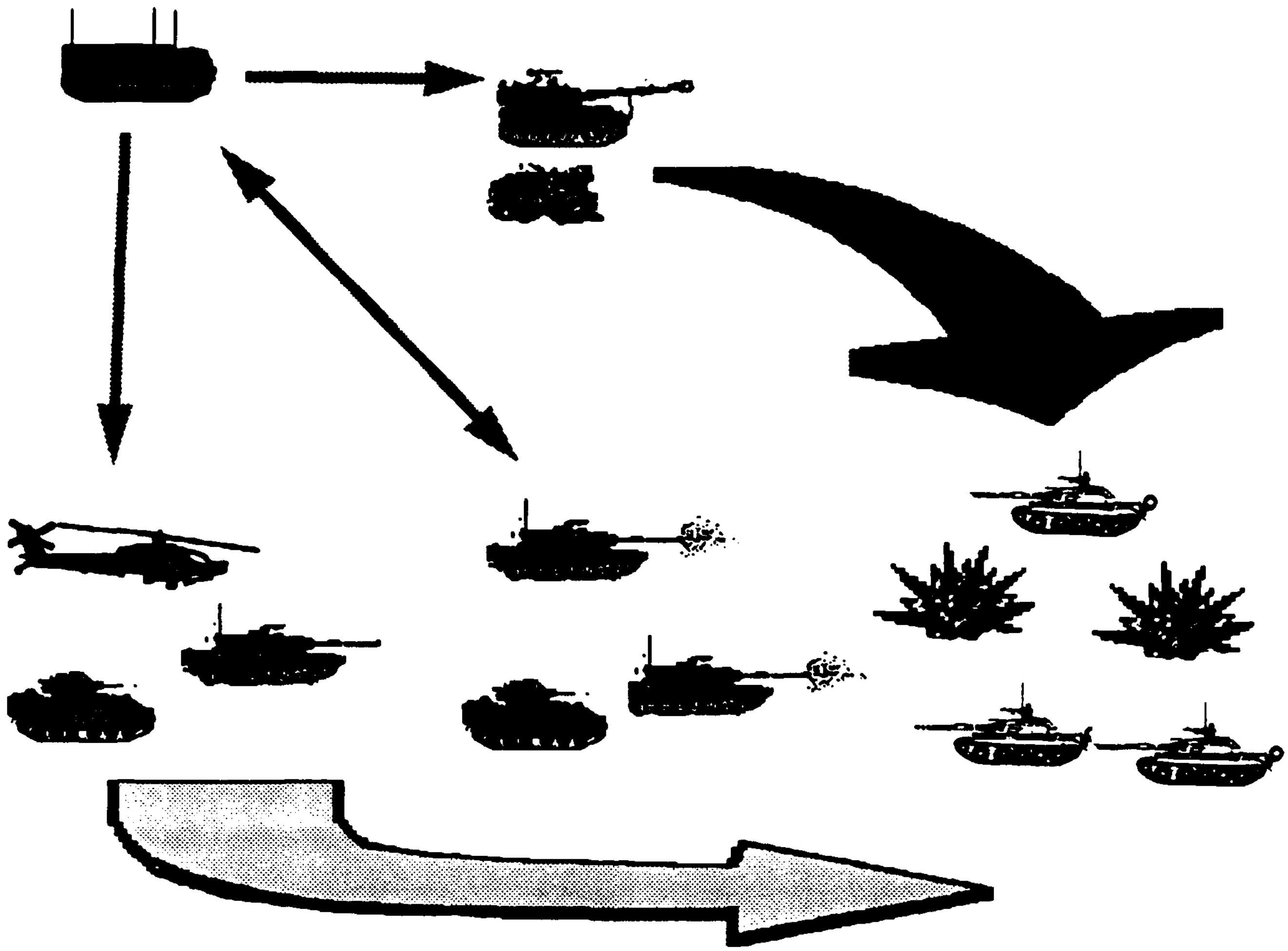
COMBAT SYNCHRONIZATION ANALYSIS FINAL REPORT



THE CENTER

UNITED STATES ARMY ARMOR CENTER
DIRECTORATE OF COMBAT DEVELOPMENTS
ANALYSIS DIVISION

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COMBAT SYNCHRONIZATION ANALYSIS

United States Army Armor Center
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ABSTRACT

The Army is moving resolutely toward the development of digital battle command systems to provide greater lethality, survivability, and tempo to maneuver units on the battlefield. This modernization will allow battlefield operating systems to fully synchronize with each other, based on a common, near-real time view of the battlefield. The total effect of such a battle command system promises to provide an overall effectiveness improvement greater than any other single modernization effort. Analyses have tried to quantify the benefits of fielding digitized battle command, but have not focused on the contributions of digitized information systems to the overall effectiveness of the combat unit at the brigade level and below. To do this, a simple network model (the Combat Synchronization Model) was developed by the Directorate of Combat Developments, United States Army Armor Center. This model of tactical unit command and control networks uses the commercially available SLAM modeling language to simulate the tactical information network within companies, battalions, and brigades. The model, input with data concerning frequency, transmission time, and processing time of tactical information, establishes the time needed for units to react in a meaningful fashion to a given battlefield situation. These time differences were then included in the normal maneuver and fire support processes within the combat simulation Janus (A). This methodology allows the determination of meaningful, quantifiable combat effectiveness performance measures when comparing alternative command and control systems. As a result, we gain insight into the time element of the battlefield, and clearly demonstrate the benefits of digitized battle command to maneuver units.

This study of the combat benefits of digital battle command was directed by the Director of Combat Developments, United States Army Center. The Study was performed by Analysis Division, supported by Simulations Division. The study leader and primary analyst was Major Jeffrey Witsken. Other study participants were Captain Alan Avery, Captain David Branscom, Mr. Lester McMannes, Mr. Josef Schroeder, and Mr. Lawrence Vowels. Questions or comments should be directed to the Chief, Analysis Division, DCD, USAARMC, ATTN: ATZK-CDC. Phone numbers are DSN 464-1347/3648 or commercial (502) 624-1347/3648.

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INTRODUCTION

Current Army weapon systems and Air Force close air support represent significant firepower which can produce decisive results on the battlefield. Yet, greatest benefit from these systems comes when they are coordinated with each other. Additionally, the performance of any weapon system depends greatly on the ability of other systems to accurately locate enemy forces and participate in their destruction. The most effective attacks occur simultaneously with other direct and indirect fires. With current battle command systems (C2), this coordination of assets to assure maximum effectiveness is very difficult to achieve (Center for Army Lessons Learned, 1988).

PROBLEM STATEMENT

Much attention has been focused on the potential benefits of digital communication systems on combat effectiveness. Unfortunately, there is little information available on the benefit of these communication advances in normal measures of combat effectiveness. Current constructive combat simulations (such as Janus and CASTFOREM) either do not address the battle command process, or lack relevant, logically based input concerning the effects of command and control delays on combat effectiveness. Our combat simulations, in effect, model the perfect world, with instantaneous communication and high quality decisions. We need to quantify rationally the time delay involved in decision cycles, both to identify potential improvements in our battle command systems, and to provide input into our combat simulations in order to determine the battlefield impact of improved communications, command, and control.

STUDY OBJECTIVES

The goal of the Armor Center's analysis was to demonstrate the benefits of digital battle command in terms of normal measures of combat effectiveness. The study objectives were:

- Study the time element of current data on information flow in tactical units.

- Use available small unit data to determine larger unit decision cycles.

- Develop a method for utilizing reaction times in current combat simulations to evaluate digital battle command, and develop insights by examining combat payoffs.

THE COMMAND AND CONTROL ENVIRONMENT

To understand what benefits a battle command system may have, one must understand the flow of information and orders within tactical units. The command and communication facilities of a maneuver unit vary based on the size and role of the unit. The basic functions can be understood by looking at a company size unit. The tank/mechanized infantry company team's command, control, and communications apparatus consists of three platoon radio nets, the platoon leader & sergeants, a single company radio net, and the commander himself. The company team commander is assisted by an XO (the XO usually forwarding reports to higher headquarters while the commander focuses on fighting the battle) and 1SG (who handles administrative and logistical traffic). Figure 1 illustrates a typical company team as an example.

Units transmit many different types of reports, orders and other information. These are generally classified as: battlefield information reports (such as contact reports, spot reports, and shell reports), calls for fire, friendly status reports (such as situation reports), and supply status reports. Commanders and their headquarters provide orders of varying size and complexity to subordinate units based on their view of the situation. These range from short directives to lengthy operations orders involving a significant change of mission. Lateral communication also occurs among adjacent units to ensure correct execution of the mission and prevent losses from friendly fire. Logistics radio nets continually pass status and resupply coordination messages. Information is passed in both directions (up and down) across the radio net.

The frequency of radio traffic varies widely, with the most intense demands for communication occurring during enemy contact. This is also the time when information needs to be passed in the most timely fashion. Units are therefore very dependent on the quality of their command and control systems to survive during a battle. Many command and control techniques, such as battle drills, hand and arm signals, and brevity codes all stem from the desire to wring maximum advantage from the battle command system.

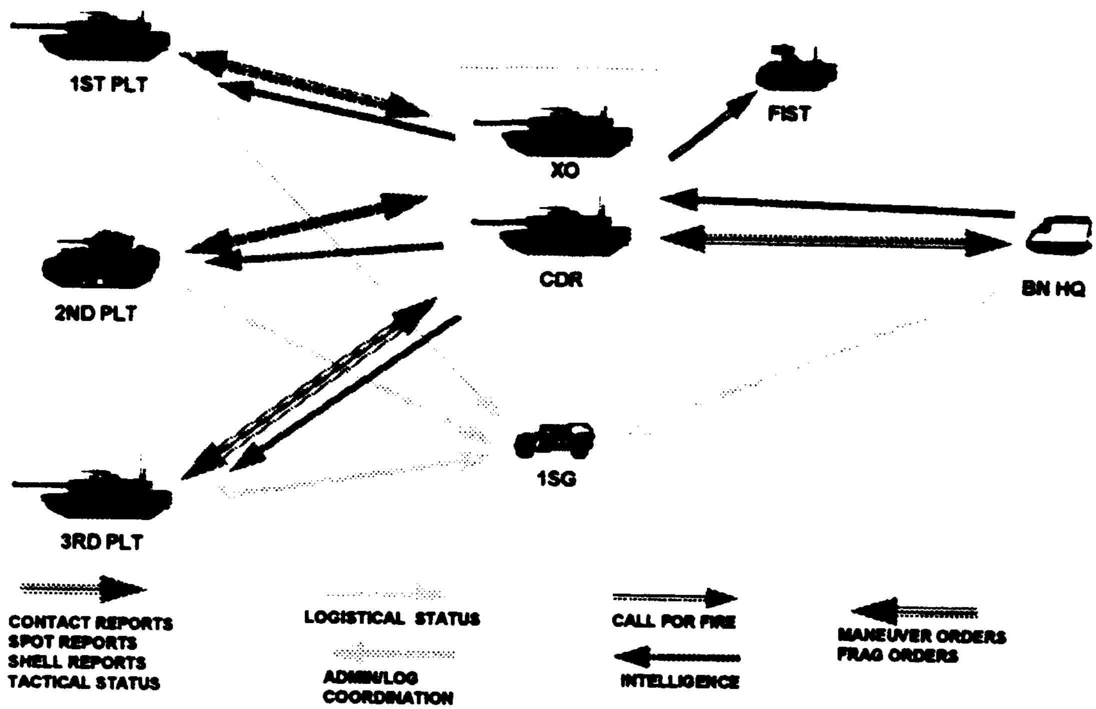


Figure 1. Company Information Flow

AVAILABLE DATA AND PREVIOUS STUDIES

A significant body of work by government agencies and consultants exists, focusing on the many problems with the current communications arrangement, and on the potential benefit of digitized systems. Tuttle (1986) describes historical examples of effective and ineffective command and control systems. Shoffner (1993) states that future battlefields will be characterized by faster tempo, requiring even faster reactions from units. He also notes that current voice-based systems are insufficient for the future. Goldsmith, Hodges, and Burn (1990) noted that most artillery fire at the National Training Center was ineffective due to excessive reliance on human judgment and voice communication in requesting fires. The U.S. Army Communications Electronics Command (CECOM, 1990) analyzed the traffic loading of communication systems during information exchange between unit elements, concluding that current systems could not support the information requirements of future operations. Most recently, the Simulation, Training, and Instrumentation Command (STRICOM, 1993) reported improvements in the ability of units to maneuver and react to combat situations, given digitized command and control systems.

Some quantitative data does exist on the information processing and transmission times of conventional and digitized C2 systems. Dubois and Smith (1990) provide information on the effect of digitized C2 on platoon level units. Leibrecht, Kerins, Ainslie, Sawyer, and Doherty (1992) similarly examine the impact of digitization on company level units. Goldsmith et al. (1990) provide some quantitative data concerning digitized systems' impact on artillery effectiveness. It is impractical at this point to obtain similar data for battalion and brigade size units. Because of the lack of resources to actually compare the alternative C2 systems, we must rely on simulation for comparison (Law and Kelton, 1991). Simulation must be used to generate the information throughput times to develop unit decision cycle/reaction times.

Some review has also been made into the linkage of command and control models with combat simulations. Strukel (1992) reviewed the linkage of a network model with a Corps and Division level model to better replicate unit performance. He concluded that C2 models and combat simulations can be linked, provided that the information flow within the C2 model represents the missions of the combat units within the combat simulation.

THE DECISION CYCLE CONCEPT

One of the first tasks in understanding unit reactions to combat situations is defining the reaction of leaders and units to combat information. Air Force Colonel John R. Boyd has characterized the mental reactions of pilots during aircraft dogfights, and later leaders of units in ground combat, as occurring in repetitive cycles (Boyd, 1987). Figure 2 depicts the essential elements of his concept.

> Conflict can be seen as time-competitive observation-orientation-decision-action cycles. Each party to a conflict begins by observing. He observes himself, his physical surroundings, and the enemy. On the basis of his observation, he orients, that is to say, he makes a mental image or "snapshot" of his situation. On the basis of this orientation, he makes a decision. He puts the action into effect, i.e., he acts. Then, because he assumes his action has changed the situation, he observes again, and starts the process anew. His action follows this cycle, sometimes called the "Boyd Cycle" or "OODA Loop." (Lind, 1985, p. 5)

As in a dogfight, tactical combat rewards the unit which has the faster decision cycle. This can be observed time and time again historically. German General Hermann Balck observed that General Guderian's greatest contribution to panzer forces was not armored vehicles, but a communication system superior to the communications of any other army (Balck, 1979). The successes of the panzer forces were largely due to the faster decision cycles permitted by their superior command and control system.

This concept of a "OODA Loop", or decision cycle was used to develop the overall flow of information within units and the "minds" of commanders (and their staffs). Each of these steps in the decision cycle can be seen as taking some amount of time to complete. The information flow by itself can consume additional time, based on the quality of the communications and C2 within the unit. Additionally, not only must the time for information to flow "up" be considered, but the time for orders to flow "down" must be also be captured.

THE BENEFITS OF DIGITAL BATTLE COMMAND

In current communications, information is sent verbally. Some modems and facsimile machines have been placed in current systems, but voice communication is still predominant. Transmission times are long, so radio nets are tied up by each sender-receiver combination. Leaders and staffs also tend to process each new bit of information individually. Leibrecht et al. (1992) noted that in current voice radio systems, 30 percent of all transmissions were followed by additional transmissions repeating or clarifying the original transmitted information. This leads to significant delays in the transfer of information, and the formation of queues of information awaiting transmission and processing. In some cases, the individual attempting to send the message may give up on transmitting if the information is low priority (or is overcome by events). These messages which become outdated or lose their usefulness represent lost information.

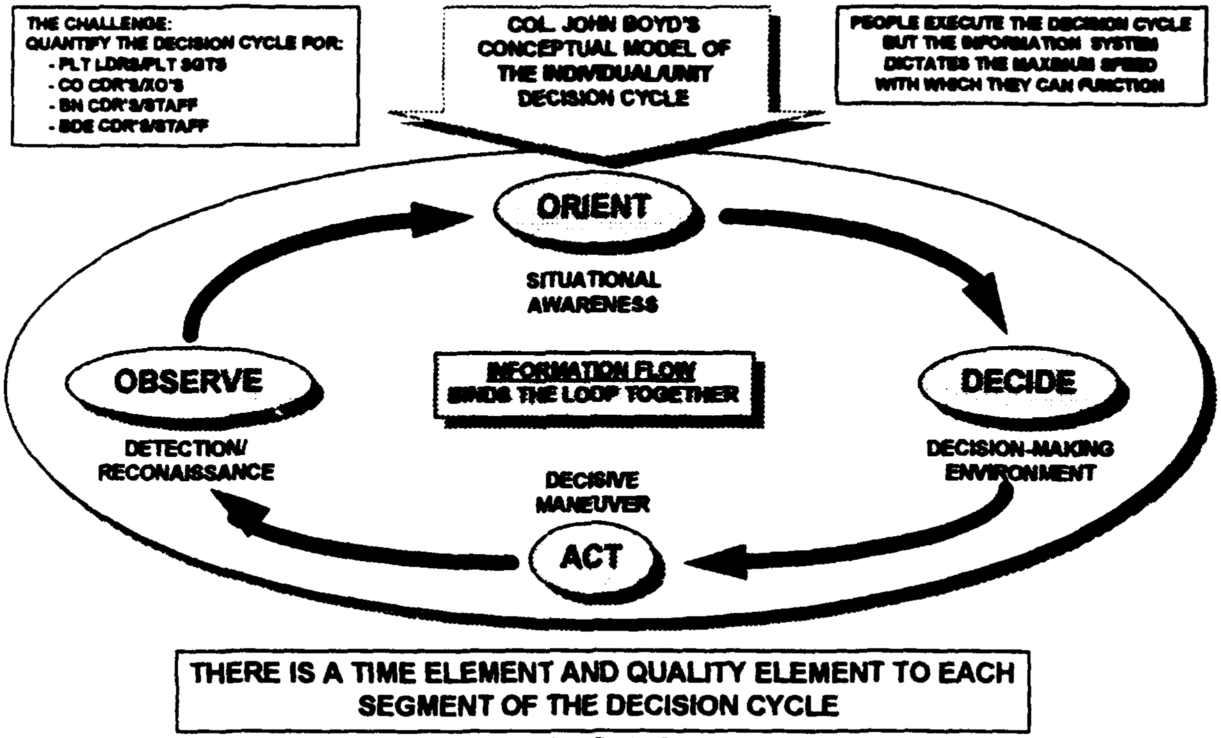


Figure 2. Decision Cycle Concept

Digitized battle command systems offer to solve many of the current problems, and provide new capabilities. These systems feature data burst communications, combined with video displays, automatic position location, and far target designation capabilities. By using data burst techniques, radio net utilization is lessened. Units can send graphics as well as text information. Since the information can be sent visually and audially, the need to clarify information drops dramatically. Leibrecht et al. (1992) noted that digital battle command systems had only a four percent repetition/clarification rate. Automatic position updates provide accurate location information, which can be broadcast to other friendly units. These systems can be set for automatic information updates, and allow rapid forwarding of information (STRICOM, 1993).

Digitized battle command systems primarily benefit maneuver units such as armor, aviation, and mechanized infantry units. These enhancements can be described as providing five major benefits to maneuver forces:

- Improved Intelligence (All Levels - All Sources). Enemy information can be rapidly forwarded to all concerned units and headquarters.

- Situational Awareness/Combat Identification. Better awareness of friendly forces decreases confusion, improves decisions by leaders, and increases the tempo of operations. This awareness also reduces the potential for fratricide.

- Command and Control on the Move. Commanders can now conduct proper planning and coordination with less need for face to face communication. Staffs can coordinate and maintain status of the battlefield with less need to operate within large, ungainly Tactical Operations Centers (TOCs)

- Synchronization and Massing of Direct/Indirect Fires. Digital communications permit accurate and timely maneuver (to include highly accurate indirect fires). A commander can tune his maneuver much more closely to the actual situation, and properly employ all of his available assets.

- Improved Force Protection. Better awareness of enemy forces allows improved deception, better use of terrain, and swifter maneuver; oriented at destroying the enemy while preserving the friendly force. This leads directly to fewer friendly losses.

Maneuver forces are most concerned with the integration of all Battlefield Operating Systems (BOS) within their operations. Supporting units such as artillery and engineers also benefit from these systems, given the greater quantity of timely information exchanged in the time available. Indirect fire from artillery and mortar batteries becomes more timely and more accurate (Goldsmith et al., 1990). Combat Service Support (CSS) can be provided in a timely fashion, with the most efficient use of available resupply resources. All BOS can be coordinated and used with greater speed and assuredness.

Digitized communication can benefit any headquarters, particularly those most involved with the synchronization of battlefield fires and maneuver (company, battalion, and brigade). The company commander integrates his unit's direct and indirect fires. The battalion commander integrates direct fires, indirect fires, and the maneuver of assigned units. At brigade level, ground units, aviation, and close air support are tied into the overall scheme of maneuver (FM 71-1, FM 71-2, FM 71-3, 1988).

METHODOLOGY

The best source of comparative data for voice and digital battle command systems is the reports of the IVIS and CVCC experiments conducted during 1991-3 at the Mounted Warfare Test Bed by the Army Research institute (Fort Knox Field Unit). These experiments captured the processing times, transmission times, and frequency of individual reports for both voice and digital battle command systems. This data was in a form usable for network analysis. It had the added advantage of being captured under controlled conditions during the execution of tactical missions within a distributed interactive simulation environment. The time data captured reflected reports and orders being created and sent while a tactical mission was in progress. Leaders had to navigate and fight their vehicles, as well as process and transfer information. The data reflects some degree of the "pressure" placed on leaders in a tactical environment, and reflects the "switchology" required to input information into a digital battle command system.

The data from the ARI reports was the most appropriate for use as inputs into a network model, which would replicate the flow of information within company, battalion, and brigade level units. The purpose of the network model was to utilize the available ARI data (which described the attributes of individual reports and orders) to determine the overall time requirements for reports and orders to move within tactical units. This simulation would replicate the competition for radio net time, the different demands placed on leaders, and permit the formulation of maneuver and fire support reaction times for units in a given tactical situation (Figure 3).

The methodology chosen for the analysis was to take available data concerning the flow of information in tactical units, conduct a network analysis to capture the total delay times for the flow of information and orders, then to impose these time delays on units within Janus. Janus gaming can then be analyzed for the combat impacts concerning timeliness of decisions and actions.

