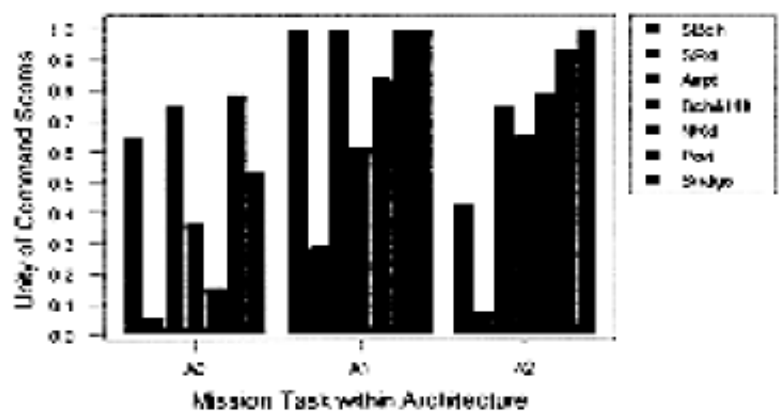

Figure 6. Unity of Command Score for Mission Task within Architecture

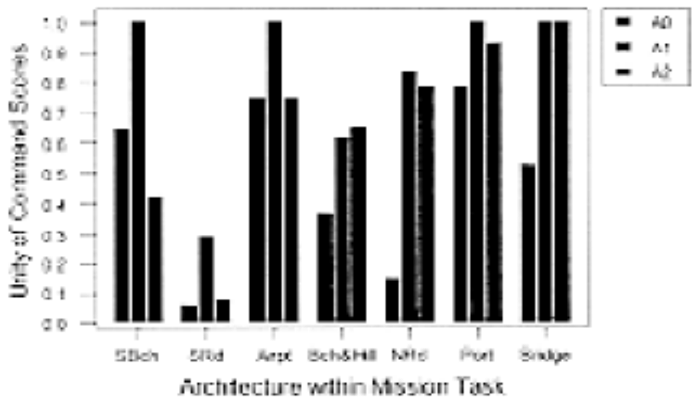

Figure 7. Unity of Command Score for Architecture within Mission Task

Of the individual tasks included in the assessment by the SMEs, four were also used in the objective assessment: beaches (south beach), airport, seaport (port), and bridge. But the rating scales were different. The SMEs scored the archi-tectures on a scale from 1 to 3, with 1 being best. The algorithmic scores ranged from 0 to 1 with 1 being best. To visually compare the ratings from the SMEs on these four tasks with those from the algorithm, the SME scores were first subtracted from 4, then divided by 3. This resulted in scores between 1/3 and 1, with 1 being best. Figures 8 - 10 show the barcharts comparing the SME and algorithmic ratings given the four tasks for archi-tectures A0, A1 and A2, respectively. The correspondence between ratings is readily appar-ent. For all but the "SBch" and "Bridge" tasks under A0, the order relationship for tasks within an architecture is the same, allowing for the ties in the SME ratings. Both methods gave architecture A1 perfect scores on all four tasks (the results are essentially identical), and the Spearman's Rank Correlation Coefficients for (transformed) SME and algorithmic ratings for architectures A0 and A2 are .738 and .949 respectively.