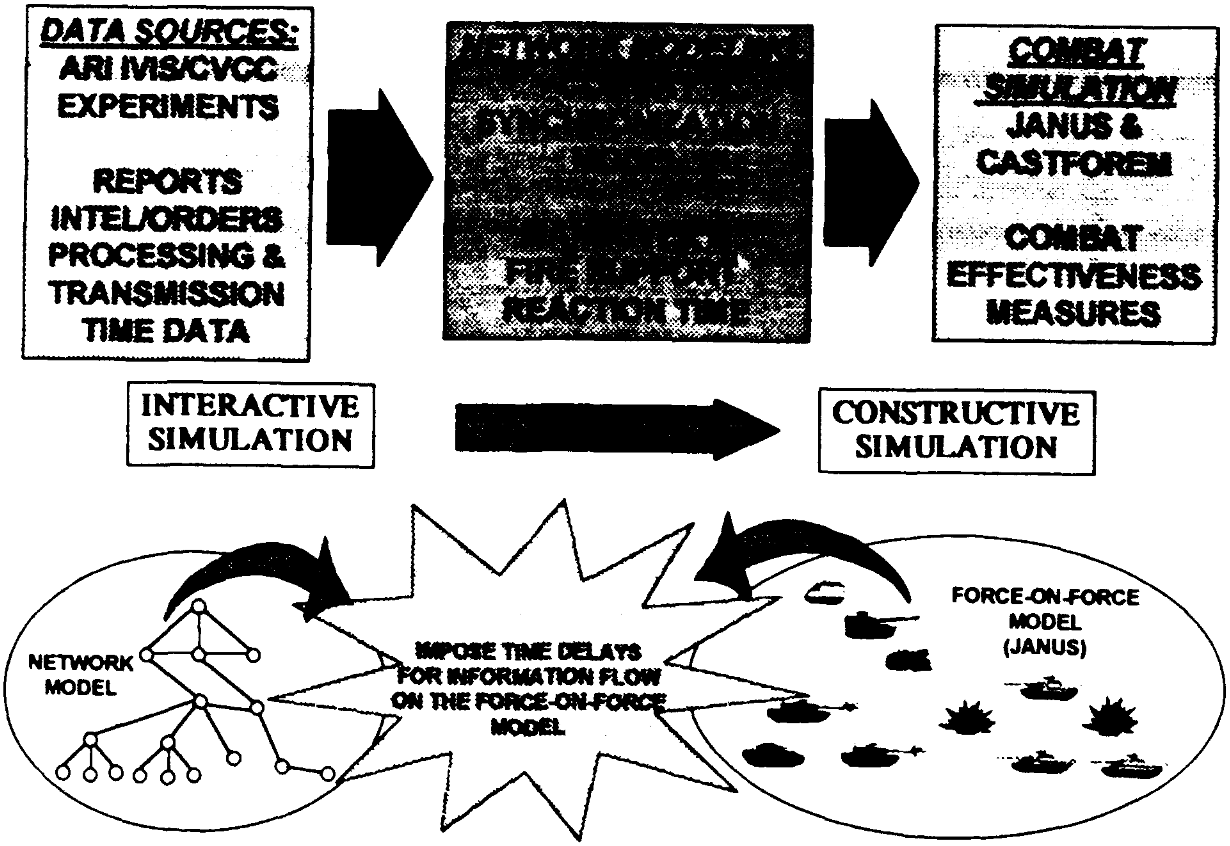


Figure 3. Combat Synchronization Analysis Methodology

METHODS OF EFFECTIVENESS/PERFORMANCE

Given the study's focus on the combat payoffs of current and digital battle command systems, the Loss Exchange Ratio (LER) became the primary measure of effectiveness. Development of measures of performance proved to be more difficult. Measures of performance were developed by examining the concept of the decision cycle or "OODA Loop" described above. Each step of the decision cycle was reviewed for potential measures of performance. Those measures concerning the time element of information transfer and combat effectiveness were used within this analysis (for a complete discussion of measures of effectiveness and performance, see Appendix B). These measures permit analysis of the overall effectiveness of the battle command system, and quantification of the expected time delays (and their effect on the battle). The primary measures of performance chosen include:

- Decision cycle times (time for critical information to reach the correct destination, combined with the time required for appropriate action to be taken).

- Time to bring supporting weapons to bear. (times for calls for fire to impact, time for requested supporting units to react to request, etc.).

- Mission execution time.

- Weapons utilization rates (how many systems participated in the battle over time).

- Volume of fires (direct and indirect - over time).

- Red and blue losses over time.

- Contribution of each blue system to total red kills.

METHODOLOGY LIMITATIONS

This network/queuing approach focuses on the time savings benefit of digital battle command systems. The methodology partially captures the benefits of improved quantity and quality of information, its completeness, and its accuracy. Current voice-based battle command systems suffer from substantial weaknesses in each of these areas. Much of our current training and doctrine attempts to work around these deficiencies.

Also, this methodology does not specifically address the quality of the decisions made by leaders. Generally, the more information available (and the sooner it is available to a commander), the better the decision, and sooner it will be made. A commander with partial information may very well make a poor decision, or spend additional time seeking the information needed to make a good decision. The data used from the ARI work in the Mounted Warfare Test Bed reflects some of this aspect of digital battle command, yet the methodology itself focuses on the time savings involved in getting key information to the necessary leader.

Digital systems also offer significant improvements in the location of targets, providing highly accurate locations of targets through linking of inertial navigation systems with laser rangefinders. This methodology does not fully address the increased accuracy of the location that the cannons are firing at (or the reduction in the time required for adjusting fire onto the target), it only captures the time savings in transmitting the call for fire to the fire support system (i.e. TACFIRE, AFATDS).

Finally, digital systems provide inertial navigation and "steer-to" devices that permit rapid, accurate movement. This methodology only captures the time savings derived from rapidly getting orders to move to all affected units, not the potential for faster, more accurate movement. This is due to the fact that all movement in constructive simulations is accurate and performed at the maximum possible speed. No systems or units become lost, and no one hesitates due to confusion concerning which way to go now.

MODELING TACTICAL COMMAND AND CONTROL

In its simplest sense, the flow of information can be seen as a queuing model, where information arrives, is processed by a leader, and then forwarded to another destination. This model is complicated by the different types of information, reports, and orders, as well as the fact that information flows in differing directions (up, down, and laterally) within tactical organizations. To further complicate the matter, the radio nets and leaders involved can only handle one report/order at a time. This imposes delays and restrictions on the whole system, accounting for much of the delay seen in the flow of information and orders during field exercises.

The speed with which information can flow among tactical radio nets and be processed by staffs is dependent on several influences. For example, if a company or battalion commander is far forward enough that he can personally observe the battlefield, he will not have to rely on the reports of his subordinates. This can save several minutes, and decreases problems with delayed or misconstrued communication. Also, the number of leaders and staff personnel available to process information is important, particularly during peak periods of unit activity. The personal observations of the commander (when forward to observe the battle) needed to be placed in the network so as to bypass the queue (and delay) of waiting for the availability of the appropriate radio net.

The type of mission and the level of unit activity can have a great effect on the frequency of reports, and how long the reports take to transfer. Generally, information flows more quickly in the defense as units are more prepared and better aware of their and the enemy's situation. The activity and distribution of a unit can also detract or contribute to information flow. A dispersed, moving unit cannot pass information as quickly and reliably as a stationary, consolidated unit. The information available (from previous studies) generally allowed these differences to be handled as part of the information input process, since data were available for both offensive and defensive missions.

Command relationships and task organization have a great deal to do with delay in passing information. It is beneficial to reduce the number of headquarters that requests for information must pass through. For example, an attack helicopter unit requested directly by a battalion will show up much sooner than if the request is passed through both battalion and brigade headquarters (FM 1-112, 1990). To account for this, the network model was specifically structured to reflect the task organization of the unit modeled in the combat situation.

Other activities and distractions take time away from a leader's ability to constantly observe the battle and process information. Leibrecht et al. (1992) found that leaders forward on the battlefield spent a great deal of time concentrating on their unit's status, navigating their vehicles, and looking for enemy activity. In the case of aviation leaders, they must also assist in flying their aircraft. These leaders have less time available to pass information than the staff officer in the rear. This factor was accounted for by designing an "activity generator", which took up a certain percentage of each leader's time, to decrease the availability of the leader as a resource for passing information.

MODEL ASSUMPTIONS

Several assumptions were made in building the model:

- That all subordinate units were performing similar missions. In other words, the entire company or battalion was conducting offensive operations, as opposed to some subordinate units performing "defensive" missions while others were "offensive". This may be a concern for larger units (division, corps), but it was not seen to be a significant issue at brigade and below.

- That voice and data communication could be transmitted on the same net without interference.

- That the radio system was capable of the necessary voice and data loads

- No natural or electromagnetic interference was factored into the model (although the model is capable of modeling levels of interference on the radio nets).

- All combat systems were assumed to have digital battle command systems. Combat support and combat service support leaders and key command and control facilities were also assumed to have digital battle command systems.

- The analysis also assumes "objective" (fully integrated) battle command system software and protocols that do not possess certain limitations currently present in current digital systems such as TACFIRE. For example, messages can be broadcast to multiple addresses if needed.

- Finally, it was assumed that the time to process and transmit a given message would not change as it flowed through the system. (although some lesser priority messages would be "batched together") before sending to higher headquarters. Batched messages were assumed to be summaries of their component messages, and not significantly different from the originating messages.

MODEL STRUCTURE

The Simulation Language for Alternative Modeling (SLAM) was chosen to perform the simulation of the tactical information networks. SLAM is a combined discrete-continuous modeling language which simulates a system's state in small time steps, while changing entities within the system at discrete events (Pritsker, 1986). This language allows the modeling of the flow of reports and orders through the battle command network.

The level of detail desired in capturing the tactical information flows involved led to the creation of a separate model for company, battalion, and brigade level. Each model is set up using leaders, staff sections, and radio nets as the nodes in the network. Processing and transmitting the information make up the activities connecting the nodes. To pass information along (i.e. perform an activity), information must be processed by a leader or transmitted across a radio net. Each leader and radio represents a resource which can only be used for one activity at a time. Reports and orders make up the entities flowing through the network.

Each entity (report or order) has several attributes assigned to it. The first attribute is the time the message is created. The second is the time needed to transmit the entity over a radio net. The third is the processing time required for a given leader or staff section to process the information. This processing time refers to the time needed to comprehend the information and make judgments as to the information's utility and what should be done about it. The fourth attribute indicates the message type and its source. Other attributes specified the level of batching permitted for a given type of report, and served as intermediate time markers.

The networks themselves were constructed per the command and control facilities and radio nets described in Field Manuals FM 71-1, FM 71-2, and FM 71-3. Complete model documentation is at Appendix D.

COMPANY LEVEL MODEL

To replicate the company level, a network model was created which simulates information coming to a company commander through his platoons, or through his own observation of the battlefield. Based on the type of information, the network then routes this information to the Fire Support Team (FIST), higher headquarters, or back to subordinate elements as an order. Information from higher headquarters (such as intelligence and orders) are routed down through the network. Leaders and radio nets are considered resources, that can be only used to transmit or process one type of report at a time (and in only one direction at a time). Figure 4 illustrates the basic structure.

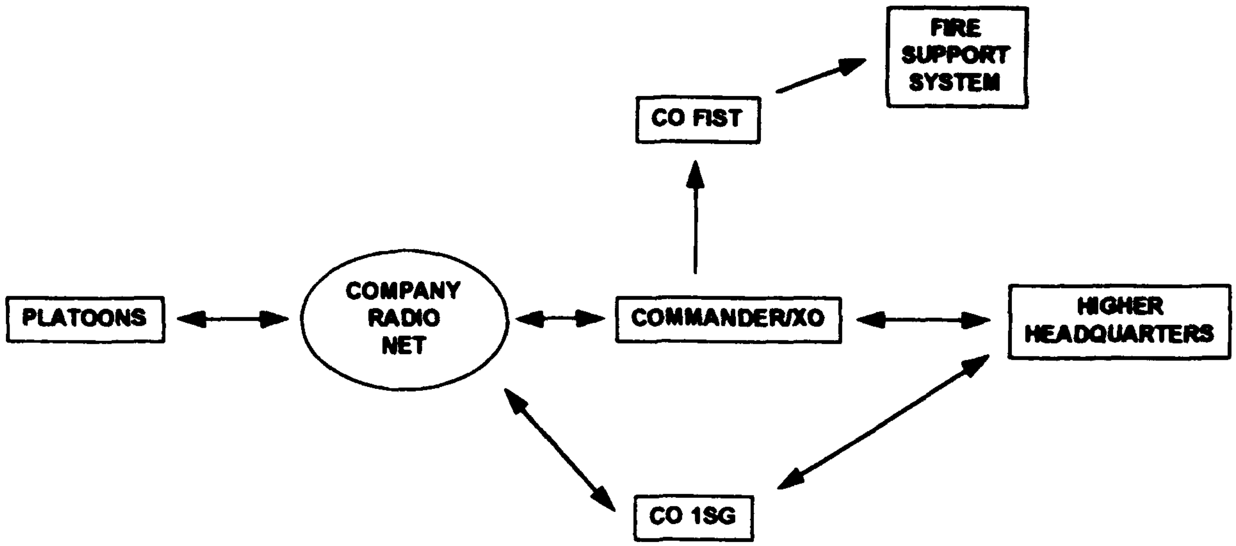


Figure 4. Company Team Model Structure

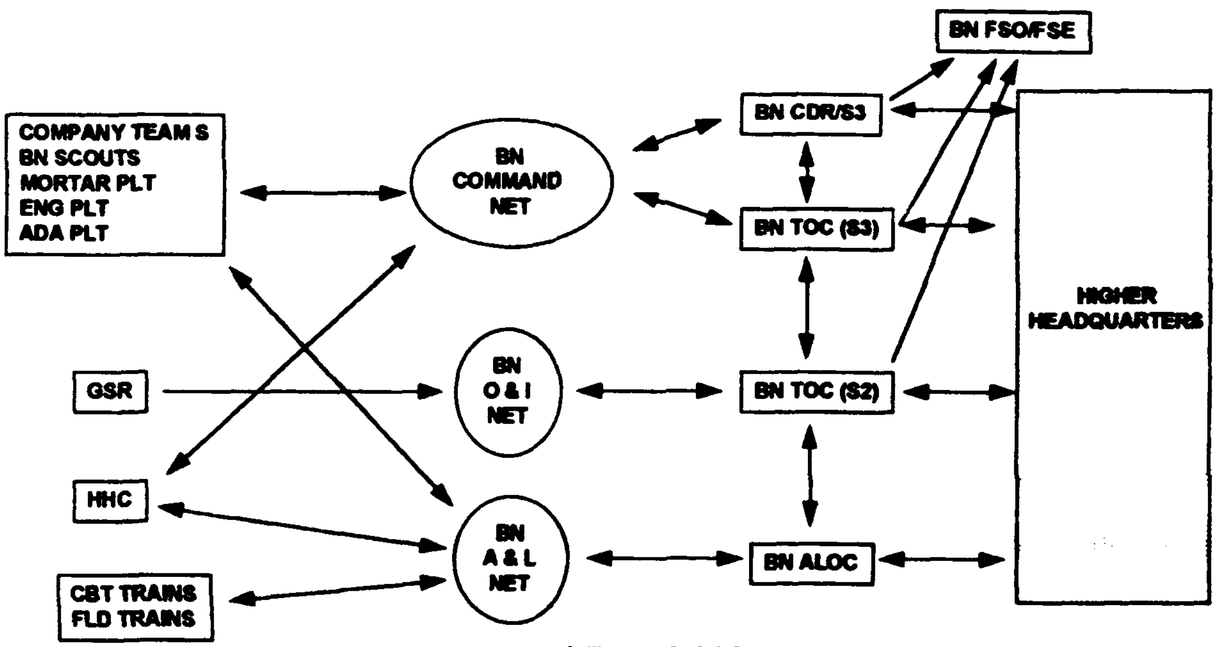


Figure 5. Battalion Task Force Model Structure

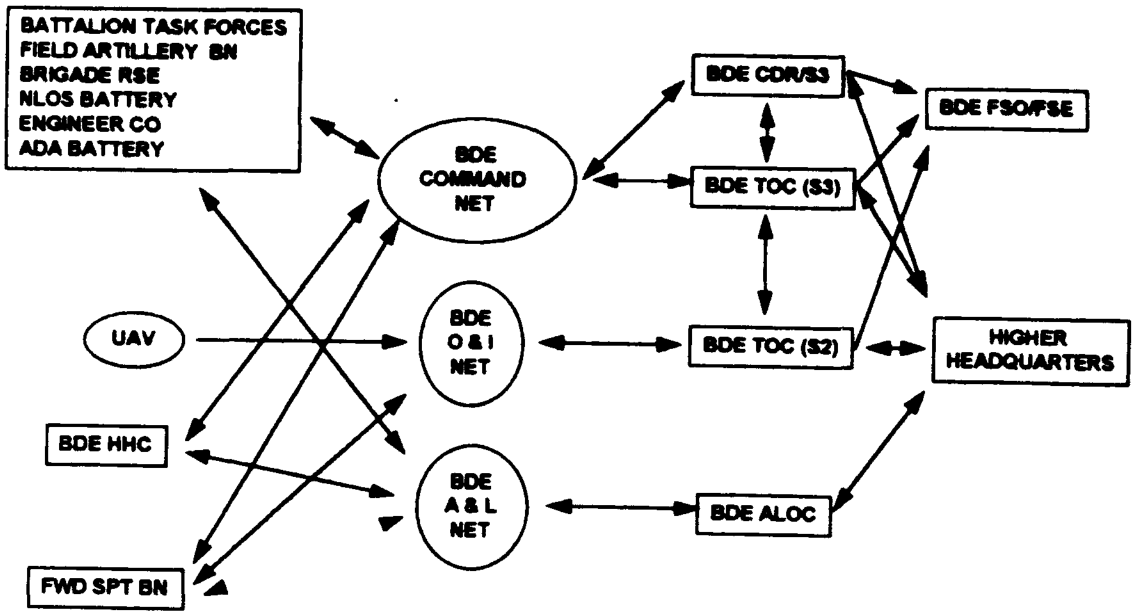


Figure 6. Brigade Model Structure

BATTALION LEVEL MODEL

At battalion level, the complexity of the command and control system increases (see Figure 5). There are now three radio nets: Command; Operations and Intelligence (O&I); and Admin and Logistics (A&L). Command and Control (C2) facilities include a tactical command post (TAC), tactical operation center (TOC), and admin-logistics operations center (ALOC). Within these facilities, the commander's staff (S-1, S-2, S-3, S-4, Fire Support Element, Air Liaison Officer, and other special staff) assists in the processing of information, coordination of the battle, and development of orders. There are also several special platoons that report directly to the battalion level (scouts, mortars, support platoon). In addition, significant additional assets are often cross-attached to the battalion task force (engineers, air defense, etc.). Logistics organizations are also present (combat trains, field trains).

Construction of battalion networks is essentially the same as for a company, although there is increased complexity in the system. As discussed above, there are now three radio nets, three C2 facilities, and many more units to be considered. Reports have to be correctly routed through the networks, and allowances must be made for cross-staff coordination.

BRIGADE LEVEL MODEL

The command and control structure of the brigade is similar to battalion, but larger in scope (Figure 6). Most significantly, the brigade possesses additional intelligence sensors, has a direct support (DS) field artillery battalion, and has a forward support battalion (FSB) managing its logistical support.

REPORTS/ORDERS

Available references were reviewed for data concerning the time required for personnel to process and transmit reports and orders. For the purposes of analysis, the following types of reports and orders were identified for network simulation (listed in order of priority):

- Spot Reports/Calls for Fire. Spot reports are descriptions of enemy size, activity, location, unit, and equipment at a certain time. These reports are often the basis of or supplemented by a call for indirect fire.

- Execution Orders. These orders are defined as short radio transmissions which provide interim guidance to subordinate units, or direct execution of a preplanned portion of the operation.

- Significant Fragmentary Orders (FRAGO). These orders are major changes in mission which require rapid execution of troop leading procedures prior to execution of the revised mission.

- Internal Detections/Intelligence). These reports are defined as enemy detections generated by internal sensors or intelligence assets (such as a GSR or UAV).

- Higher Intelligence. These reports are defined as enemy detections generated by external sensors or intelligence assets (such as IEW assets or JSTARS).

- Tactical Status Reports. These reports are defined as descriptions of current unit activity and location. Also includes lateral communication between units to ensure proper execution of the mission.

- Logistical Status Reports. These reports are defined as descriptions of current unit supply and maintenance status. Includes requests for medical, maintenance, and resupply support.

- Admin/Logistics Coordination. These reports represent the necessary messages required to ensure proper coordination and link-up of logistical support.

Generally, the references specified a total time for processing and transmission, without a detailed breakout of the exact transmission time and processing time. This did not present a problem for digital data, as nearly all of the time listed was due to report preparation and processing. For voice data, subject matter experts were consulted to estimate the breakout of total time into processing time and transmission time. "Digital" data processing and transmission times are not solely digital messages. Data actually reflects a combination of voice and digital traffic needed to pass the necessary information contained in a given report or order. In addition, each report was "source coded" to permit capturing information flow times from specific units. All times are listed as the mean time, followed by the standard deviation.

Other report attributes were also specified, including frequency of occurrence. For small units (platoon level and individual systems), the frequency of reports observed in the ARI experiments (approximately one report every eight minutes on the company net) was used. Some reports, such as calls for fire, were generated as a certain percentage of spot reports. Tactical status reports were assumed to be generated averaging every 15 minutes (by unit SOP) when voice command and control was used, and every 10 minutes (automatic IVIS/CVCC updates) with digitized battle command.

Data was available for offensive and defensive related missions, so two groups of data were specified. The different types of orders and reports were defined as shown in Table 1. Reports are listed in order of priority used within the network simulation.

REPORT/ORDER TYPE	OFFENSE TRANS TIME(M)	OFFENSE PROCESS TIME(M)	DEFENSE TRANS TIME(M)	DEFENSE PROCESS TIME(M)
SPOT REPORTS/ CALLS FOR FIRE				
Basecase	1.3, 0.4	0.6, 0.2	1.1, 0.3	0.6, 0.3
Digitized	1, 0.5	0.5, 0.3	0.7, 0.1	0.3, 0.1
EXECUTION ORDERS				
Basecase	0.3, 0.2	0.2, 0.12	0.3, 0.2	0.2, 0.12
Digitized	0.3, 0.2	0.2, 0.12	0.3, 0.2	0.2, 0.12
SIGNIFICANT FRAGO				
Basecase IVIS	5,1	10,2	4.3, 1.4	8.6, 2.9
Digitized IVIS	2, 0.7	4, 1.3	2, 0.3	4, 0.7
Basecase CVCC	1.9, 0.9	3.8, 1.8	3.4, 3.0	6.8, 6.0
Digitized CVCC	0.8, 0.6	1.6, 1.2	0.6, 0.4	1.2, 0.8
INTERNAL DETECTIONS/ INTEL				
Basecase	1.0, 0.5	0.5, 0.3	1.1, 0.5	0.6, 0.3
Digitized	0.4,0.2	0.2, 0.1	0.4, 0.2	0.2, 0.1
HIGHER INTEL				
Basecase	1, 0.5	0.5, 0.3	1.1, 0.5	0.6, 0.3
Digitized	0.02	0.5, 0.3	0.02	0.5, 0.3
TACTICAL STATUS				
Basecase	0.7, 0.3	0.3, 0.1	0.7, 0.3	0.3, 0.1
Digitized	0.02	0.2,0.1	0.02	0.2,0.1
LOGISTICAL STATUS				
Basecase	0.7, 0.3	0.3, 0.1	0.7, 0.3	0.3, 0.1
Digitized	0.02	0.2, 0.1	0.02	0.2, 0.1
HIGHER A/L COORD				
Basecase	0.7, 0.3	0.3, 0.1	0.7, 0.3	0.3, 0.1
Digitized	0.02	0.2, 0.1	0.02	0.2, 0.1

Note: Times listed are means, followed by standard deviation.

Table 1. Order/Report Processing/Transmission Times

LEADER ACTIVITY GENERATOR

As discussed above, leaders do not constantly process information. Some percentage of their time is devc..d to other activities. To replicate this, a sub-network was placed into each model which used dummy activities to occupy some of each leader's time. These dummy activities did not flow through the information network, yet placed additional demands on each leader, and prevented leaders from reaching 100% utilization (spending all of their time processing information). After a review of available data, "other activity " rates were established for each leader (see Table 2).

POSITION	% TIME OTHER ACTIVITIES
PLATOON LEADER	50
COMPANY COMMANDER	30
1SG	30
BN/BDE STAFF	10
BN COMMANDER	30
BDE COMMANDER	10

Table 2. Leader "Other Activity" Rates.

REPORT GENERATION

Each level model has two report generators, which represent the observers, headquarters, and systems generating reports/orders to each element. It creates reports (of each type) at the specified frequency and then randomly determines which leaders or units receive the report. Tactical status reports are generated averaging every fifteen minutes in the basecase, and every ten minutes using digital battle command systems. A certain percentage of detections are assumed to be directly observed by the unit commander (and so are routed directly to him, simulating the commander's personal observation of that battlefield event). Reports are then routed to each of the specified leaders and units (see Figure 7).

LEADER/STAFF NODES

The nodes for other leaders and staff sections are shown in Figure 8. Incoming information arrives from subordinate units, internal sensors, and other staff sections. This information is held in a queue, sorted in priority, processed and then routed to the appropriate other nodes. These include higher headquarters, other staff sections, and the fire support element. Orders and information from higher headquarters is also processed, then sent to other staff sections and subordinate units. At battalion and brigade level, quite a bit of information is shared between staff sections before it is sent on.

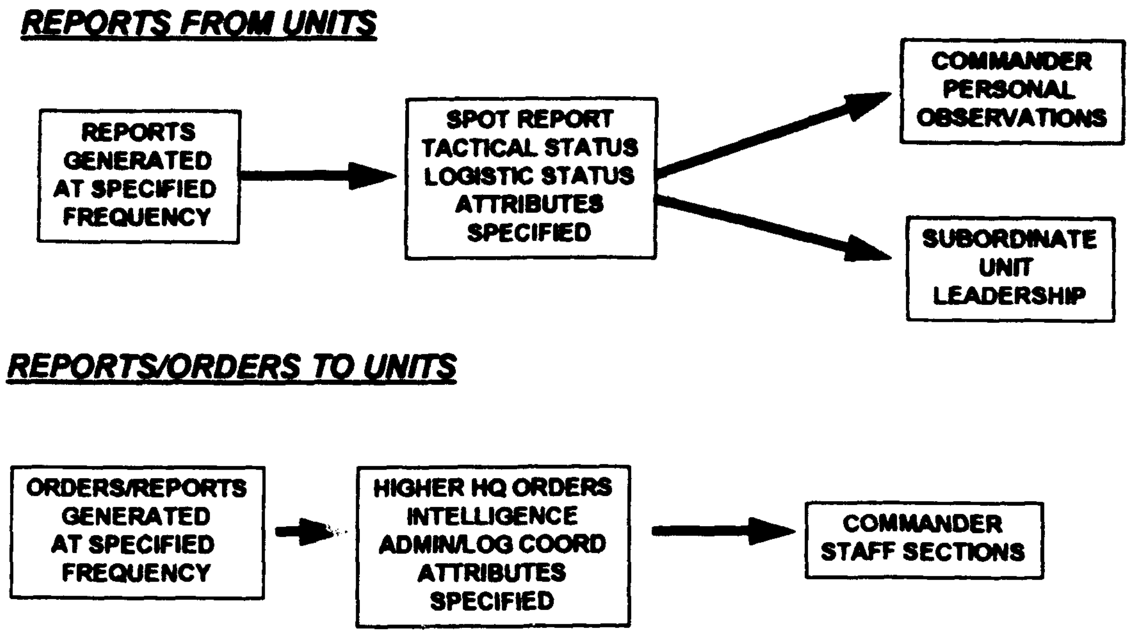


Figure 7. Report Generators

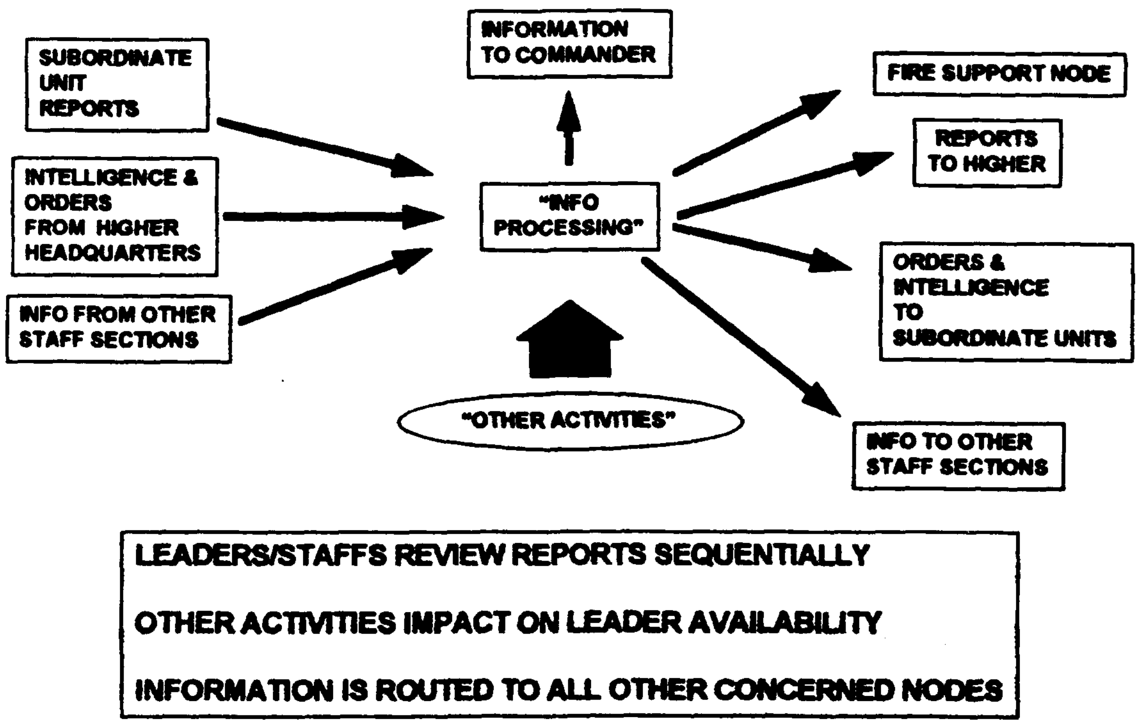


Figure 8. Leader/Staff Nodes

RADIO NET NODE

Radio nets pass messages in both directions (See Figure 9). Since the radio nets are treated as a resource, only one message can be passed at a time. Waiting messages are held in a queue (and sorted by priority) until they can be sent. Transmissions from subordinate units (reports heading "up") are assigned a time immediately upon arrival into the queue. Prior to being broadcast on the net, the time in the queue is checked. If the message has been delayed longer that 10 minutes, it is assumed that the report is outdated and is tracked as a "lost" report. Reports and orders from higher are always sent, regardless of time waiting in the queue. Also, transmissions on the radio net are assumed to require clarification or retransmission, so they are recycled back into the queue for re-transmission.

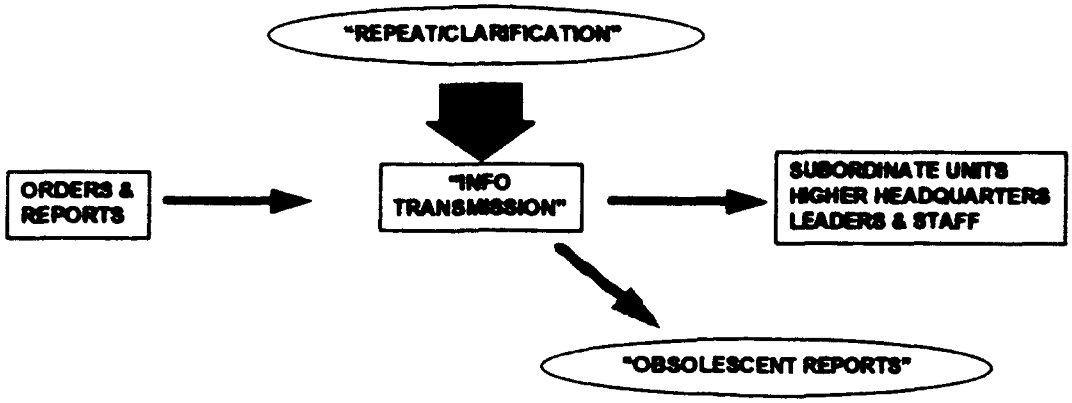
In each case, the repeat/clarification rate is established. Messages to be clarified or repeated are selected at random per the rate specified, and returned to the queue for retransmission. As mentioned above, the message clarification rate was set at 30% for voice command and control, and 4% for digital battle command systems.

COMPANY/BATTALION COMMANDER NODES

Historically, successful commanders have moved far enough forward on the battlefield to gain a personal view of the battle. This is due to the difficulty of trying to form an accurate picture of a battle solely from other's reports. Having personal observation of the battle has another advantage, in that the commander can immediately order the correct action for the actual situation, instead of waiting to gain an impression of the situation from reports. Since our doctrine calls for company and battalion commanders to be forward enough to personally observe the battle, provision was made to capture this effect of forward battle command (Figure 10). Commander nodes were built to process their personal observations as well as any reports they receive.

At company through brigade level, each commander has a primary assistant forward with him to assist in the command and control of the unit (the XO at company level, and the S3 at battalion and brigade). Although these individuals assist the commander in the forwarding of reports, planning, and execution of orders, they were not treated as a second "server" that could simultaneously process information with the commander. The commander makes decisions based on personal observations, perception, and judgment. The XO/S3 assist the commander in that, yet do not independently make decisions for the entire unit unless the commander is unable to do so. Because of this, commander nodes were not given "dual server" capability.

These nodes are set up so that a commander receives detections directly from the report generator (simulating events he can see personally) and reports over the radio net. The commander "processes" the information, "sees" the battlefield, then makes decisions. Most information is forwarded to higher headquarters. A certain percentage is sent to the FIST/FSO for fire support, and a small percentage trigger orders that are sent to subordinates. The commander node also processes intelligence and orders from higher.

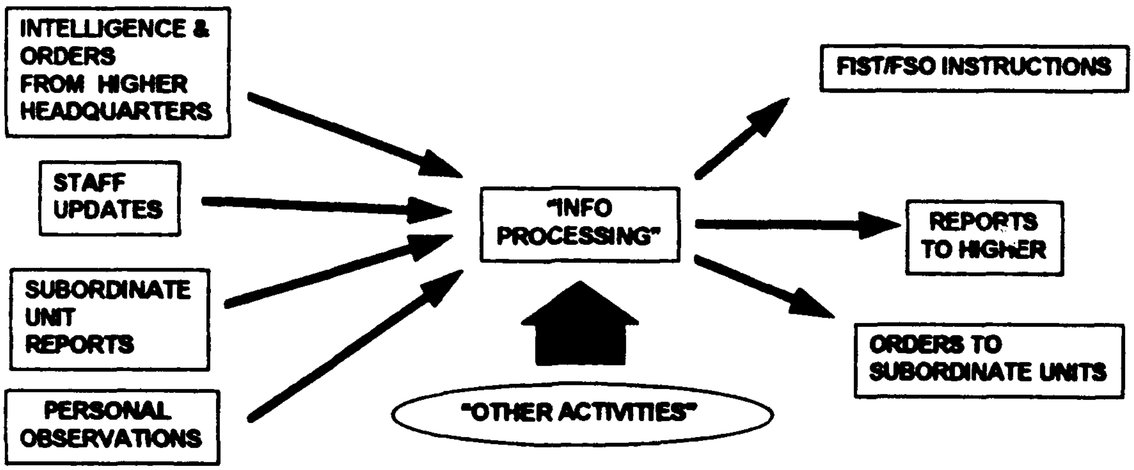


REPEAT/CLARIFICATION RATES FORCE RETRANSMISSION OF MESSAGES

RADIO NETS ARE A RESOURCE (ONE MESSAGE/ONE DIRECTION AT A TIME)

OBSOLESCENT REPORT TRAP CAPTURES CRITICALLY DELAYED INFORMATION AND WASHES IT OUT OF THE SYSTEM

Figure 9. Radio Net Node



COMMANDERS PROCESS THEIR OWN OBSERVATIONS COMBINED WITH RADIO REPORTS TO ARRIVE AT DECISIONS

Figure 10. Commander Nodes

FIRE SUPPORT NODES

Fire support nodes include the FIST, FSO, and FSE (Figure 11). These nodes receive calls for fire support from several sources: subordinate units, from supported commanders and their staffs, and from sensors organic to the supported unit. For example, a percentage of UAV detections would be routed through the Brigade staff to the Brigade FSE.

The model collects the time required from the time of detection entering the system to the time that the FIST/FSE/FSO has entered the call for fire into the digital artillery system. As currently structured, the model does not calculate the time required for the digital artillery system to get the fire request to the appropriate gun. The network model also does not play round time of flight, or calculate delays for adjusting fire on target. The time values already loaded into Janus for artillery systems delays were used in these two cases.

DATA COLLECTED

Model outputs are designed to provide transit time through the network, quantity of reports, and their frequency of exit. The total time needed for a report to reach the commander, for the commander to decide to act, and for the appropriate orders to go out is also collected. Statistics are collected on radio net utilization rates, leader/staff utilization rates, and consolidated statistics for reports going to the next higher/lower unit levels. The model also collects the quantities of orders and reports that passed through the system, or were washed out of the system due to age or overburdening a leader.

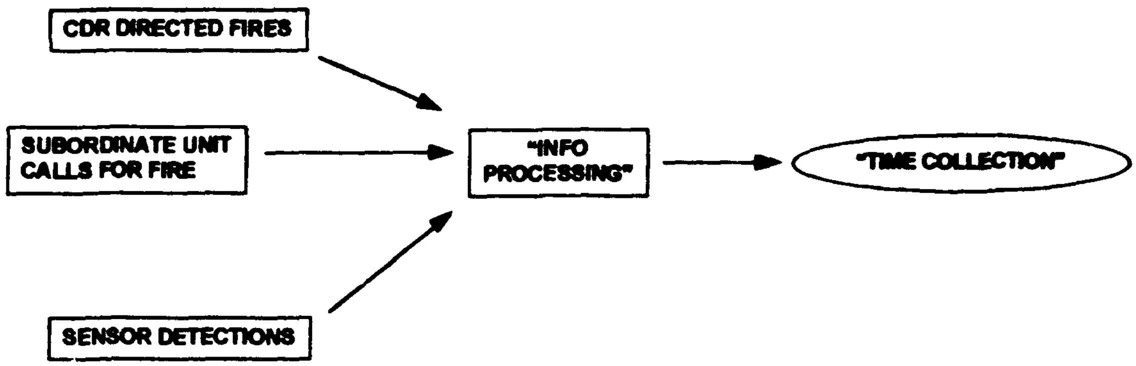
Each model captures the total time for reports and orders to transit the system (up or down). These times are captured for reports from each "source" where needed. For example, times for calls for fire to reach the fire support system are broken out into times for calls for fire from the scouts, from subordinate units, and from GSR detections. This feature permits the needed fidelity in determining fire support delay times based on the source of the enemy detection. In the case of orders generated by a commander, the time captured is for the "triggering" entity to enter the system, reach the commander, and for the commander's order to exit the system.

CSM OUTPUT ANALYSIS

Output from each of the model runs was reviewed for insight into the differences between voice and digital battle command systems. Although the specific results are different for each scenario due to the differing force structures and missions, general trends have been observed. See Appendix C for a full discussion. In summary, the observed trends are:

- Digital battle command saves time in moving information within and between units. The advantage in time increases for larger units (battalion/brigade), and for complicated procedures (call for fire, requests for attack helicopters).

- Units can react more swiftly to battlefield events with digital battle command.



MODEL COLLECTS THE TIME FOR CALLS FOR FIRE TO REACH THE FIST/FSO/FSE FROM VARIOUS SOURCES

TRANSMISSION AND PROCESSING TIME WITHIN TACFIRE/AFATDS NOT INCLUDED IN REPORTED TRANSIT TIMES

Figure 11. Fire Support Nodes

- Radio net utilization drops slightly when using digital battle command, yet much more information is passed.

- Leaders (particularly battalion and brigade staffs) experience dramatic increases in the amount of information requiring processing.

- Information sent using digital systems is "newer" (and more accurate) than voice delivered information.

CONSTRUCTING UNIT REACTION TIMES

MODEL/SCENARIO PREPARATION

The first step in performing the analysis was to perform an initial examination of the scenario. Each scenario was played without time delays, in order to develop the scenario (work out the "bugs") and to identify what key decision points would be for both blue and red commanders. For each of these key decision points, potential triggers were identified. For example, a counterattack might be launched once a company-sized enemy force crosses a certain phase line. This enemy force could be detected across the phase line by a scout platoon, or by an UAV within the scenario. Therefore, both the scout platoon and the UAV are designated as "triggers" for the decision to launch the counterattack.

In order to construct delay times for a given scenario, the Combat Synchronization Model must be "customized". This customization must reflect:

- The force structure and task organization used within the scenario.

- The input data used must be from a similar mission to what the unit in the scenario will be performing.

- Report generation must reflect the scenario. For example, only those units in contact with the enemy should be generating spot reports and calls for fire.

The company model was run for a sufficient length of time to develop statistically verifiable averages. Once the outputs were briefly analyzed, the appropriate company level information outputs were placed into the battalion level model. Platoon inputs used within the company model were used for the platoon size elements assigned to the battalion. After the battalion model was run, the results were analyzed to develop the information flow characteristics for each radio net. Finally, the brigade level model was utilized, using battalion, company, and platoon level inputs based on the size elements assigned to the brigade. Then the brigade model was run to develop the frequency and size of the brigade information output. A similar procedure was followed for the threat units portrayed in the simulation (the threat was assumed to only have voice command and control systems within this study).

INFORMATION FLOW TIME CONSTRUCTION

The information output of each C2 model was then reviewed in light of the critical paths information must follow. Using the example described above, the scout platoon or the UAV may serve as "triggers" for a counterattack. The critical path for the information from these systems to the decision authority for the counterattack must be laid out. Once this path is known, the expected time delays for that information to reach the decision authority, for the decision authority to make the decision, and for the appropriate orders to reach the counterattack unit are pulled form the output of the Combat Synchronization Model. This process must be followed for each relevant path of information flow. These times from each level of the network model, once consolidated together, represent a time-oriented description of unit decision cycles and reaction capabilities (see Figure 12).

TIME DELAY INTEGRATION INTO JANUS

As a final step, these time delays were utilized within Janus (A). They were either scripted in or provided to game players as mandatory delays prior to having units in the game react to changes in their situation.

JANUS SCENARIOS

The Janus (A) combat simulation was then run for current and future C2 systems. Four scenarios were gamed, using different terrain, threat, and mission combinations. In each scenario, the baseline blue maneuver force consisted of current C2 capabilities, M1A1 tanks, M2/M3 Bradley Fighting Vehicles and projected aviation, field artillery, and close air support capabilities. The digital alternative used the same force structure except for digital C2 capabilities and M1A2 tanks (sensitivity runs were conducted to ensure that the gaming results were not substantially affected by the presence of M1A2 tanks).

SOUTHWEST ASIA MEETING ENGAGEMENT (SWA)

SCENARIO OVERVIEW

In the SWA combat scenario (HRS 36) chosen for Janus (A), an enemy (red) motorized rifle regiment (180+ vehicles) moving northwest encounters a friendly (Blue) battalion/task force moving southeast. The Blue battalion/task force (which is moving in a two-up, two-back formation) attempts to bring its company/teams on line while laying artillery delivered minefields just ahead of the forward enemy battalions. The commander's intent is to destroy the forward enemy battalions by attacking them simultaneously with artillery, tank and missile fire, attack helicopters, and close air support. The supporting attack helicopter company and close air support aircraft relied on artillery and direct fires to "strip away" the enemy air defense during their attack. Figure 13 illustrates the basic scenario and highlights the reaction times used in each alternative.