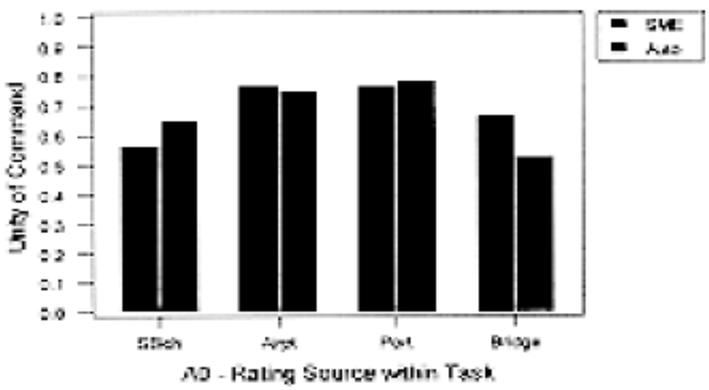

Figure 8. Comparison of SME and Algorithmic Ratings for Architecture A0

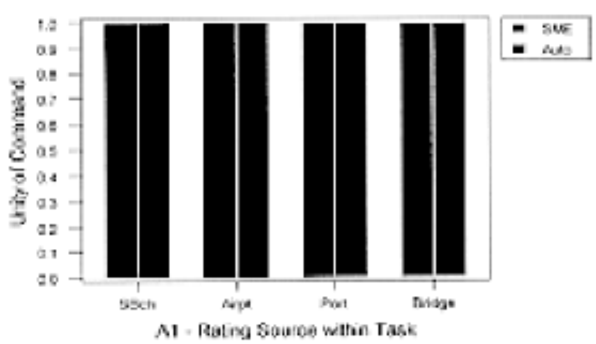

Figure 9. Comparison of SME and Algorithmic Ratings for Architecture A1

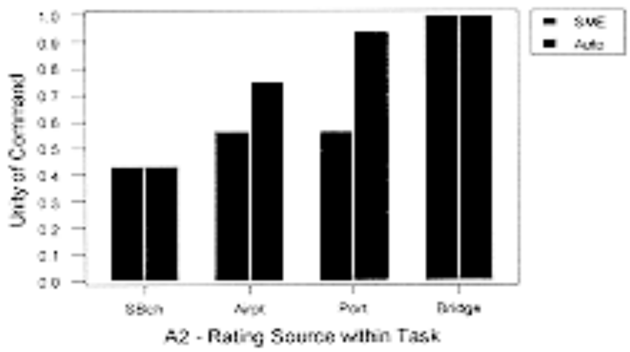

Figure 10. Comparison of SME and Algorithmic Ratings for Architecture A2

6. Discussion

6.1 Participant Ratings of Architectures

Discussion of the results will focus on the first two principles**.** The main reason is that we believe the data for the other principles is confounded by participants' ratings of the first two principles. A second reason is that participants may have been biased when making their ratings. Participants received their initial training (on use of the simu-lator and how to operate as a team for the exper-iment) in the A0 architecture. This acclimation to A0, coupled with A0 being the most traditional looking architecture, may have predisposed the participants to rate A0 higher on all five principles.

6.1.1 Unity of Command

Unity of command refers to the relationships among people in the organization. A high rating on unity of command means that all forces are organ-ized under, and report to, a single commander. As an example, an Army unit conducting an amphib-ious operation would have all personnel organized under the same commander if only rotary wing assets, or helicopters, were needed to accomplish the task. However, if fixed wing aircraft were needed, these aircraft would have to come from the Air Force or the Navy. At the highest level of all organizations there is good unity of command because one person is in charge of the overall mission (or organization). As one looks deeper in the organization there are greater differences across the architectures.

Regarding the A0 (post-trigger) architecture being rated highest on unity of command by the experiment participants, it does appear that this architecture is organized such that each respon-sible commander has all the forces necessary to accomplish the respective mission tasks when viewed at only the top two echelons of the organ-ization. However, at the third echelon, Snake's CAS is required to support CLF's infantry for one task, Gator's infantry for a second task, and Specter's engineers for a third task. All three tasks require assets (and personnel) from more than one node, thus, at the lowest echelon, A0 does not have high unity of command. This same situation exists for Gator when assisting in accomplishing the final two objectives—the airport and seaport tasks. Gator's infantry is required to support CLF in the seaport task and Gator's infantry is required to support Snake in the airport task. The participants may have made their judgments without focusing on the bottom tier of the organization where A0 does not necessarily have the best unity of command.