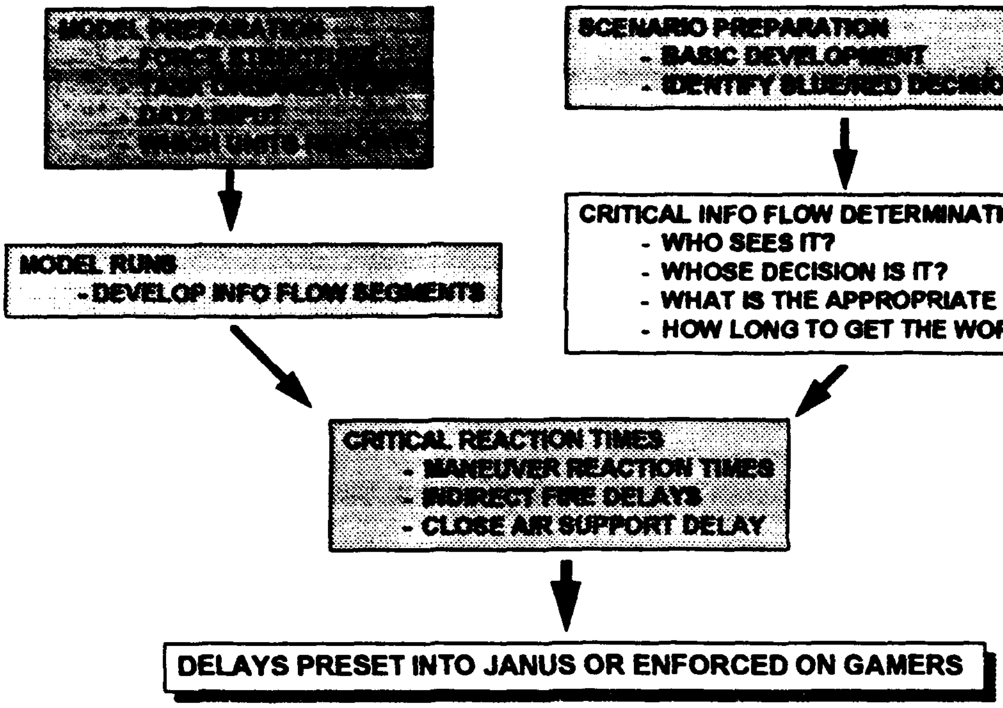


Figure 12. Construction of Unit Reaction/Delay Times

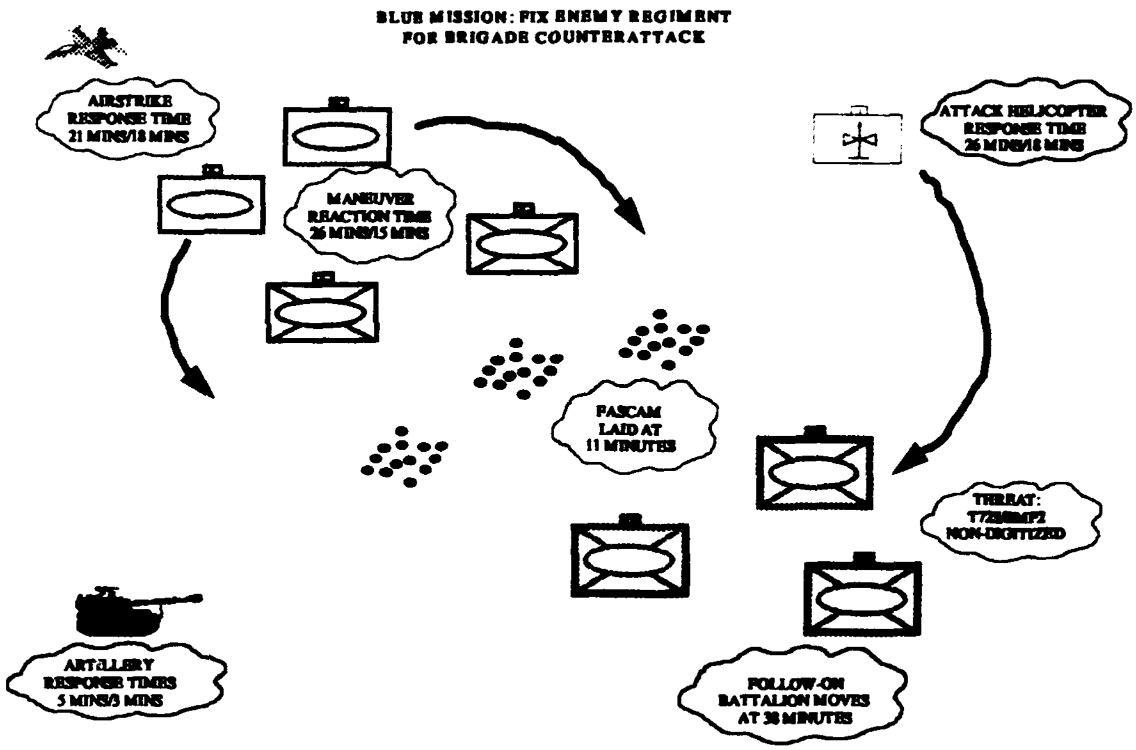


Figure 13. SWA Scenario (HRS 36)

As displayed in Figure 13, digital battle command offers significant time savings. Less time is needed to get the information to the battalion task force. The battalion task force, because of its better situational awareness, is able to make a faster decision. The resulting FRAGO is then rapidly transmitted by digital and voice means to the subordinate elements of the task force. As we shall see, this faster reaction allows much better synchronization and massing of forces.

In the basecase runs, the blue force is unable to move all of its company teams on line before the forward enemy battalions hit the FASCAM minefield (Figure 14). The forward company teams bear the brunt of the fighting until the rearward company teams can run forward. Although the enemy is usually halted, blue suffers heavy losses. In the digital case, the blue force is able to bring all the elements of available combat power together (Figure 15).

BATTLEFIELD COMPARISON (SWA-WEST)

Perhaps the best way to demonstrate the effect of digital battle command is to compare two identical moments in the battle, differing only in the reaction times permitted by digital systems, as opposed to current voice systems. The threat regiment has two forward battalions. Of these two, the western battalion hit the field artillery scatterable mines approximately 21 minutes into the scenario. Figure 16 depicts direct and indirect fires between red and blue forces for the 21 minute to 25 minute time frame, for each alternative within the analysis.

With non-digital communications, only one company/team is in position to engage the enemy in the minefield. The second company/team is still "processing" its fragmentary order to move, and will not begin to move until after the time period shown on the slide. During this critical four minute period (in addition to the company/team's fires), an airstrike has arrived, one NLOS missile, and 35 rounds of artillery/mortar fire impact on the enemy battalion. Invariably, the sole forward company team is decimated (reduced to less than 35% strength), and the following company/team eventually comes forward to complete defeat of this enemy battalion (by the 38 minute mark).

When the battalion/task force has digital battle command, the time savings in information/orders processing and transmission permits earlier movement of company/teams. In this case, both company teams are in position as the enemy battalion hits the minefield. In addition, the air strike, six NLOS missiles, and 80 rounds of artillery/mortar fire hit this enemy battalion in the same five minute period. As a result, the enemy battalion is defeated by the 26 minute mark within the scenario.

BATTLEFIELD COMPARISON (SWA-EAST)

The eastern battalion hit the field artillery scatterable mines approximately 28 minutes into the scenario. Figure 17 depicts direct and indirect fires between red and blue forces for the 28 minute to 32 minute time frame, for each alternative within the analysis.

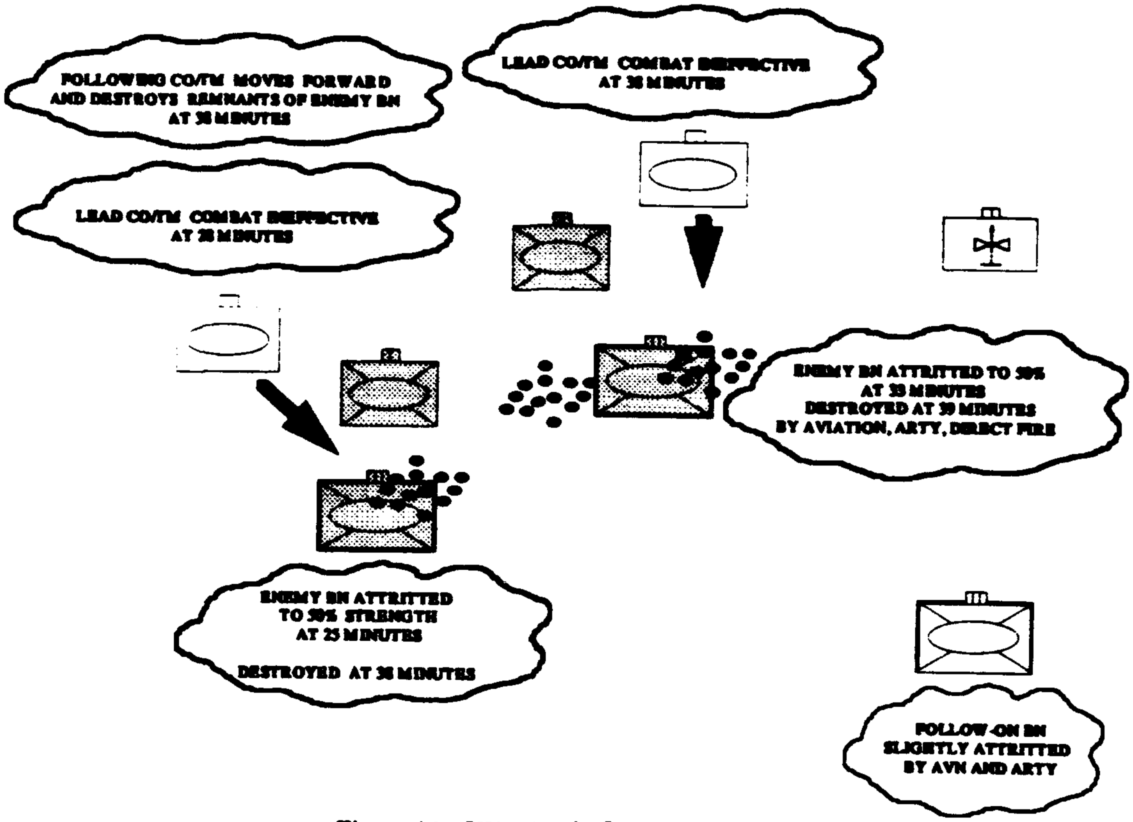


Figure 14. SWA Battle Outcome (Voice)

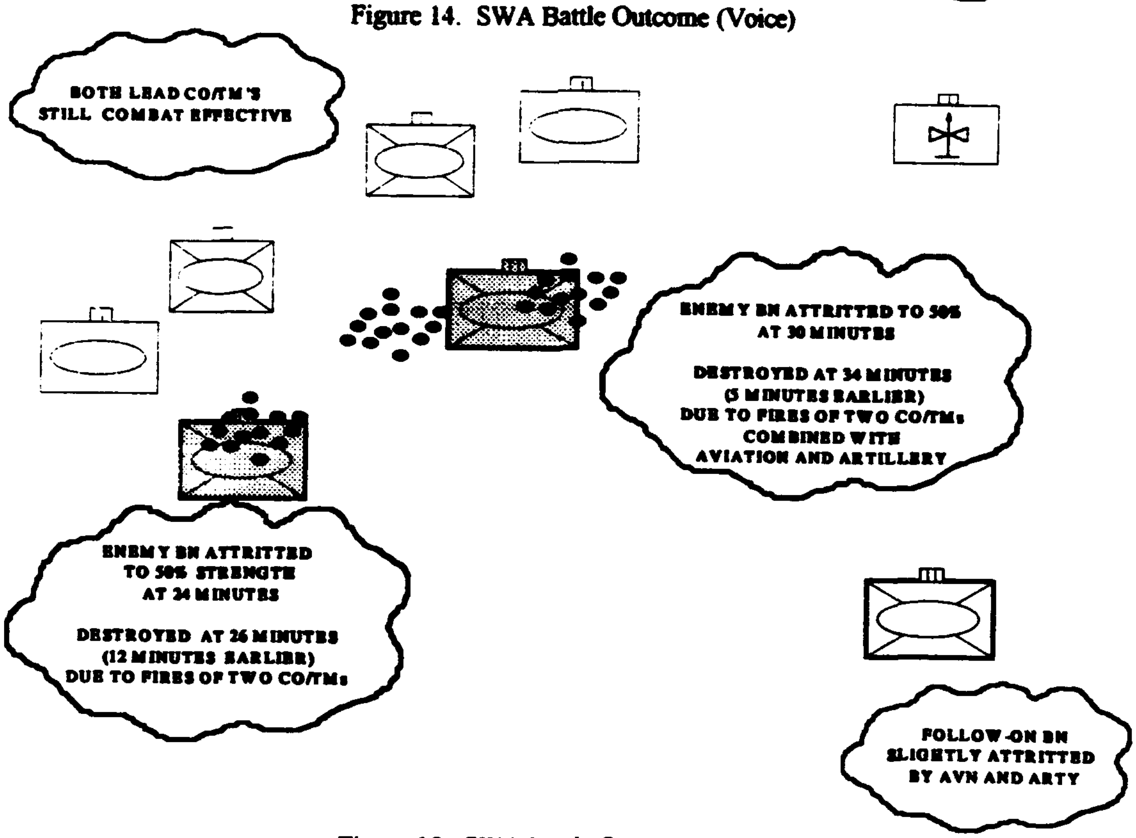
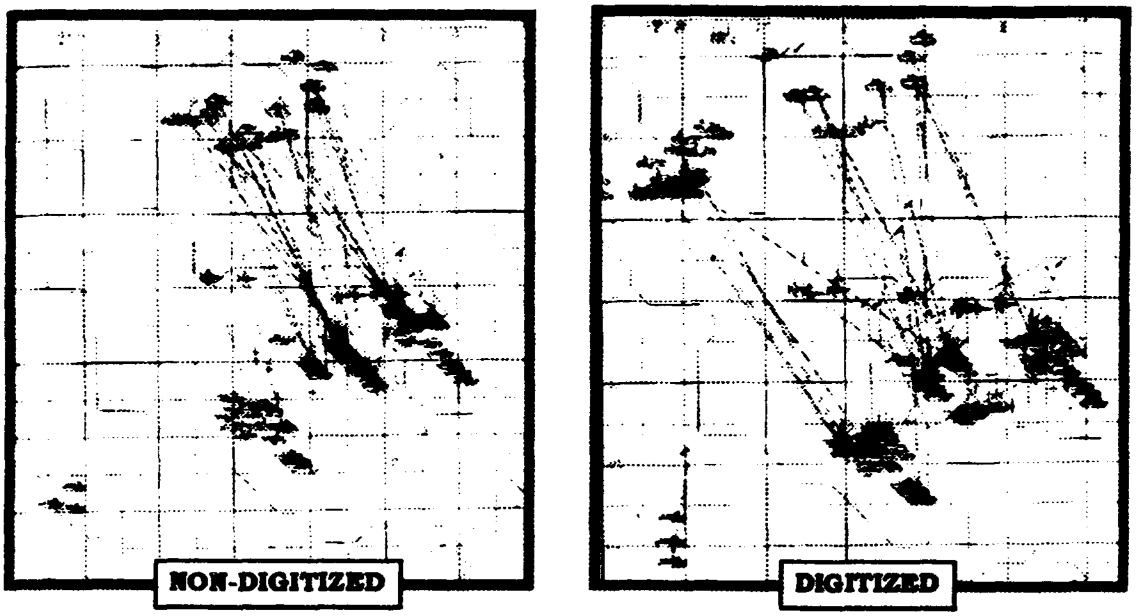


Figure 15. SWA Battle Outcome (Digital)

FORCES ENGAGED AGAINST WEST BATTALION
AS IT HIT MINES (21-25 MINUTES)

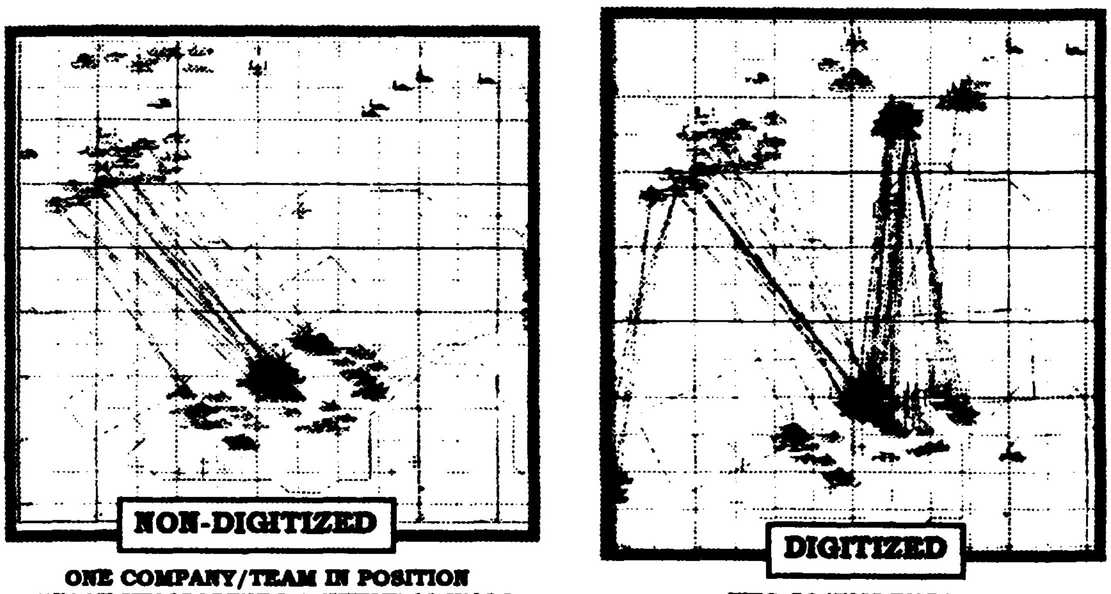


ONE COMPANY/TEAM ENGAGED
FOLLOW-ON COMPANY/TEAM
STILL ENROUTE

TWO COMPANY TEAMS ENGAGED
FOLLOW-ON COMPANY/TEAM
BEGAN MOVEMENT AT 15 MINUTES,
AVAILABLE AT THE CRITICAL TIME

Figure 16. SWA Battle Comparison (West)

FORCES ENGAGED AGAINST EAST BATTALION
AS IT HIT MINES (28-32 MINUTES)



ONE COMPANY/TEAM IN POSITION
ATTACK HELICOPTERS ACHIEVE 11 KILLS
LITTLE ARTILLERY INVOLVED

TWO CO/TMS ENGAGED
ATTACK HELICOPTERS ACHIEVE 18 KILLS
IMMEDIATE, ACCURATE ARTILLERY

Figure 17. SWA Battle Comparison (East)

With non-digital communications, only one company/team is in position to engage the enemy in the minefield. The second company/team is enroute, but is not yet in position to flank the enemy battalion. During this critical four minute period (in addition to the company/team's fires), the attack helicopter company has just arrived, and 44 rounds of artillery/mortar fire impact on the enemy battalion. Invariably, the sole forward company team is decimated (reduced to less than 35% strength), and the following company/team eventually comes forward to complete defeat of this enemy battalion (by the 39 minute mark).

When the battalion/task force has digital battle command, the time savings in information/orders processing and transmission permits earlier movement of company/teams. In this case, both company teams are in position as the enemy battalion hits the minefield. In addition, the attack helicopter company arrived eight minutes earlier, and has already seriously damaged the flank of the enemy battalion. 59 rounds of artillery/mortar fire hit this enemy battalion in the same five minute period. As a result, the enemy battalion is defeated by the 34 minute mark within the scenario.

CUMULATIVE RED LOSSES

Figure 18 depicts cumulative red losses over time. Clearly, the ability to bring forces together sooner resulted in faster attrition of the enemy, and a shorter time to mission accomplishment. Digital battle command resulted in more rounds (both direct and indirect) fired at the two enemy battalions. Overall, digital battle command resulted in 7% more indirect rounds and 19% more direct fire rounds impacting on each battalion (within a shorter time frame). The greater number of indirect rounds fired stemmed largely from the shorter response time for indirect fires made possible by digital battle command. Also, greater blue survivability meant more platforms were available to call for fire. The greater quantity of direct fire stemmed from the greater number of blue systems that got into the fight earlier, and survived longer due to the better "local force ratios". As a result, more rounds were fired.

The ability to bring artillery to bear faster also benefited the battalion/task force. Artillery effectiveness more than doubled (8 kills in the basecase, 20 kills in the digitized case). The earlier employment of attack helicopters also improved system effectiveness support attack (11 kills in the basecase, 18 kills in the digitized case). These improvements helped add to the greater success of the blue forces during the battle. Direct fire systems such as tanks and infantry fighting vehicles saw little or no improvement, caused by the exhaustion of available targets. Since far more blue direct fire systems survived, they were capable of inflicting much more damage on the enemy. The table below shows digitized battle command's overall effect on major systems. The improved performance of the artillery and aviation further improves the ratio of blue to red systems at the critical portions of the battle, resulting in improved survivability for all blue systems.

SYSTEM:	TANKS	BRADLEYS	ARTILLERY	ATK HELO
AVG KILLS (VOICE C2)	30.6	36.6	8	11.2
AVG KILLS (DIGITAL)	29	35.5	20	18.67

Table 3. Effect of Digital Battle Command on System Kills

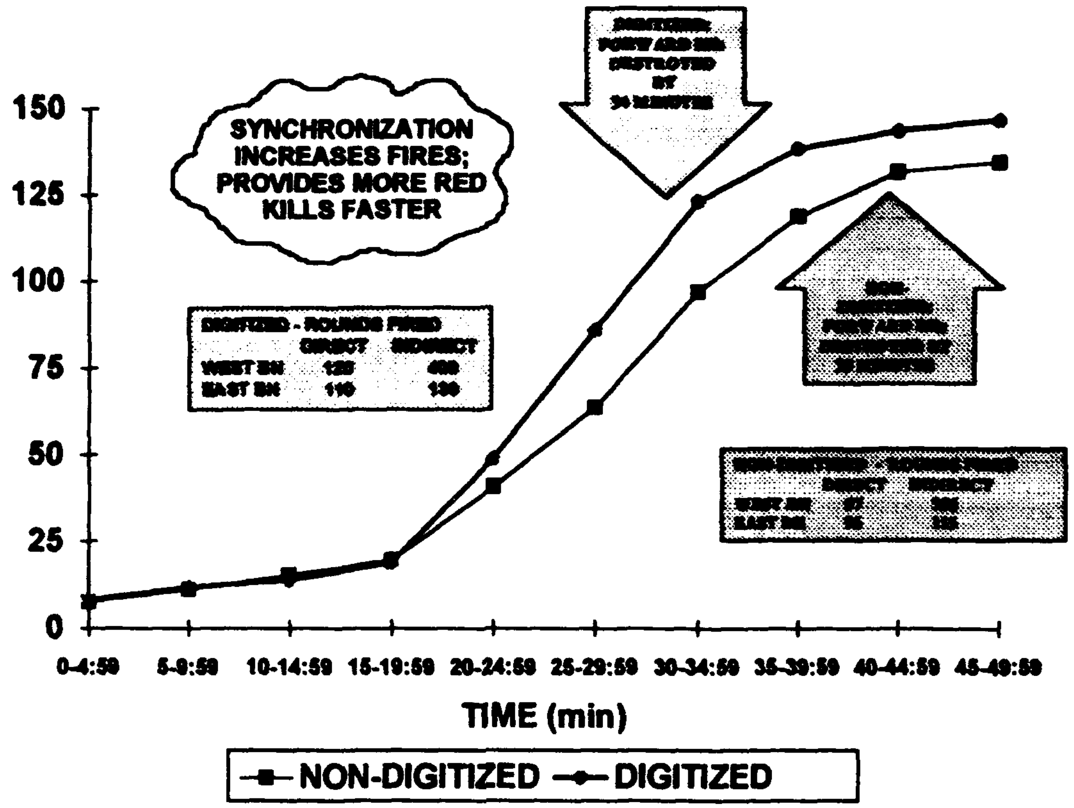


Figure 18. Cumulative Red Losses Over Time

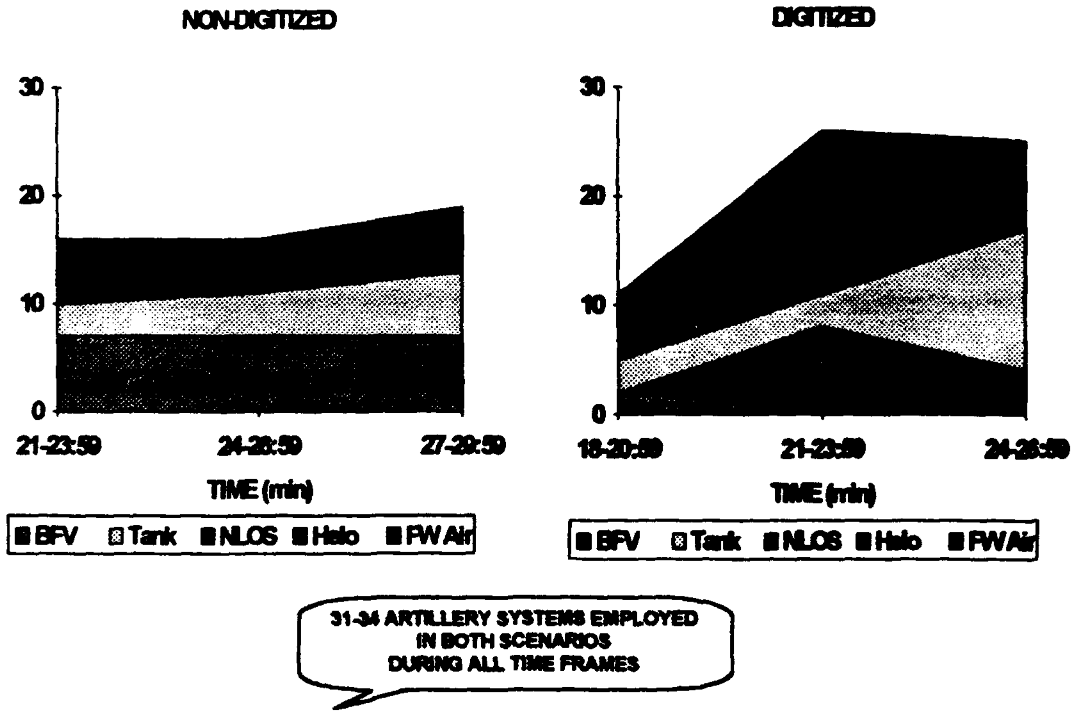


Figure 19. Systems Engaging Enemy Over Time

SYNCHRONIZATION COMPARISON

By comparing the numbers of systems involved in the battle over time, it can be seen that digital battle command permitted the commander to more rapidly mass his combat power (Figure 19). In fact, with only voice communications, the commander was unable to attain as great a massing of systems, as the enemy was destroying his systems nearly as fast as they got into the battle. It was the early massing of systems and fires that resulted in the rapid defeat of his forward two battalions.

It should be pointed out that the success seen by Blue in the digitized case resulted by rapidly achieving a large concentration of systems at the critical points on the battlefield (as chosen by the Blue commander). Simply rushing pell-mell into the battle would only result in a swifter conclusion to the battle, but not necessarily a favorable one. Success comes from not only getting into the fight earlier, but from combining all available assets together optimally at the critical point. The goal, in a sense, is the creation of favorable force ratios at the points of the commander's choosing. Digital battle command allows a commander to sooner sense the enemy's intentions and moments of weakness ("trigger points"), and to determine when to achieve these ratios (and at which locations). It also permits him to get his orders out more quickly and accurately, and assists his systems in getting where they are needed on shorter notice.

EUROPE FLANK GUARD

SCENARIO OVERVIEW

The next scenario gamed was a derivative of HRS 32. This scenario depicts a regimental cavalry squadron conducting a flank guard for a corps (Figure 20). In the portion of the scenario modeled, an armored cavalry troop is established in a screen along a major north-south flowing river in eastern Europe. An attack helicopter company and the squadron's tank company are available in reserve. The mission of the cavalry troop is to destroy the enemy's reconnaissance elements and combat reconnaissance patrols, then delay the forward security elements as long as possible without becoming decisively engaged. The cavalry troop is to fall back into a prepared battle position, where attacks by the attack helicopter company and tank company will destroy the main body of the enemy advance guards. Artillery and close air support are in support. For this scenario, mission success was defined as reducing the two enemy battalions to 35% strength or less prior to their crossing the rear guard line. It was judged that company-sized enemy forces (or greater) penetrating the corps flank was unacceptable to the corps commander.

The threat consists of two advance guard battalions, which attempt to drive through the cavalry troop and other blue assets to reach the corps flank. The battalion main bodies have deployed reconnaissance elements, combat reconnaissance patrols, and forward security elements as part of their march formation.

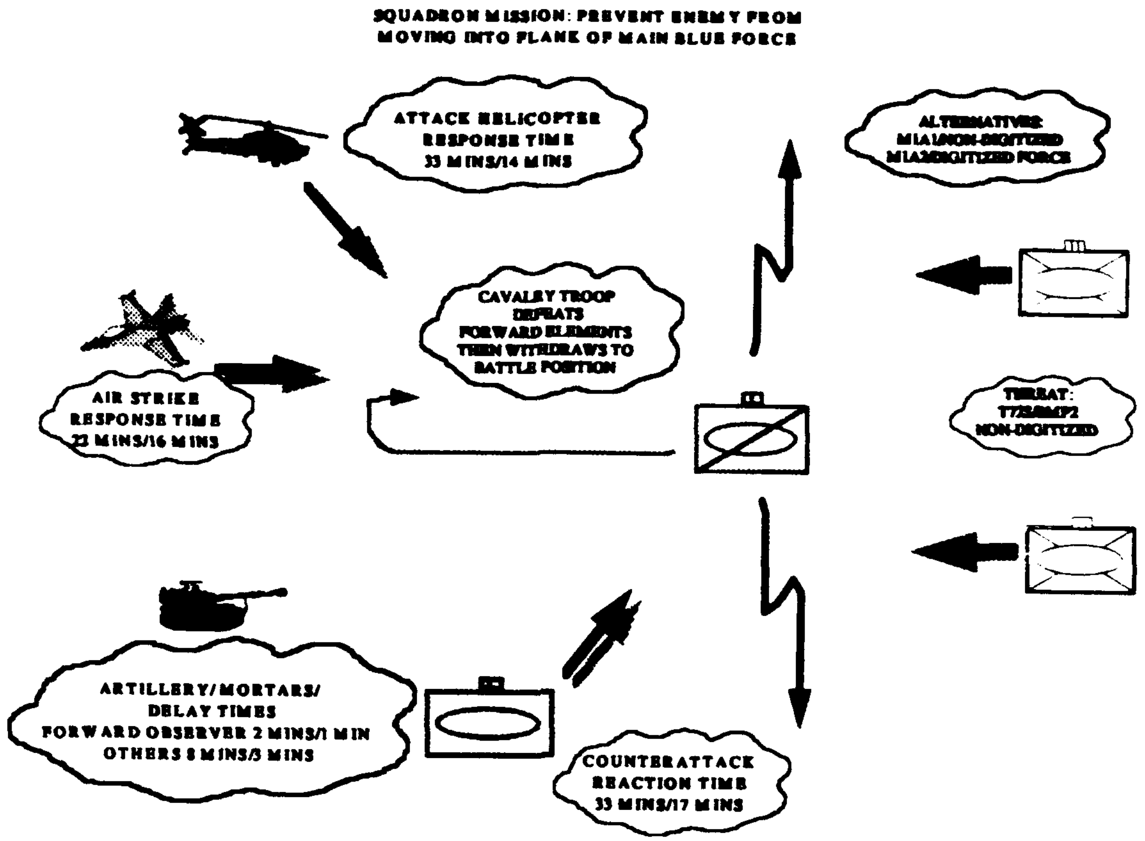


Figure 20. Eastern European Scenario (HRS 32)

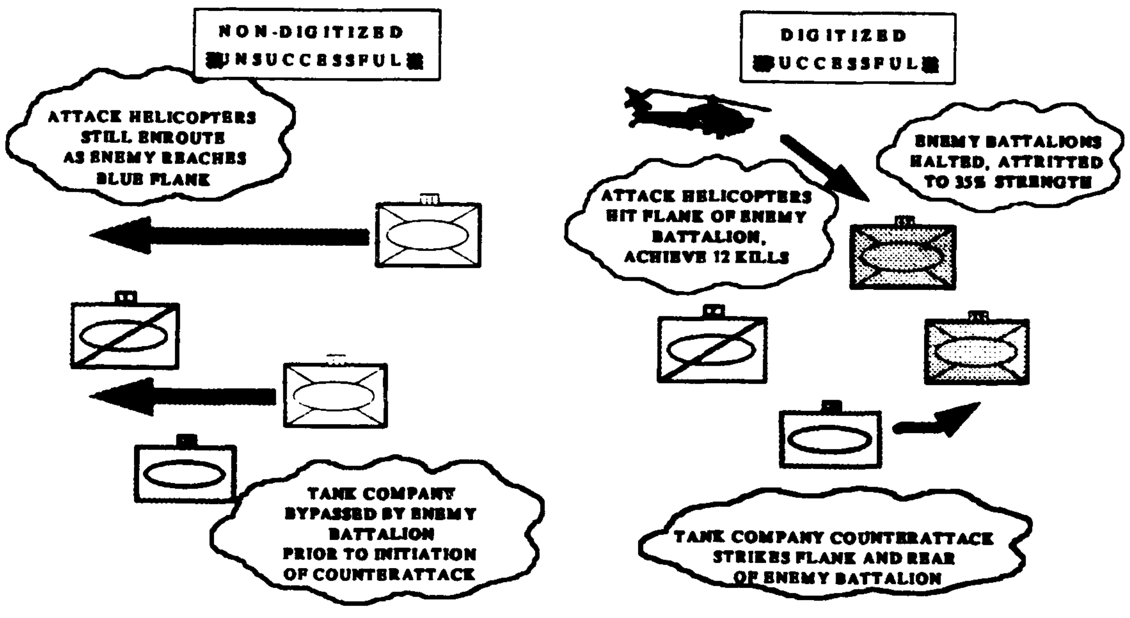


Figure 21. Europe Scenario Battle Outcome

EUROPE BATTLE OUTCOME

Figure 21 shows that blue forces could not accomplish the mission using voice battle command. The sector assigned to the cavalry squadron was shallow, and did not allow much warning time for the blue units to attack. Although the cavalry troop is able to destroy the forward enemy elements, the supporting attack helicopters and tank company cannot be brought into the fight quickly enough to halt the enemy's main body before it moves into the corps flank.

With digital battle command, blue is able to employ all of its assets in time to engage the enemy forces with the cavalry squadron's sector. Blue has a total of 47 direct fire systems in the fight, opposed to only 25 in the basecase (an 88% improvement). As a result, the enemy forces are halted with great losses. The loss exchange ratio improved 40% over the basecase.

HRS 32 RESULTS	RED LOSSES	BLUE LOSSES	LER
VOICE C2	45	16.4	2.74
DIGITAL BATTLE CMD	66.8	17.4	3.84

Table 4. Europe Scenario Effectiveness Comparison

NORTHEAST ASIA HASTY ATTACK (NEA)

SCENARIO OVERVIEW

An NEA scenario was then developed using Korea terrain. This scenario depicted a balanced blue battalion task force (two tank companies, two mechanized infantry companies), which was exploiting as part of a brigade attack (see Figure 22). The scenario involves the battalion task force encountering a strongpoint, bypassing it, and then seizing its assigned objective, which is lightly defended. At the 50 minute mark into the scenario, an organized red counterattack (battalion-sized) attempts to defeat the blue force while it is consolidating on the objective. Once detecting the enemy counterattack, the blue force must then react. Blue attack helicopters and close air support were available upon request.

NEA BATTLE OUTCOME

Voice battle command resulted in the blue force achieving its objective (Figure 23). However, the task force was still in the process of reorganization and consolidation when the enemy counterattack occurred. Reaction to the enemy strongpoint (to include bypassing it) was somewhat slow (due to the normal voice reporting and FRAGO procedures). By the time the enemy counterattack was on the move, the blue task force had just completed overrunning its objective. As a result, the task force was not well positioned for defense, (it had not yet completed reorganization and consolidation procedures) and suffered heavy casualties to two company/teams before the counterattack was defeated. Close air support did not arrive in time, and the supporting attack helicopters arrived in time to engage the remnants of the counterattack.

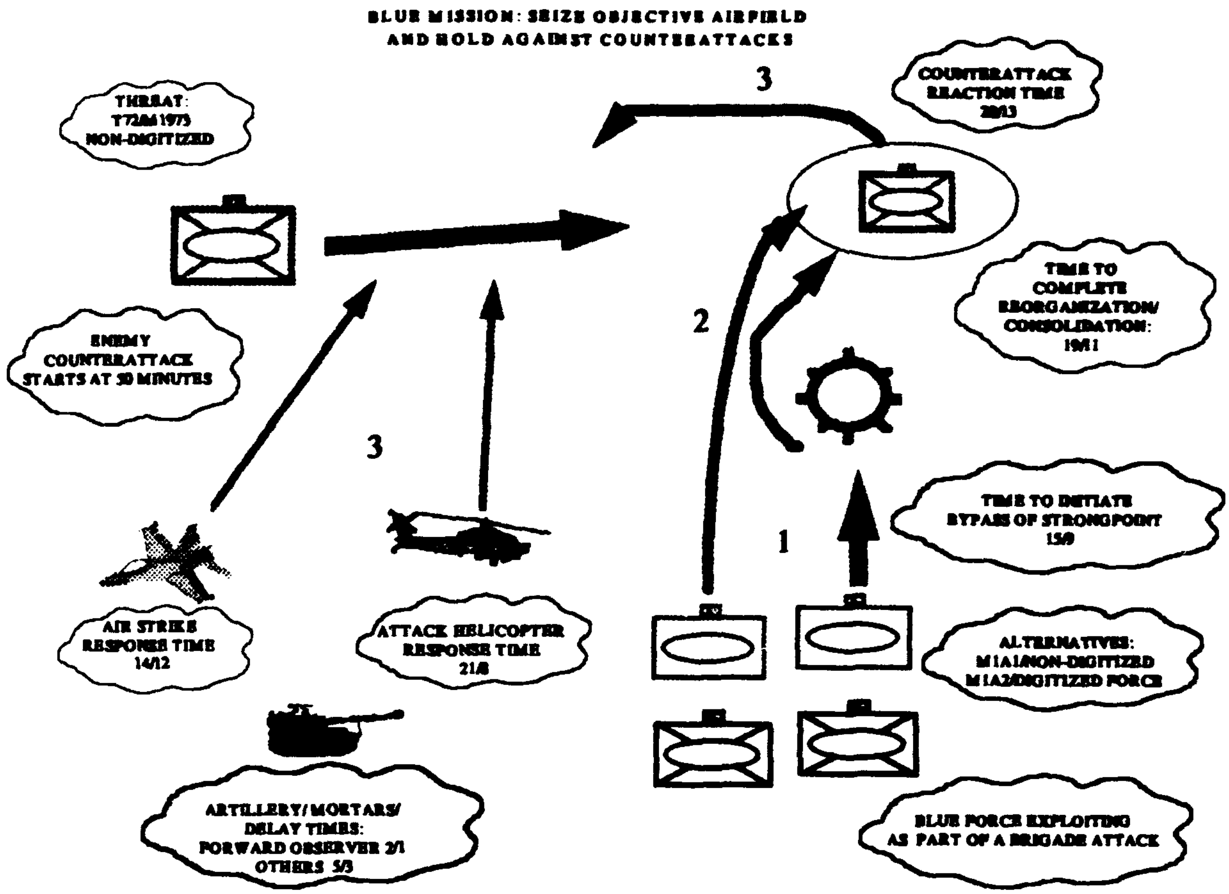


Figure 22. Northeast Asia Scenario

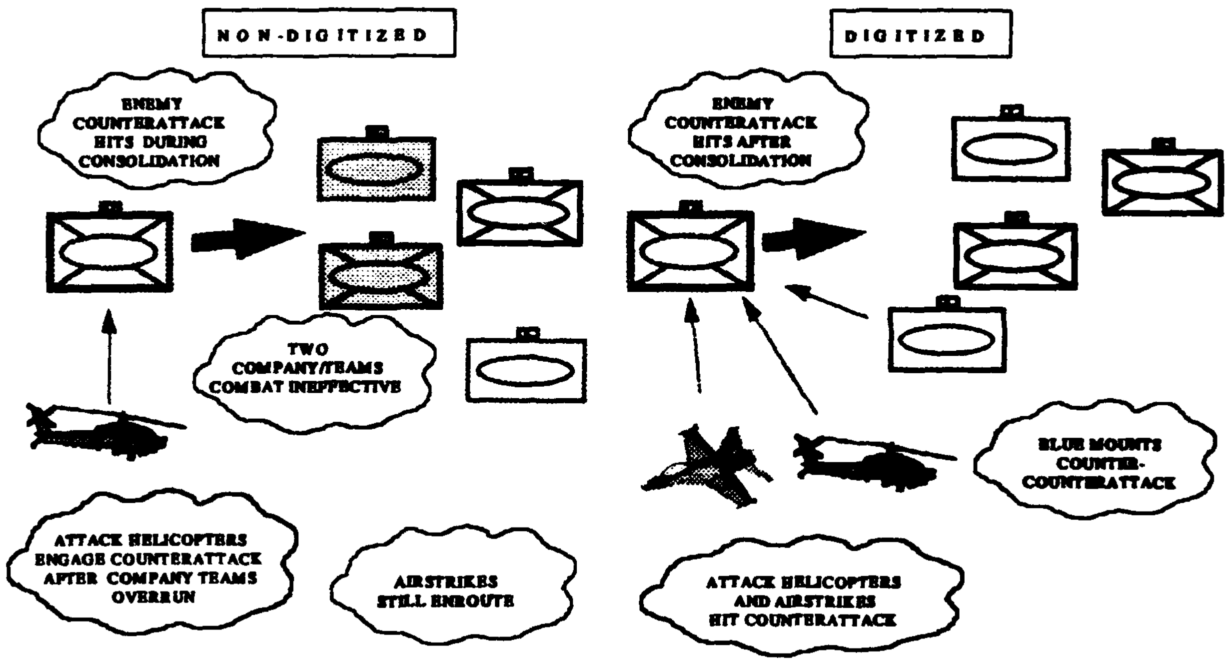


Figure 23. Northeast Asia Scenario Outcome

With digital battle command, blue was able to attain a faster tempo of operations. The enemy strongpoint was bypassed more rapidly, the objective was captured sooner, and reorganization/consolidation was completed sooner. The enemy counterattack struck a unit prepared and positioned for defense against a counterattack. Attack helicopters and close air support were successfully employed. Again, the enemy forces were halted without significant loss to blue forces. The loss exchange ratio improved dramatically over the basecase.

NEA RESULTS	RED LOSSES	BLUE LOSSES	LER
VOICE C2	41.6	25.8	1.61
DIGITAL BTL CMD	47.2	14.8	3.18

Table 5. NEA Scenario Effectiveness Comparison

This scenario indicates the cumulative effect of time savings during the scenario. The digitized task force was able to begin the bypass of the enemy strongpoint six minutes earlier than the basecase unit. This led to an earlier seizing of the objective, followed by a faster reorganization and consolidation. By the time the enemy counterattack was detected, the digital battle command task force was executing actions up to 17 minutes faster than its voice battle command counterpart. In effect, the digitized force was executing three decision cycles to the enemy's one.

BOSNIA QUICK REACTION FORCE

SCENARIO OVERVIEW

A Bosnia scenario was also developed, to assess the impact of the severe terrain encountered in that section of the world (Figure 24). In this scenario, a red force conducts a dismounted attack against a United Nations outpost overwatching key avenues of approach. Shortly after the dismounted attack goes in, two reinforced motorized companies bypass the outpost and attempt to establish a blocking position on key terrain beyond the outpost. This blocking position is designed to prevent relief of the UN outpost. Irregular forces are also positioned to delay or halt any Blue reaction forces. Blue has two company/teams (one tank heavy, one infantry heavy) available as a quick reaction force. Blue attack helicopters and close air support were also available if requested. Blue's mission is to halt the enveloping force and re-establish contact with the outpost.

BOSNIA BATTLE OUTCOME

Voice battle command resulted in the blue quick reaction force (QRF) moving after the enemy had established its blocking positions (Figure 25). This was due to the greater delay in getting the request for help to the local area headquarters, and for the appropriate headquarters to issue the necessary FRAGO. After briefly executing troop leading procedures, the quick reaction force moved out. Because of the time involved, both elements of the QRF were attacked by irregulars at about the same time they were taken under fire by the red blocking force (which had already reached its assigned objectives). The quick reaction force was halted, and prevented from accomplishing its mission.