6.1.2 Unity of Effort

It is possible to have unity of effort without having unity of command. Mission objectives are typically included within a hierarchy of overall objectives and for each objective it is advanta-geous to have unity of effort. The goal is to have everyone who is conducting a particular mission task, during a particular time period, deal with that objective only (at least to the extent possible). In an ideal world, each objective would have both unity of command and unity of effort.

In the A0 (post-trigger) architecture, CLF had all the resources required to accomplish his tasks. At the next level, Spector also possessed all the assets needed to accomplish his tasks; however, Snake was required to support *both* of these people (i.e., CLF and Spector). So Snake would not have unity of effort. Similarly, Gator's efforts were also split across objectives. Since Gator was in possession of all the advanced armored amphib-ious vehicles (AAAVs) he was required to send AAAVs to both the North and South Roads to support two separate tasks being conducted by CLF (to take the airport) and Snake (to take the seaport). If the respondents did not closely examine the individual tasks and realize that people in some nodes were required to perform several tasks simultaneously—which meant they had to support two nodes simultaneously—they could have missed some of these points.

Our interpretation is that the respondents probably did not consider this level of detail when rating the architectures. For example, architecture A2 is structured such that it has better unity of command than A0. While architecture A2's struc-ture was very similar to A0, in A0 all the AAAVs belonged to Gator and in A2 the AAAVs were split between CLF and Snake. One person had to deal with the road to the North, the other had to deal with the road to the South. So better unity of effort exists in A2; however, if the respondents only focused on the top two echelons they would have missed these important distinctions.

Another example of a subtle difference that was missed when comparing these architectures was that while A0 appears to be very traditional, in A0 Gator is required to accomplish all the infantry tasks with his superior commander (i.e., CLF) assisting. Contrast this situation in A0 with the situation in A2 where infantry are located in three places, thus providing each node with an asset it needs to conduct their respective tasks. Again, this may not have been apparent to the participants when doing the ratings. While at first glance A2 doesn't appear as "clean" as A0 (because of its less traditional grouping of assets from different warfare areas under the various commanders), when examined in detail, A2 is cleaner in terms of unity of effort. Due to the non-traditional look of A2 (i.e., combining ground and air assets under one commander/ node) it is not as apparent that they are actually better organized in A2 to accomplish the mission tasks.

In both architecture A1 and A2, the VF aircraft are located in three nodes so that the air defense task has been decentralized. The air space has been divided into three sectors and each commander has a sector to defend. Each node has its own air defense capability. This makes sense if air defense is viewed as coupled with the mission task to be performed by each commander. (In this scenario air defense is a secondary task, albeit critical, to specific mission objectives stated in the operations order, e.g., take the beaches, seaport, airport, etc.) Thus, because there is no unity of command for air defense, per se, this task appears fragmented, from an organizational perspective, due to the non-traditional way the VF assets are located in three separate task units/ groups. Yet, from an *operational* perspective, in terms of accomplishing the task, this could be a superior way to allocate assets in that they are controlled by the commanders who will actually use them. The point to be made is that these three VF assets do not need to be organized under one commander to effectively and efficiently carry out these tasks. Allocating a VF asset to each node increased unity of command for the tasks to be conducted by the commander in each of the three nodes.

Similar to the case presented above regarding unity of command, one could argue that A0 is best organized to support the principle of unity of effort. This is because each node is organized to accomplish its specific mission subtasks with "minimal interference or cross purpose of objective." However, this is not to say that A1 and A2 were not organized such that they could also achieve unity of effort.

6.1.3 Economy of Force

As was the case with the principles discussed thus far, it is necessary to trace through the tasks to be performed by the various nodes in each architecture to determine the degree to which an architecture supports economy of force. This entails mapping each of the tasks—and the requisite grouping of assets that each node would bring to bear to accomplish that task—against the decision making nodes in each architecture.