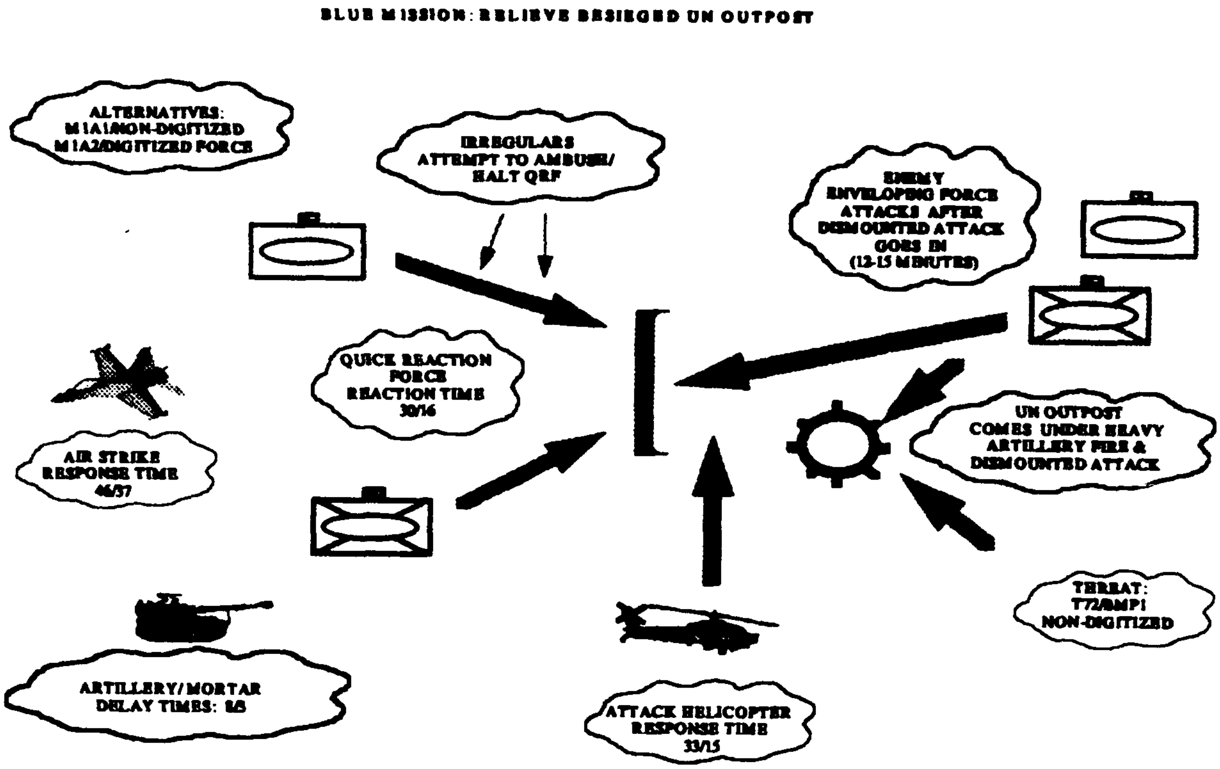


Figure 24. Bosnia Scenario

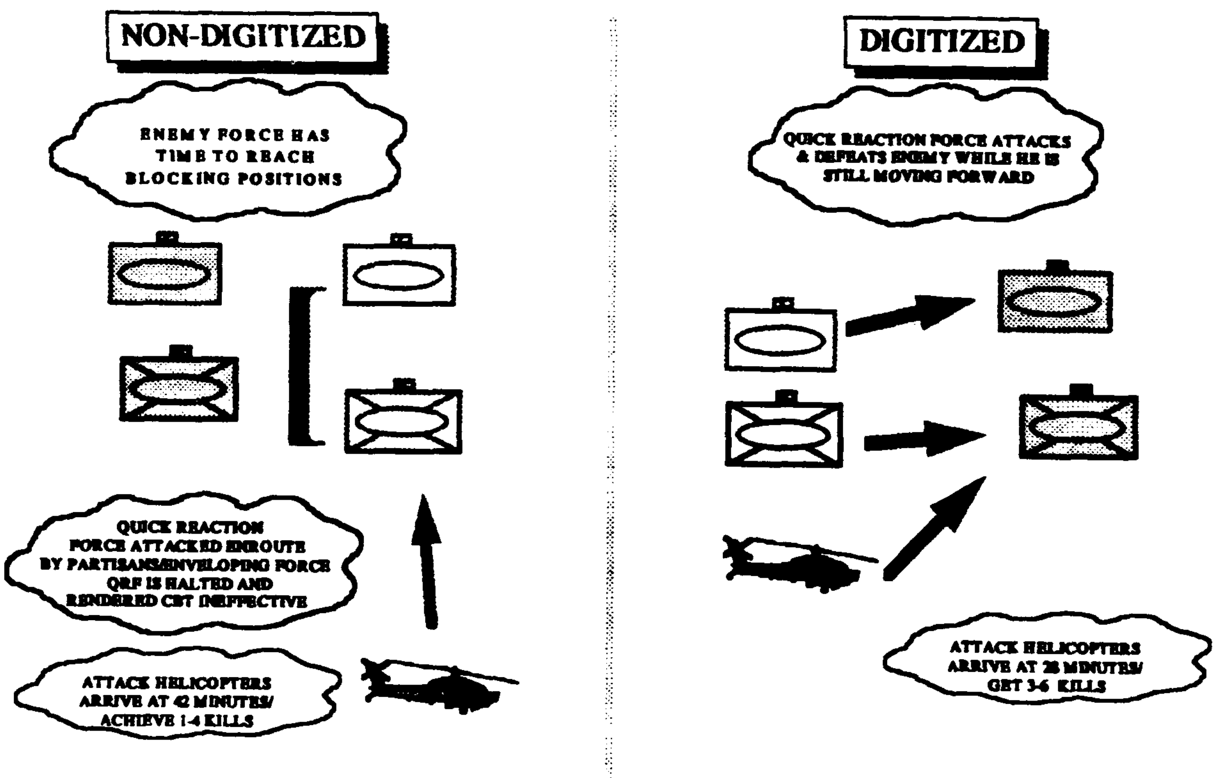


Figure 25. Bosnia Scenario Outcome

With digital battle command, notification of the attack and production of a FRAGO took less time. Blue forces were therefore able to begin movement much earlier. The enemy enveloping force was caught enroute to its objectives by the quick reaction force and supporting attack helicopters. The red enveloping force was defeated, and the quick reaction force was able to re-establish contact with the UN outpost. The loss exchange ratio showed a 37% improvement.

BOSNIA RESULTS	RED LOSSES	BLUE LOSSES	LER
VOICE C2	14.4	17.8	0.81
DIGITAL BTL CMD	23.4	21	1.11

Table 6. Bosnia Scenario Effectiveness Comparison

Improved reaction times meant that Blue was able to fight enemy formations while they were on the move, as opposed to fighting them from hasty positions. Blue was also able to engage the enemy forces with both attack helicopters and ground systems. In the basecase, this synergism did not occur. This improved utilization of supporting weapons helped improve Blue's chances of mission success.

CONCLUSIONS

Digital battle command offers the commander increased flexibility on the battlefield. This stems from his improved ability to communicate with his subordinates, better situational awareness, and increased speed/accuracy of movement. Automated systems additionally offer the potential to keep the staff (and all battlefield operating systems) apprised of the situation. This capability offers an improved ability to react in a timely fashion to a rapidly changing situation on the battlefield. The revised "scheme of maneuver" can be swiftly and accurately transmitted to all key leaders. In essence, units can expect to conduct "deliberate" operations within a time frame that previously would have required "hasty" planning and execution. These reduced decision cycles lead to increased tempo, improved lethality, and better survivability.

Time is a critical element on the modern battlefield. This is readily demonstrated historically, and within the four Janus scenarios described in this analysis. A time savings of a few minutes can have a dramatic effect on the outcome of the battle. Digital battle command offers commanders this ability to create favorable battlefield conditions on short notice, which can have a cumulative effect on the tempo of the battle. Proper synchronization can be more easily achieved, with improvements in lethality and survivability for all participating weapons systems. Efforts to control the tempo of enemy operations take on greater significance, because they widen the time gap between our ability to act and the enemy's ability to act. Better combat effectiveness results from this ability to pass information, share a common view of the battlefield among units, and create favorable battlefield situations.

This area of research is hampered by the comparatively limited amount of data on tactical information flow within combat units. The more refined and detailed the available data, the more exact future analysis can become. Yet, this potential can be demonstrated using a network model to bridge the gap between data for information flow within small units, and the time delay inputs needed for analysis of larger units and battlefield operating system synchronization within constructive combat simulations. The outputs of a network model also help quantify the advantages of digital C2 systems. The outcome of the network model and battle field scenarios reinforce findings of previous work concerning digitized systems.

There are many areas for future research suggested by this research effort. The methodology suggested herein should be further explored for analysis of different battle command systems, and also for future combat systems. Further effort should be applied to embed C2 models into combat simulation models, to provide a more refined approach to combat simulation and analysis.

In addition, part of the decision cycle is the time needed to develop an accurate picture of the enemy situation. Further analysis needs to be done on the effect of reconnaissance systems and organizations on shortening the decision cycle. Other analysis should be performed to examine ways to make our battle command systems less vulnerable to attack, and to determine the effect of our attacks on the enemy battle command structure.

Additional analysis will need to be performed concerning requirements for battle command systems, and assessing communications architecture/materiel development issues. Funds will probably not be available in the near term to permit 100% digitization across all battlefield operating systems. Some weapons systems will become digitized before others, and some units will have digital capability before others. Analysis will need to directed at these resourcing issues to determine the best purchases and payoffs for the Army in the future.

Digital battle command provides the capability for improved lethality, survivability, and tempo. This analysis indicates that our digitization efforts will allow us to achieve better execution of current doctrine. However, to truly take advantage of digital battle command, current tactics, techniques, and procedures (TTP) will need revision. The battle outcomes within the Janus scenarios show improvement using current TTP, yet lead to some insights concerning these digital TTP. Further work must look at the best TTP for a digital maneuver force.

Appendices:

A - References
B - Measures of Effectiveness/Performance
C - Network Analysis
D - Combat Synchronization Model Documentation

APPENDIX A: REFERENCES

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APPENDIX B: MEASURES OF EFFECTIVENESS/PERFORMANCE

"Militarily speaking, an hour is not sixty minutes, but that which can be accomplished in one hour" - J. F. C. Fuller

In the main report, the concept of the decision cycle is briefly covered. In review, a decision cycle can be considered to consist of four sequential steps: observation, orientation, decision, and action. Within tactical units, information flow between units and leaders is essential to permit these steps to be accomplished. Each of these steps has a time element, and the quality of each is affected by the quality and quantity of information available. Measures of effectiveness and performance were developed for each of the four pieces of the decision cycle (as well as information flow).

The crucial first step of the decision cycle is observation, "seeing" the battlefield. Proper decisions cannot be made unless good reconnaissance has occurred, and observation is maintained of enemy forces. Time can be lost waiting until a better picture of enemy intentions unfolds. Conversely, it is beneficial to deny the enemy such information concerning friendly forces. Once the enemy is detected, this information has to be rapidly forwarded. Measures of performance applicable include:

- Time and range at which threat systems are detected.

- Time to report detections to higher headquarters.

- Total percent of threat force detected over time. This can be calculated as a cumulative percentage, or considered at discrete points in time (at twelve minutes into the battle, only XX % of the enemy force was detected).

- Total detections of enemy forces by friendly scout/reconnaissance assets over time.

- Total friendly scout/reconnaissance assets lost over time.

- Artillery missions generated by friendly scout/reconnaissance assets.

- Enemy artillery losses from artillery missions generated by friendly scout/reconnaissance assets.

- Time and range at which friendly systems are detected by enemy systems.

- Total percent of friendly force detected by enemy systems over time. This can be calculated as a cumulative percentage, or considered at discrete points in time (at twelve minutes into the battle, only XX % of the friendly force was detected).

- Total detections of friendly forces by enemy scout/reconnaissance assets over time.

- Total enemy scout/reconnaissance assets lost over time.

- Artillery missions generated by enemy scout/reconnaissance assets.

- Friendly artillery losses from artillery missions generated by enemy scout/reconnaissance assets.

Available detections and intelligence of enemy actions must be placed within the context of the friendly force situation. Only then can good decisions be made. The more complete, accurate, and recent the friendly force information, the faster a decision can be made. If friendly force information is not available, time can be lost attempting to gain that information prior to making a decision. Decisions based on an incomplete picture of friendly forces can result in fratricide, and excessive losses due to inappropriate actions. Measures include:

- Percentage of own force known to unit commander (and staff) at discrete points in time.

- Average age of friendly force formation by the time information reaches the commander and his staff.

- Accuracy of friendly force information (unit tactical and logistical status, activity, current location, and timing of actions).

- Incidence of fratricide.

For leaders and staffs to make timely decisions, they must have a good decision making environment, with a minimum of distracters. Part of this is possession of timely, accurate enemy and friendly force information. In higher headquarters, a good decision making environment is derived from use of the staff to assist the commander. For leaders at brigade level and below, the decision making environment represents a challenge. Leading from a tank or Bradley, positioned far enough forward to observe the battle, places additional demands on a leader. Some time is spent directing the movement of the vehicle, observing the battlefield, engaging targets, and communicating to higher and lower units. As a result, leaders (or their staffs) cannot spend 100% of their time processing information and making decisions.

The press of events in combat often allows little time for information intake and decision making. The need, therefore, is for digital battle command systems that are user friendly, permit rapid assessment of the current situation, and require minimal operation time. Heads-up displays and wireless CVC's are both examples of such devices. Measures of performance include:

- Percent time leader spends navigating his own vehicle.

- Percent time leader conducts target acquisition.

- Percent time leader observes the battlefield (by use of optics, own senses, or digital battle command system).

- Percent time leader spends planning and decision making.

- Percent time leader reports and coordinates with higher headquarters.

- Percent time leader directs and coordinates with subordinate units.

- Percent time leader spends conducting lateral communication and coordination with sister units.

Time is the most critical element on the battlefield. Commanders strive to bring their combat power together at critical time and place, while simultaneously dissipating the enemy's combat power. These two efforts are meant to create overwhelming ratios of combat power (through massing of fires and forces) that defeat the enemy. The opportunities to achieve these results are fleeting. The measure of a battle command system is its ability to allow a unit to identify, create, and take advantage of these opportunities. Measures of effectiveness and performance include:

- Loss exchange ratio (LER).

- System exchange ratio (SER).

- Friendly losses over time (at discrete intervals or over time).

- Unit reaction time to FRAGO's or critical battlefield events.

- Mission and task execution time.

- Time required to br[illegible]g supporting weapon systems and units to bear.

- Weapons utilization rates. How many systems were involved in the battle? How often did they fire?

- Quantity (and percentage) of effective artillery missions.

- Volume of fires (direct and indirect) over time. This measure may be further broken out to capture the volume of fires directed at specific elements of the enemy force.

A battle command's handling of the flow of information is critical for the successful completion of decision cycles. Good information flow avoids bottlenecks, has minimal information transfer delay times, and minimizes the loss of information due to interference or obsolescence. Measures of performance include:

- Report transmission times (by type of report).

- Report processing time (by leader processing the information and by type of report).

- Transit time of information (from source to each destination). Also defined as age of information upon arrival at its destination.

- Radio net utilization rates.

- Leader/staff utilization rates (percent of time spent processing information).

- Message clarification or re transmission rate.

- Message loss rate (due to information overload, obsolescence, or interference).

- Quantity of messages passed across each radio net.

- Radio net loading over time.

APPENDIX C: NETWORK ANALYSIS

Output from each of the model runs was reviewed for insight into the differences between voice and digital battle command systems. Specific results for each run are different, due to differing missions, task organizations, quantity of units in contact with the enemy, etc. However, the same trends are observed with each run of the model. This appendix will compare data taken from various runs to show the comparisons of voice and digital battle command systems.

Digital battle command permits more messages to flow over radio nets. This is due to automatic updates, automated routing matrices, and greater ease in forwarding information. The shorter transmission times help to lower radio net utilization, yet the greater quantity of information increases the amount of time leaders must spend on processing information. Figures 1,2, and 3 illustrate the trends seen in leader and radio net utilization.

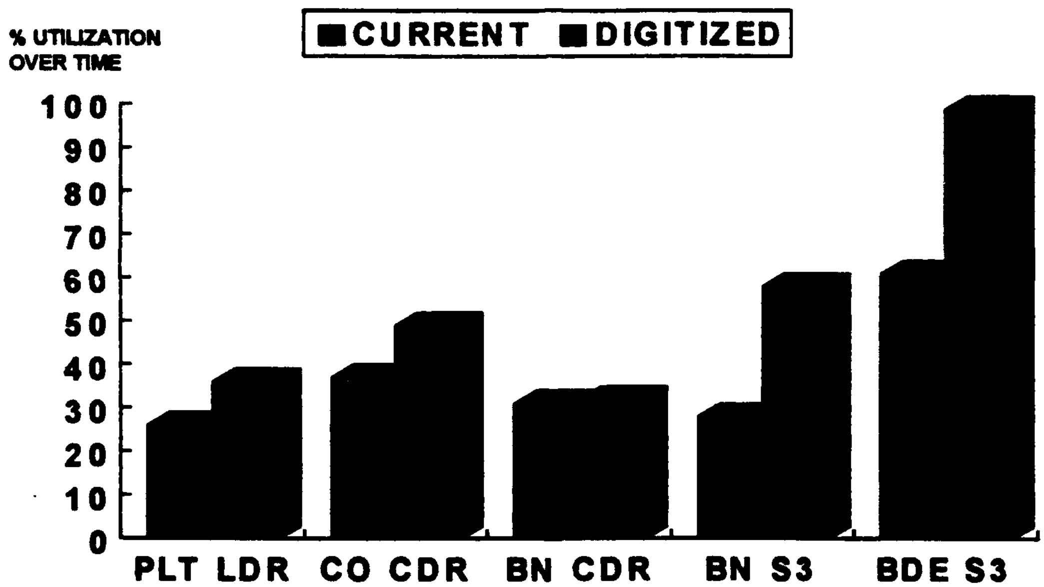

Figure 1. Key Leader Utilization Rates

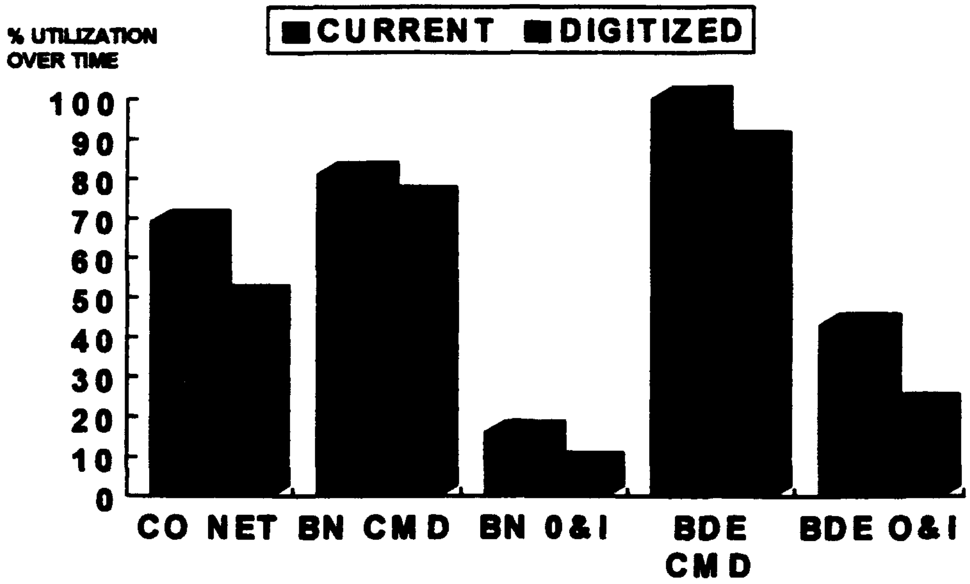

Figure 2. Radio Net Utilization Rates

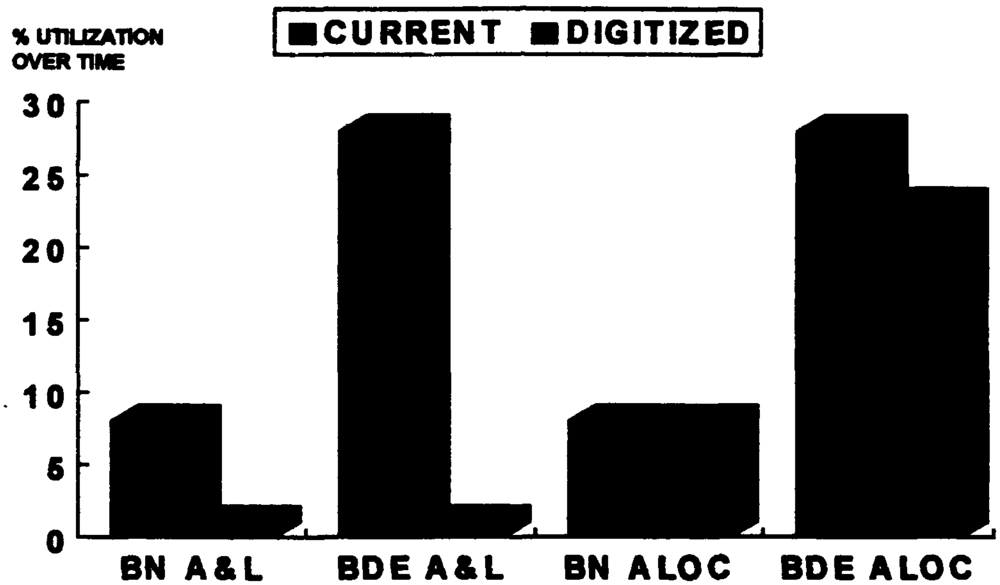

Figure 3. Admin/Logistics Radio Net and Facility Utilization Rates

These utilization rates can vary dramatically, based on the mission and level of activity of the unit. One critical variable is the number of subordinate elements in contact with the enemy at any certain time. The greater the level of enemy contact, the more reports and orders flow across the net. Leaders also find themselves with less time to process information. As a result, critical information can be delayed, ignored, or lost. Digital battle command systems are less vulnerable to this problem, but careful attention needs to be paid to the peak loads on the entire command and control system during periods of heavy contact. Battle command systems must be designed to minimize the time needed to process and forward critical information.

Digital battle command permits increased volumes of traffic. These increased volumes do not impose excessive delays. In fact, the shorter transmission times, shorter processing times, and higher clarity of information means that more information is transmitted in less elapsed time. Within each network model, "filters" were present which removed reports which had waited more than 10 minutes for transmission. Other filters removed reports which exceeded the queue capacity of the various leader and staff nodes. Figure 4 illustrates the results of one model run. Average messages sent per hour are compared to the average quantity of messages lost (obsolescent or exceeded queue length) per hour.

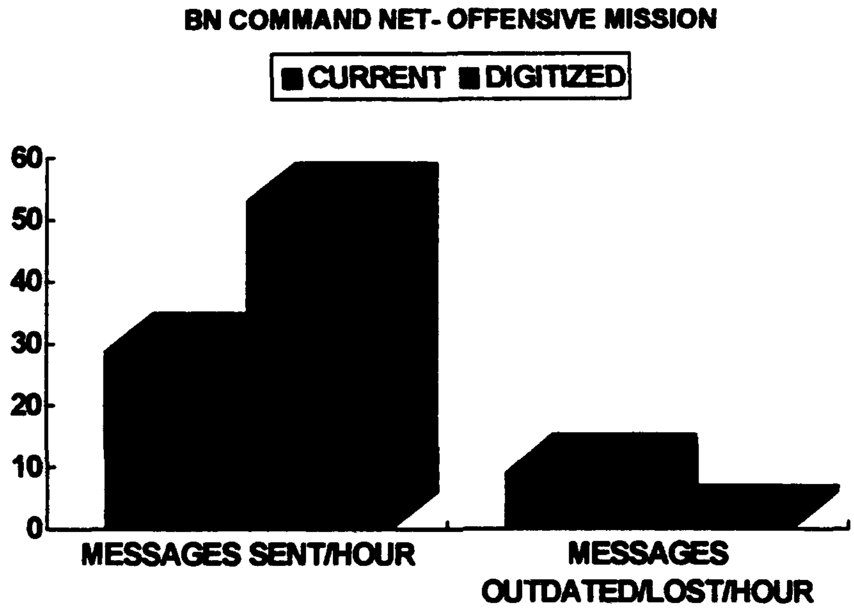

Figure 4. Messages Sent/Lost Per Hour

Digital battle command improves message transit time. Improved transmission and processing times allow units to report higher faster, and to react to orders faster. The results are better situational awareness, faster decision cycles, and better targeting. Figure 5 illustrates report and order transit times, as observed at the company level in one run.

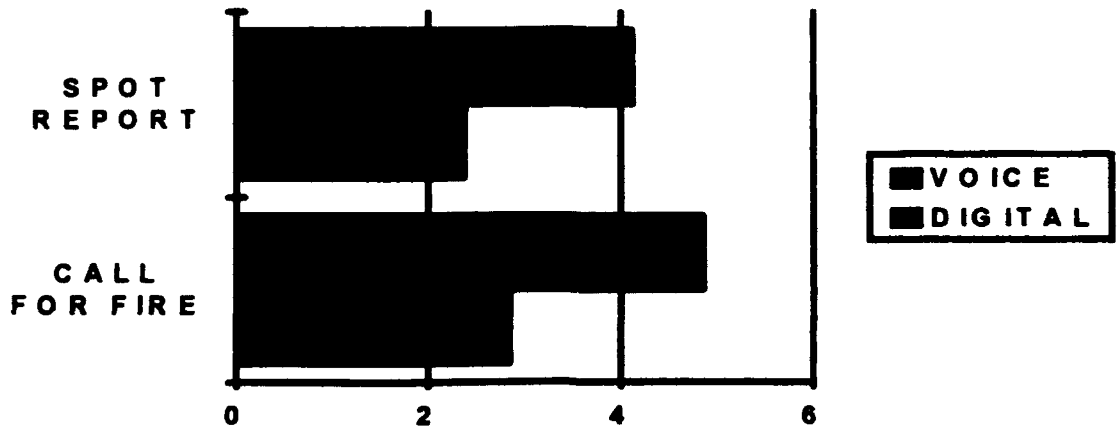

Figure 5. Company Report Transit Times (Up)

The data presented above clearly illustrates the advantages of a digital battle command system. In addition, changes in battle command system performance have been observed as part of external factors. For example, system performance improves as fewer elements are on the net. Also, time required for information to pass drops as the number of intermediate nodes decreases. This study focused on digitization of the current command and control architecture. Future battle command systems should be designed for passing information in the minimum time possible. The following observations can be made for future studies of battle command system architecture:

- Communication protocols which broadcast information simultaneously to several destinations are preferable to sequential transmissions of the same message. This concept may need to be expanded to permit the broadcast of the same message over different radio nets automatically. Care must also be taken to eliminate transfer of redundant information, which can provide a needless burden on the system.

- Key information routings need to have as few intermediate nodes as possible. For example, an observer's call for fire may need to be routed directly to a firing gun, with all the intermediate points (unit commanders, fire support officers, etc.) receiving information updates only.

- Battle command staffs should be provided the capability to work off of a common database, from which they can draw the needed information. This structure would avoid the current sequential passing of information between staff sections, and permit better parallel planning.

- Voice and data communications cause each other interference when transmitted on the same net. Although use of digital communication appears to lessen radio net utilization over time, the peak loads experienced during enemy contact can degrade both voice and radio communications. Future battle command architecture work should consider the use of separate voice and data radio nets to facilitate communications within the needed time frames.

APPENDIX D: COMBAT SYNCHRONIZATION MODEL DOCUMENTATION

The Simulation Language for Alternative Modeling (SLAM) was chosen to perform the actual simulation of the tactical information networks. SLAM is a combined discrete-continuous modeling language which simulates a system's state in small time steps, while changing entities within the system at discrete events (Pritsker, 1986). This language allows the modeling of the flow of reports and orders through the C2 network. SLAMSYSTEM Ver 2.1.1 (for Windows) was used to build the models described in this appendix.

SLAM documentation is attached for each level of the Combat Synchronization Model (company, battalion, and brigade). The control statement, network schematic, network statement, and note files are attached for each level. The inputs in the control and network statements reflect baseline command system inputs. Digital battle command models are identical in structure to the baseline models, differing only in their inputs (as described in the report).

```
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NETWORK;
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FIN;
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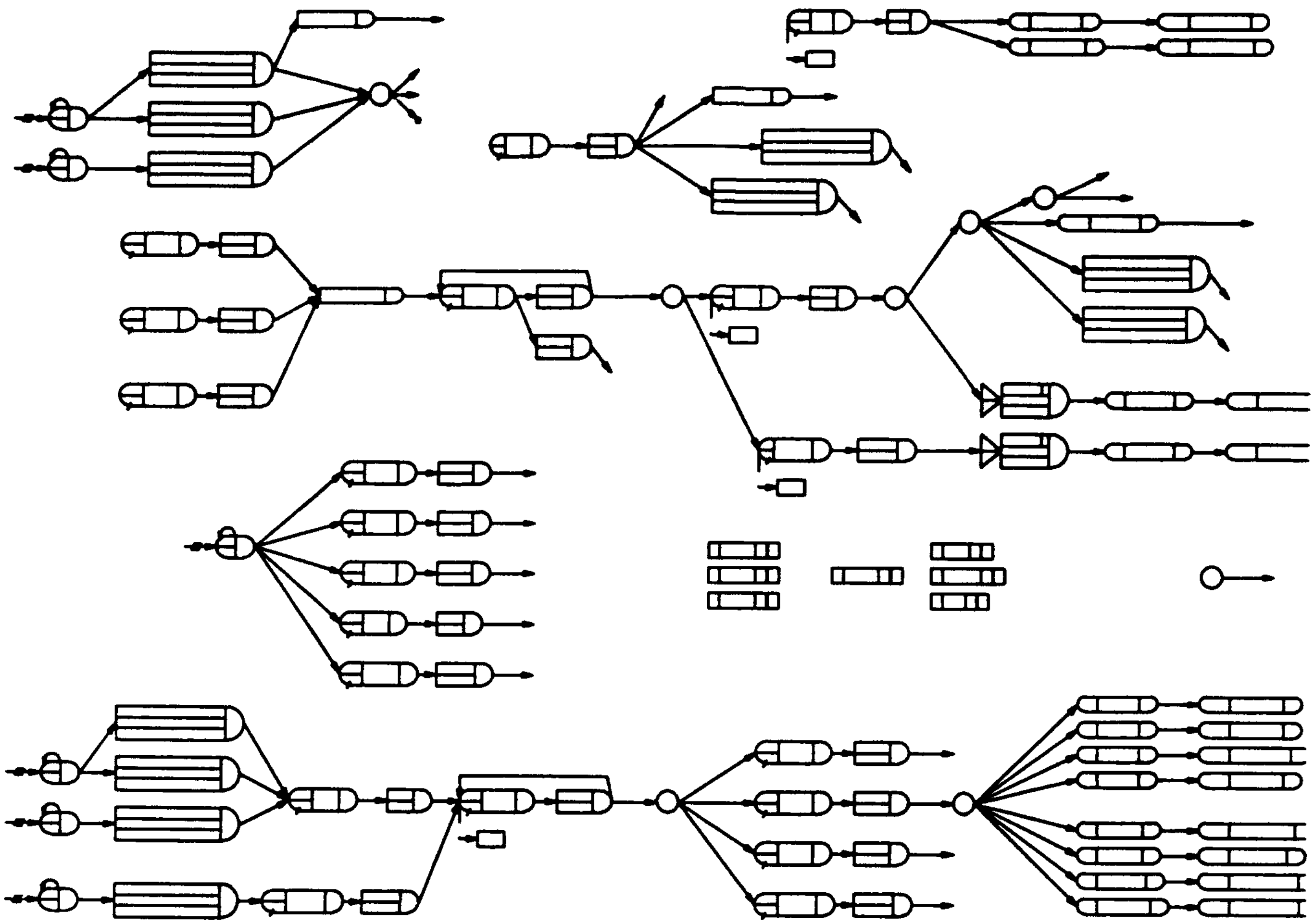
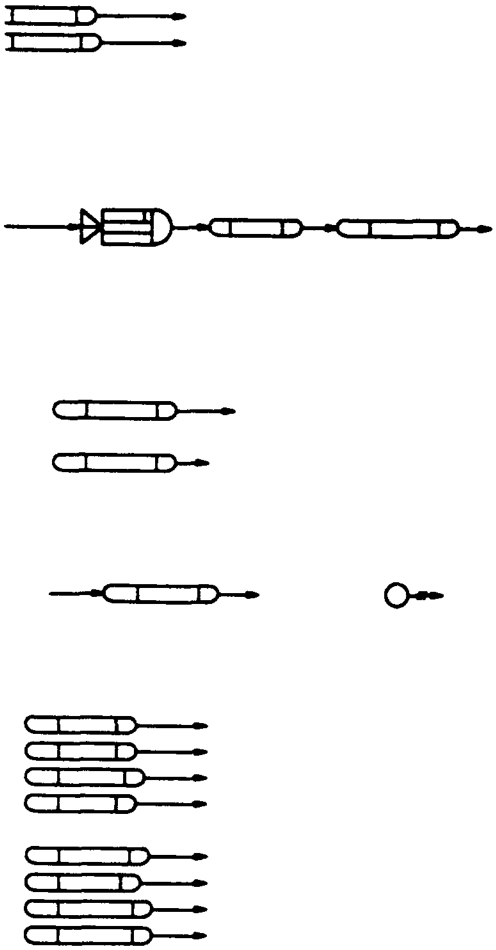
Company Level Control Statement



Company Network Schematic (2 pages)

D-3



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        RESOURCE/2,PLTLDR2,2;
        RESOURCE/3,PLTLDR3,3;
        RESOURCE/4,CORADIO,4;
        RESOURCE/5,COCDR,5;
        RESOURCE/6,FIRSTSGT,6;
        RESOURCE/7,FIST,7;
;
FIST    AWAIT(7),FIST,BALK(CLOST);
        ACTIVITY,ATRIB(3);
        FREE,FIST;
        ACTIVITY,,ATRIB(4).EQ.10;
        ACTIVITY,,ATRIB(4).EQ.12,ZABE;
        COLCT,BET,CDR CFF TBC;
        ACTIVITY;
        COLCT,INT(1),CDR CFF UPTIME;
        ACTIVITY,,,TERM;
ZABE    COLCT,BET,FLOT CFF TBC;
        ACTIVITY;
        COLCT,INT(1),FLOT CFF UPTIME;
        ACTIVITY,,,TERM;
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        ACTIVITY,,0.333,PLT2;
        ACTIVITY,,0.333,PLT3;
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;
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        ACTIVITY,,0.25,ZABH;
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        ACTIVITY;
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        ACTIVITY;
ZABJ    AWAIT(4),CORADIO;
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        FREE,CORADIO;
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        ACTIVITY,,0.7;
        GOON;
        ACTIVITY,,ATRIB(4).EQ.12.OR.ATRIB(4).EQ.70;
        ACTIVITY,,ATRIB(4).EQ.80,ZABO;
CDR     AWAIT(5),COCDR,BALK(CLOST);
        ACTIVITY,ATRIB(3);
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Company Network Statement (4 pages)

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        GOON;
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        ACTIVITY,,ATRIB(4).EQ.70,ZABN;
        GOON;
        ACTIVITY;
        ACTIVITY,,,ZABK;
        ACTIVITY,,0.05,ZABL;
        ACTIVITY,,0.01,ZABM;
        GOON;
        ACTIVITY,,0.25,FIST;
        ACTIVITY,,0.75,TERM;
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        ACTIVITY;
BATCH   BATCH,3/4,ATRIB(5),,FIRST/3;
        ACTIVITY;
        COLCT,BET,SPOTREP TBC;
        ACTIVITY;
        COLCT,INT(1),SPOTREP UP TIME;
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        ACTIVITY;
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        ACTIVITY;
        COLCT,INT(1),TACSTAT UP TIME;
        ACTIVITY,,,TERM;
ZABO    AWAIT(6/6),FIRSTSGT,BALK(CLOST);
        ACTIVITY,ATRIB(3);
        FREE,FIRSTSGT;
        ACTIVITY;
        BATCH,1/4,ATRIB(5),,FIRST/3;
        ACTIVITY;
        COLCT,BET,LOGSTAT TBC;
        ACTIVITY;
        COLCT,INT(1),LOGSTAT UP TIME;
        ACTIVITY,,,TERM;
ZABP    FREE,CORADIO;
        ACTIVITY,,,CLOST;
;
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        FREE,PLTLDR2;
        ACTIVITY,,,ZABQ;
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        ACTIVITY,,,ZABS;
        ACTIVITY,,,ZABT;
        ACTIVITY,,,ZABU;
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        ACTIVITY,0.5;
        FREE,PLTLDR1;
        ACTIVITY,,,TERM;
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        ACTIVITY,0.5;
        FREE,PLTLDR2;
        ACTIVITY,,,TERM;
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        ACTIVITY,0.5;
        FREE,PLTLDR3;
        ACTIVITY,,,TERM;
ZABT    AWAIT(5),COCDR;
        ACTIVITY,0.3;
        FREE,COCDR;
        ACTIVITY,,,TERM;
```

```
ZABU  AWAIT(6),FIRSTSGT;
      ACTIVITY,.30;
      FREE,FIRSTSGT;
      ACTIVITY,,,TERM;
;
TERM  TERMINATE;
;
CLOST GOON;
      ACTIVITY;
      COLCT,INT(1),CLOST REPORTS;
      ACTIVITY,,,TERM;
;
      CREATE,EXPON(170),,1;
      ACTIVITY;
      ACTIVITY,,,ZACG;
      ASSIGN,ATRIB(2)=RNORM(0.3,0.2),ATRIB(3)=RNORM(0.2,0.12),ATRIB(4)=50;
      ACTIVITY;
CDOWN AWAIT(5),COCDR;
      ACTIVITY,ATRIB(3);
      FREE,COCDR;
      ACTIVITY;
ZABV  AWAIT(4),CORADIO,BALK(CLOST);
      ACTIVITY/2,ATRIB(2);
      FREE,CORADIO;
      ACTIVITY,,0.3,ZABV;
      ACTIVITY,,0.7;
      GOON;
      ACTIVITY;
      ACTIVITY,,,ZACD;
      ACTIVITY,,,ZACE;
      ACTIVITY,,,ZACF;
      AWAIT(1),PLTLDR1;
      ACTIVITY,ATRIB(3);
      FREE,PLTLDR1;
      ACTIVITY,,,TERM;
ZACD  AWAIT(2),PLTLDR2;
      ACTIVITY,ATRIB(3);
      FREE,PLTLDR2;
      ACTIVITY;
      GOON;
      ACTIVITY,,ATRIB(4).EQ.20;
      ACTIVITY,,ATRIB(4).EQ.22,ZABW;
      ACTIVITY,,ATRIB(4).EQ.30,ZABX;
      ACTIVITY,,ATRIB(4).EQ.32,ZABY;
      ACTIVITY,,ATRIB(4).EQ.50,ZABZ;
      ACTIVITY,,ATRIB(4).EQ.51,ZACA;
      ACTIVITY,,ATRIB(4).EQ.60,ZACB;
      ACTIVITY,,ATRIB(4).EQ.90,ZACC;
      COLCT,BET,ORD20 TBC;
      ACTIVITY;
      COLCT,INT(1),ORD20 DWNTME;
      ACTIVITY,,,TERM;
ZABW  COLCT,BET,ORD22 TBC;
      ACTIVITY;
      COLCT,INT(1),ORD22 DWNTME;
      ACTIVITY,,,TERM;
ZABX  COLCT,BET,ORD30 TBC;
      ACTIVITY;
      COLCT,INT(1),ORD30 DWN TIME;
      ACTIVITY,,,TERM;
ZABY  COLCT,BET,ORD32 TBC;
      ACTIVITY;
      COLCT,INT(1),ORD32 DWNTME;
      ACTIVITY,,,TERM;
ZABZ  COLCT,BET,HORD50 TBC;
      ACTIVITY;
      COLCT,INT(1),HORD50 DWN TIME;
      ACTIVITY,,,TERM;
ZACA  COLCT,BET,HORD52 TBC;
      ACTIVITY;
      COLCT,INT(1),HORD52 DWNTME;
      ACTIVITY,,,TERM;
ZACB  COLCT,BET,HGH INT TBC;
      ACTIVITY;
      COLCT,INT(1),HGH INT DWN TIME;
      ACTIVITY,,,TERM;
```

```
ZACC  COLCT,BET,AL COORD TBC;
      ACTIVITY;
      COLCT,INT(1),AL COORD DWNTIME;
      ACTIVITY,,,TERM;
ZACE  AWAIT(3),PLTLDR3;
      ACTIVITY,ATRIB(3);
      FREE,PLTLDR3;
      ACTIVITY,,,TERM;
ZACF  AWAIT(6),FIRSTSGT;
      ACTIVITY,ATRIB(3);
      FREE,FIRSTSGT;
      ACTIVITY,,,TERM;
ZACG  ASSIGN,ATRIB(2)=RNORM(1.9,0.9),ATRIB(3)=RNORM(3.8,1.8),ATRIB(4)=51;
      ACTIVITY,,,CDOW;
;
      CREATE,EXPON(35),,1;
      ACTIVITY;
      ASSIGN,ATRIB(2)=RNORM(1.0,0.5),ATRIB(3)=RNORM(0.5,0.3),ATRIB(4)=60;
      ACTIVITY,,,CDOW;
;
      CREATE,EXPON(35),,1;
      ACTIVITY;
      ASSIGN,ATRIB(2)=RNORM(0.7,0.3),ATRIB(3)=RNORM(0.3,0.1),ATRIB(4)=90;
      ACTIVITY;
      AWAIT(6),FIRSTSGT;
      ACTIVITY,ATRIB(3);
      FREE,FIRSTSGT;
      ACTIVITY,,,ZABV;
      END;
```

COMPANY LEVEL MODEL NOTES VER 1.4

ATTRIBUTE NUMBERS

- 1=TIME OF CREATION
- 2=TRANSMISSION TIME
- 3=EVALUATION/PROCESSING TIME
- 4=MESSAGE TYPE/RELATIVE PRIORITY (1 IS HIGHEST)
  - SPOT REPORTS/CALL FOR FIRES
    - 10=FROM CDR'S PERSONAL OBSERVATION
    - 11=FROM SCOUTS
    - 12=FROM SUBORDINATE UNITS
  - CDR GENERATED EXECUTION ORDERS
    - 20=FROM CDR'S PERSONAL OBSERVATION
    - 21=FROM SCOUTS
    - 22=FROM SUBORDINATE UNITS
    - 23=FROM INTERNAL SENSORS
  - CDR GENERATED FRAGOS
    - 30=FROM CDR'S PERSONAL OBSERVATION
    - 31=FROM SCOUTS
    - 32=FROM SUBORDINATE UNITS
    - 33=FROM INTERNAL SENSORS
  - INTERNAL DETECTIONS/INTEL
    - 43=FROM INTERNAL SENSORS
  - HIGHER LEVEL ORDERS
    - 50=EXECUTION ORDERS
    - 51=SIGNIFICANT FRAGOS
  - EXTERNAL DETECTIONS/INTEL = 60
  - TACTICAL STATUS REPORTS = 70
  - LOGISTICAL STATUS REPORTS = 80
  - ADMIN/LOG COORDINATION = 90
- 5=NUMBER OF REPORTS PER "BATCH"

COMPANY LEVEL RESOURCE NUMBERS:

- 1=1ST PLT LDR
- 2=2ND PLT LDR
- 3=3RD PLT LDR
- 4=CO RADIO NET
- 5=CO CDR/XO
- 6=CO 1SG
- 7=FIST

COMPANY LEVEL FILE NUMBERS

- 1=AWAITING 1ST PLT LDR TO PROCESS
- 2=AWAITING 2ND PLT LDR TO PROCESS
- 3=AWAITING 3RD PLT LDR TO PROCESS
- 4=AWAITING CO RADIO NET AVAILABILITY
- 5=AWAITING CO CDR/XO/1SG TO PROCESS
- 6=AWAITING CO 1SG TO PROCESS
- 7=AWAITING FIST TO PROCESS