6.2 Subject Matter Expert Ratings of Architectures

A1 was rated highest on unity of command and unity of effort because in A1 all the assets required by the three subordinate commanders to accomplish their requisite tasks were collocated within their respective nodes. However, A0 was rated higher than A1 for span of control because two of the SMEs felt that when a task required the use of three assets, such as is the case when taking the hill and the north beach simultaneously with taking the south beach, it would not be possible for one person to conduct this many mission tasks simultaneously. The SMEs felt it would be easier for Gator to coordinate with the other two nodes (Snake and AW) to accomplish these tasks (as was done in A0) rather than trying to accomplish all three subtasks alone (as was done in A0). The SMEs felt there were too many things for one commander to do in the A1 architecture.

An important point to be considered when rating the architectures on the principles of war, and specifically on span of control, is that in real life a node would comprise several decision-makers, versus the one used in the experiment. These subordinates would assist in carrying out the tasks. SMEs were asked to rate the archi-tectures according to how well they envision they would work in the real world. Even with assuming these subordinates are included in Gator’s node in A1, SMEs thought it would be easier to coordi-nate with another commander (i.e., node) than to supervise this many assets (and the associated subordinates). The SMEs pointed out that span of control basically means how well the commander can manage the number of people assigned to that node. They also noted that the current way of doing business is to call and ask for support when needed and they felt this way of obtaining support is easier then having these assets under the commander's direct control (because of the associated management overhead).

7. Conclusions

This paper reports on exploratory efforts to develop measurement instruments based on the principles of war. Applying the principles of war to assess military architectures is not a simple process. For example, there are a number of pos-sible ways to accomplish the tasks, i.e., several tasks can be accomplished by more than one combination of assets/ nodes. Which "asset package" the person envisions being used when forming their assessments can affect their ratings. The "best case" situation could be used when having raters, or an algorithm, examine architec-tures from the perspective of the degree to which the architecture supports the principles of war.

A second complication is that an architecture may be optimal for some tasks, in terms of supporting the concepts embodied in the princi-ples of war, but not necessarily all the tasks required in the scenario. Prioritizing the criticality of the various tasks would help to direct this rating process. A third complication when rating the architectures, on a task-by-task basis, is that there are temporal considerations that cannot be precisely predicted. For example, will a certain asset be available to conduct a specific task when needed or will it still be involved in conducting a prior task, especially toward the end of the scenario when it becomes more difficult to predict what assets be available?

We believe participants' responses were influenced by a bias ("halo") effect as a result of (1) their being more familiar with A0 because of its traditional appearance and (2) because they had trained in A0 and had acclimated to A0. In addition, there may have been some confounding when rating the other principles. After rating the architectures on the first two principles they may have "followed suit" when rating the architectures on the other principles. Another factor that most likely impacted the respondent's perceptions (and their ratings) is the idea of loosing a node in architecture A2 and loosing two nodes in A1, which was most likely viewed as a negative.

The SMEs rated architecture A1 highest on unity of command because they thought this architecture would require the least amount of inter-nodal coordination. This explanation for their rating A1 as superior on unity of command and unity of effort supports the underlying rationale used by the modelers.

8. Future Research

Use of the principles of war to rate model-derived architectures offers good potential for providing valuable information for future A2C2 experiments. Future work includes further refine-ment of the measurement instrument and develop-ing additional objective measures for the principles of war.

8.1 Revised Principles of War Measurement Instrument

A modified procedure for the measurement instrument to be used by participants is currently being developed. This would include (1) providing more specific guidance on the process participants should use to make their evaluations, i.e., to assure they closely examine all tasks and at the lowest echelon of the organization where the task is being performed; (2) counterbalancing the order in which architectures are rated or partitioning the sample to avoid any bias; and (3) providing additional time for raters to complete the instrument.

8.2 Additional Objective Measures for the Principles of War

We are currently pursuing development of additional objective measures for other principles. For example, a process similar to the one used for unity of command can be applied to develop a measure for economy of force.

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