Company Model Notes

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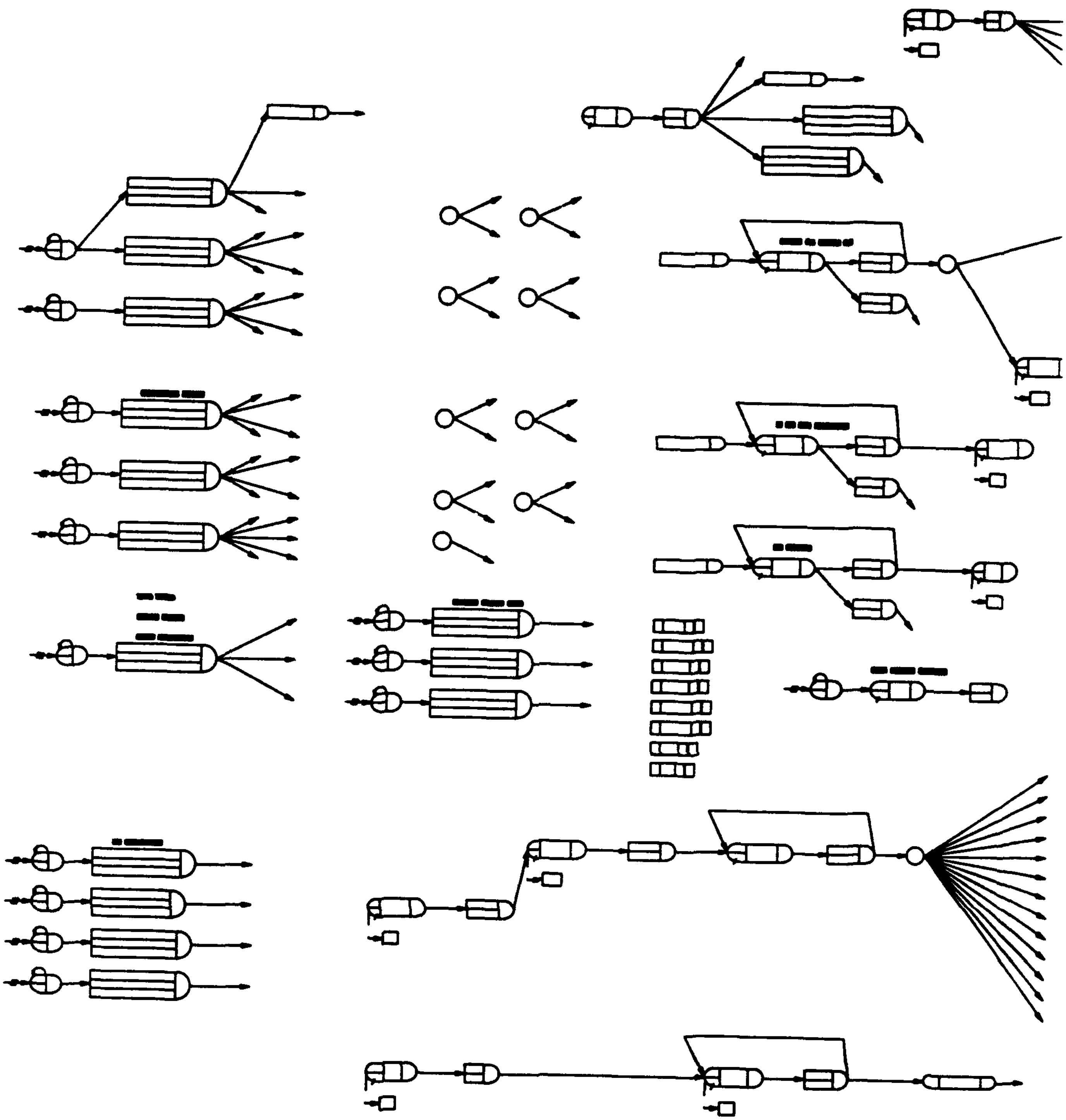
GEN,MAJ  WITSKEN,BNCOMMO CSM VER 1.4,9/1/1993,1,Y,Y,Y/Y,Y,Y/1,72;
LIMITS,8,6,300;
NETWORK;
PRIORITY/1,LVF(4)/2,LVF(4)/3,LVF(4)/4,LVF(4)/5,LVF(4)/6,LVF(4)/7,LVF(7)/8,LVF(4);
INITIALIZE,,1440,Y;
FIN;
```

Battalion Model Control Statement



Battalion Network Schematic (2 pages)
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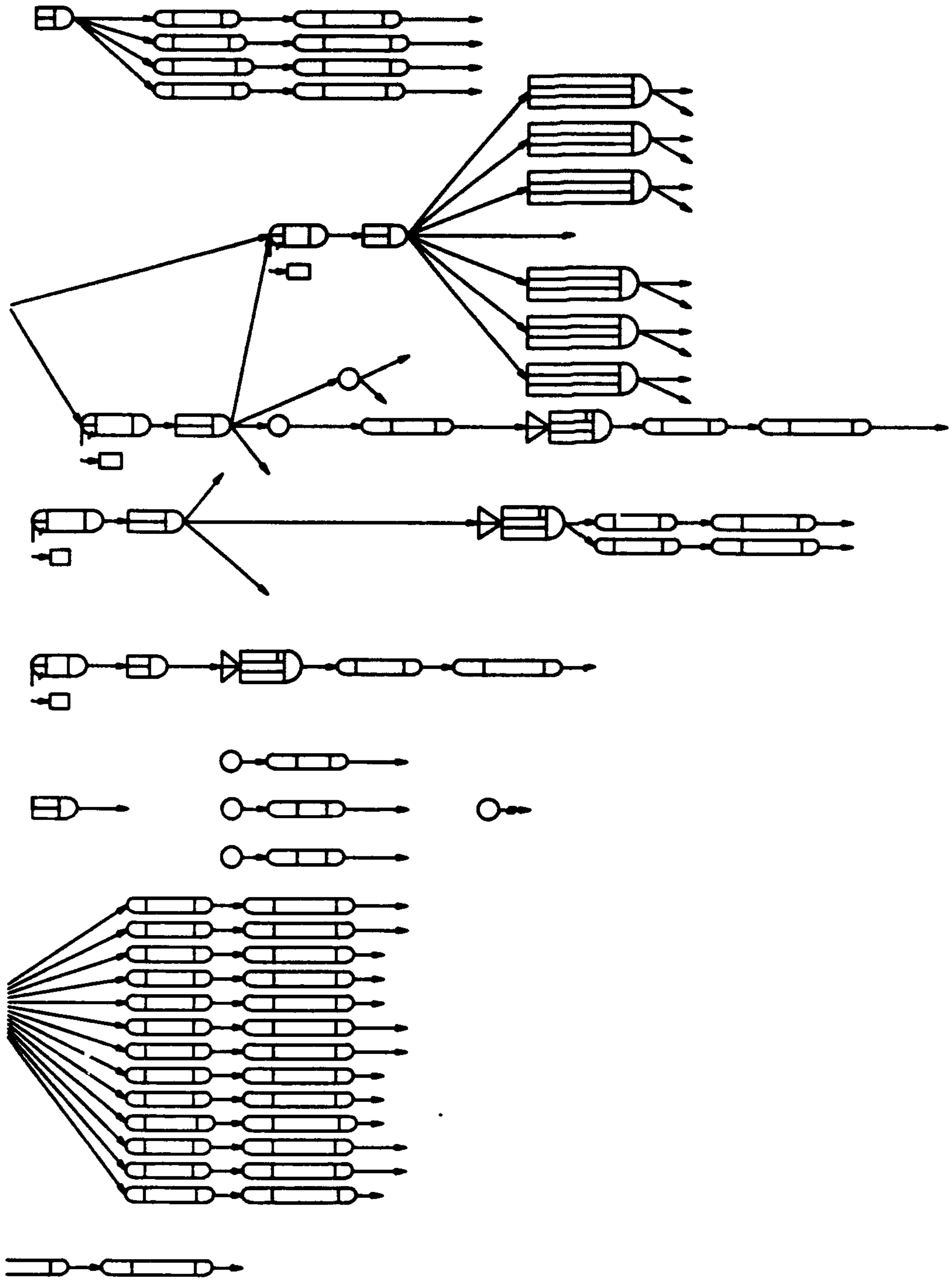

```
      RESOURCE/1,BNCDR,1;
      RESOURCE/2,BNCMDNET,2;
      RESOURCE/3,BNOINET,3;
      RESOURCE/4,BNALNET,4;
      RESOURCE/5,TOCTACS3,5;
      RESOURCE/6,TOCTACS2,6;
      RESOURCE/7,ALOC,7;
      RESOURCE/8,FSE,8;
;
FSE   AWAIT(8),FSE,BALK(CMDL);
      ACTIVITY,ATRIB(3);
      FREE,FSE;
      ACTIVITY,,ATRIB(4).EQ.10;
      ACTIVITY,,ATRIB(4).EQ.11,ZAAB;
      ACTIVITY,,ATRIB(4).EQ.12,ZAAC;
      ACTIVITY,,ATRIB(4).EQ.43,ZAAD;
      COLCT,BET,CDR CFF TBC;
      ACTIVITY;
      COLCT.INT(1),CDR CFF UPTIME;
      ACTIVITY,,,TERM;
ZAAB  COLCT,BET,SCOUT CFF TBC;
      ACTIVITY;
      COLCT,INT(1),SCOUT CFF UPTIME;
      ACTIVITY,,,TERM;
ZAAC  COLCT,BET,SUBUNIT CFF TBC;
      ACTIVITY;
      COLCT,INT(1),SUBUNIT CFF TIME;
      ACTIVITY,,,TERM;
ZAAD  COLCT,BET,INTDET CFF TBC;
      ACTIVITY;
      COLCT,INT(1),INTDET CFF TIME;
      ACTIVITY,,,TERM;
;
CDET  AWAIT(1/6),BNCDR;
      ACTIVITY,ATRIB(3);
      FREE,BNCDR;
      ACTIVITY,,0.25,FSE;
      ACTIVITY,,0.45;
      ACTIVITY,,0.25,ZAAE;
      ACTIVITY,,0.05,ZAAF;
      ASSIGN,ATRIB(4)=12;
      ACTIVITY,,,BATCH;
ZAAE  ASSIGN,ATRIB(2)=RNORM(0.3,0.2),ATRIB(3)=RNORM(0.2,0.12),ATRIB(4)=20;
      ACTIVITY,,,S3TOC;
ZAAF  ASSIGN,ATRIB(2)=RNORM(5,1),ATRIB(3)=RNORM(10,2),ATRIB(4)=30;
      ACTIVITY,,,S3TOC;
;
SCTS  GOON;
      ACTIVITY,,ATRIB(4).EQ.11.OR.ATRIB(4).EQ.70,BNCMD;
      ACTIVITY,,ATRIB(4).EQ.80,BNAL;
;
MORT  GOON;
      ACTIVITY,,ATRIB(4).EQ.11.OR.ATRIB(4).EQ.70,BNCMD;
      ACTIVITY,,ATRIB(4).EQ.80,BNAL;
;
;TOC/TAC AND COMMAND NET
;
      CREATE,EXPON(8),,1;
      ACTIVITY,,0.833;
      ACTIVITY,,0.167,ZAAG;
      ASSIGN,ATRIB(2)=RNORM(1.3,0.4),ATRIB(3)=RNORM(0.6,0.2),ATRIB(4)=11,ATRIB(
      5)=4;
      ACTIVITY,,0.25;
      ACTIVITY,,,SCTS;
      ACTIVITY,,0.01,ADA;
      ASSIGN,ATRIB(4)=10;
      ACTIVITY,,,CDET;
ZAAG  ASSIGN,ATRIB(2)=RNORM(0.7,0.3),ATRIB(3)=RNORM(0.3,0.1),ATRIB(4)=80,ATRIB(
      5)=4;
      ACTIVITY,,0.25,SCTS;
      ACTIVITY,,,MORT;
      ACTIVITY,,,ADA;
      ACTIVITY,,,ENG;
;
BNCMD ASSIGN,ATRIB(6)=TNOW;
      ACTIVITY;
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Battalion Network Statement (6 pages)

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```
ZAAH  AWAIT(2),BNCMDNET;
      ACTIVITY/1,ATRIB(2),TNOW-ATRIB(6).LE.10;
      ACTIVITY,,TNOW-ATRIB(6).GT.10,ZAAP;
      FREE,BNCMDNET;
      ACTIVITY,,0.3,ZAAH;
      ACTIVITY,,0.7;
      GOON;
      ACTIVITY;
      ACTIVITY,,,S3;
ZAAN  AWAIT(1/1),BNCDR,BALK(TERM);
      ACTIVITY,ATRIB(3);
      FREE,BNCDR;
      ACTIVITY,,ATRIB(4).EQ.11;
      ACTIVITY,,ATRIB(4).EQ.12,ZAAI;
      ACTIVITY,,ATRIB(4).EQ.43,ZAAJ;
      ACTIVITY,,,TERM;
      ACTIVITY,,ATRIB(4).EQ.11,ZAAK;
      ACTIVITY,,ATRIB(4).EQ.12,ZAAL;
      ACTIVITY,,ATRIB(4).EQ.43,ZAAM;
      ASSIGN,ATRIB(2)=RNORM(0.3,0.2),ATRIB(3)=RNORM(0.2,0.12),ATRIB(4)=21,ATRIB(
      5)=1;
      ACTIVITY,,0.9,TERM;
      ACTIVITY,,0.1,S3TOC;
ZAAI  ASSIGN,ATRIB(2)=RNORM(0.3,0.2),ATRIB(3)=RNORM(0.2,0.12),ATRIB(4)=22,ATRIB(
      5)=1;
      ACTIVITY,,0.9,TERM;
      ACTIVITY,,0.1,S3TOC;
ZAAJ  ASSIGN,ATRIB(2)=RNORM(0.3,0.2),ATRIB(3)=RNORM(0.2,0.12),ATRIB(4)=23,ATRIB(
      5)=1;
      ACTIVITY,,0.8,TERM;
      ACTIVITY,,0.2,S3TOC;
ZAAK  ASSIGN,ATRIB(2)=RNORM(5,1),ATRIB(3)=RNORM(10,2),ATRIB(4)=31,ATRIB(5)=1;
      ACTIVITY,,0.97,TERM;
      ACTIVITY,,0.03,S3TOC;
ZAAL  ASSIGN,ATRIB(2)=RNORM(5,1),ATRIB(3)=RNORM(10,2),ATRIB(4)=32,ATRIB(5)=1;
      ACTIVITY,,0.97,TERM;
      ACTIVITY,,0.03,S3TOC;
ZAAM  ASSIGN,ATRIB(2)=RNORM(5,1),ATRIB(3)=RNORM(10,2),ATRIB(4)=33,ATRIB(5)=1;
      ACTIVITY,,0.97,TERM;
      ACTIVITY,,0.03,S3TOC;
S3    AWAIT(5/9),TOCTACS3,BALK(CMDL);
      ACTIVITY,ATRIB(3);
      FREE,TOCTACS3;
      ACTIVITY,,ATRIB(4).EQ.43,ZAAN;
      ACTIVITY,,ATRIB(4).GE.10.OR.ATRIB(4).LE.50;
      ACTIVITY,,ATRIB(4).LT.50,ZAAO;
      ACTIVITY,,ATRIB(4).EQ.11.OR.ATRIB(4).EQ.70,S2;
      GOON;
      ACTIVITY,,0.33,FSE;
      ACTIVITY,,0.67,TERM;
ZAAO  GOON;
      ACTIVITY,,ATRIB(4).GE.10.OR.ATRIB(4).LT.20;
      COLCT,INT(1),PIR UPTIME;
      ACTIVITY;
BATCH BATCH,18/5,ATRIB(5),,FIRST/2,3;
      ACTIVITY;
      COLCT,BET,SPOTREP TBC;
      ACTIVITY;
      COLCT,INT(1),SPOTREP UP TIME;
      ACTIVITY,,,TERM;
ZAAP  FREE,BNCMDNET;
      ACTIVITY,,,CMDL;
;
ADA   GOON;
      ACTIVITY,,ATRIB(4).EQ.11.OR.ATRIB(4).EQ.70,BNCMD;
      ACTIVITY,,ATRIB(4).EQ.80,BNAL;
;
ENG   GOON;
      ACTIVITY,,ATRIB(4).EQ.11.OR.ATRIB(4).EQ.70,BNCMD;
      ACTIVITY,,ATRIB(4).EQ.80,BNAL;
;
      CREATE,EXPON(15),,1;
      ACTIVITY;
      ASSIGN,ATRIB(2)=RNORM(0.7,0.3),ATRIB(3)=RNORM(0.3,0.1),ATRIB(4)=70,ATRIB(
      5)=4;
      ACTIVITY,,0.25,SCTS;
```

```
        ACTIVITY,,,MORT;
        ACTIVITY,,,ADA;
        ACTIVITY,,,ENG;
;
;COMPANY/TEAM REPORTS
;
        CREATE,RNORM(36,19),,1;
        ACTIVITY;
        ASSIGN,ATRIB(2)=RNORM(0.7,0.1),ATRIB(3)=RNORM(0.3,0.1),ATRIB(4)=12,ATRIB(
        5)=4;
        ACTIVITY,,0.25,TMA;
        ACTIVITY,,,TMB;
        ACTIVITY,,,TMC;
        ACTIVITY,,,TMD;
;
;BN O&I NET/ TAC/TOC/S-2
;
TMA     GOON;
        ACTIVITY,,ATRIB(4).EQ.12.OR.ATRIB(4).EQ.70,BNCMD;
        ACTIVITY,,ATRIB(4).EQ.80,BNAL;
;
TMC     GOON;
        ACTIVITY,,ATRIB(4).EQ.12.OR.ATRIB(4).EQ.70,BNCMD;
        ACTIVITY,,ATRIB(4).EQ.80,BNAL;
;
BNOI    ASSIGN,ATRIB(6)=TNOW;
        ACTIVITY;
ZAAQ    AWAIT(3),BNOINET;
        ACTIVITY/2,ATRIB(2),TNOW-ATRIB(6).LE.10;
        ACTIVITY,,TNOW-ATRIB(6).GT.10,ZAAS;
        FREE,BNOINET;
        ACTIVITY,,0.3,ZAAQ;
        ACTIVITY,,0.7;
S2      AWAIT(6/9),TOCTACS2,BALK(OIL);
        ACTIVITY,ATRIB(3);
        FREE,TOCTACS2;
        ACTIVITY,,ATRIB(4).EQ.43,S3;
        ACTIVITY;
        ACTIVITY,,ATRIB(4).EQ.11.OR.ATRIB(4).EQ.43,S3TOC;
        BATCH,18/4,ATRIB(5),,FIRST/2,3;
        ACTIVITY,,ATRIB(4).EQ.43;
        ACTIVITY,,ATRIB(4).EQ.70,ZAAR;
        COLCT,BET,INTDET TBC;
        ACTIVITY;
        COLCT,INT(1),INTDET UPTIME;
        ACTIVITY,,,TERM;
ZAAR    COLCT,BET,TACSTAT TBC;
        ACTIVITY;
        COLCT,INT(1),TACSTAT UPTIME;
        ACTIVITY,,,TERM;
ZAAS    FREE,BNOINET;
        ACTIVITY,,,OIL;
;
        CREATE,RNORM(60,30),,1;
        ACTIVITY;
        ASSIGN,ATRIB(2)=0.02,ATRIB(3)=RNORM(0.2,0.1),ATRIB(4)=70,ATRIB(5)=4;
        ACTIVITY,,0.25,TMA;
        ACTIVITY,,,TMB;
        ACTIVITY,,,TMC;
        ACTIVITY,,,TMD;
;
TMB     GOON;
        ACTIVITY,,ATRIB(4).EQ.12.OR.ATRIB(4).EQ.70,BNCMD;
        ACTIVITY,,ATRIB(4).EQ.80,BNAL;
;
TMD     GOON;
        ACTIVITY,,ATRIB(4).EQ.12.OR.ATRIB(4).EQ.70,BNCMD;
        ACTIVITY,,ATRIB(4).EQ.80,BNAL;
;
        CREATE,RNORM(190,60),,1;
        ACTIVITY;
        ASSIGN,ATRIB(2)=0.02,ATRIB(3)=RNORM(1.4,0.2),ATRIB(4)=80,ATRIB(5)=4;
        ACTIVITY,,0.25,TMA;
        ACTIVITY,,,TMB;
        ACTIVITY,,,TMC;
        ACTIVITY,,,TMD;
```

```
      ACTIVITY,,,HHC;
;
;A&L NET/ALOC
;
HHC   GOON;
      ACTIVITY,,,BNAL;
;
BNAL  ASSIGN,ATRIB(6)=TNOW;
      ACTIVITY;
ZAAT  AWAIT(4),BNALNET;
      ACTIVITY,ATRIB(2),TNOW-ATRIB(6).LE.10;
      ACTIVITY,,TNOW-ATRIB(6).GT.10,ZAAU;
      FREE,BNALNET;
      ACTIVITY,,0.3,ZAAT;
      ACTIVITY,,0.7;
      AWAIT(7/9),ALOC,BALK(ALL);
      ACTIVITY,ATRIB(3);
      FREE,ALOC;
      ACTIVITY;
      BATCH,1/4,ATRIB(5),,FIRST/2,3;
      ACTIVITY;
      COLCT,BET,LOGSTAT TBC;
      ACTIVITY;
      COLCT,INT(1),LOGSTAT UPTIME;
      ACTIVITY,,,TERM;
ZAAU  FREE,BNALNET;
      ACTIVITY,,,ALL;
;
;INTERNAL SENSORS (GSR)
;
;FIELD TRAINS
;
      CREATE,EXPON(14),,1;
      ACTIVITY;
      ASSIGN,ATRIB(2)=RNORM(1,0.5),ATRIB(3)=RNORM(0.5,0.3),ATRIB(4)=43,ATRIB(5)=
      4;
      ACTIVITY,,,BNOI;
;
;SUPPORT PLATOON
;
;COMBAT TRAINS/OMCP
;
CMDL  GOON;
      ACTIVITY;
      COLCT,INT(1),CMDLOST;
      ACTIVITY,,,TERM;
;
      CREATE,EXPON(10),,1;
      ACTIVITY;
      ASSIGN,ATRIB(2)=RNORM(0.7,0.3),ATRIB(3)=RNORM(0.3,0.1),ATRIB(4)=70,ATRIB(
      5)=4;
      ACTIVITY,,,BNOI;
;
      CREATE,EXPON(70),,1;
      ACTIVITY;
      ASSIGN,ATRIB(2)=RNORM(0.7,0.3),ATRIB(3)=RNORM(0.3,0.1),ATRIB(4)=80,ATRIB(
      5)=3;
      ACTIVITY,,,BNAL;
      ACTIVITY,,,BNAL;
      ACTIVITY,,,BNAL;
;
;OTHER ACTIVITY GENERATOR
;
TERM  TERMINATE;
;
OIL   GOON;
      ACTIVITY;
      COLCT,INT(1),OILOST;
      ACTIVITY,,,TERM;
;
      CREATE,1;
      ACTIVITY;
      AWAIT(1),BNCDR;
      ACTIVITY,0.3;
      FREE,BNCDR
      ACTIVITY,,,TERM;
```

```
;
        CREATE,EXPON(70),,1;
        ACTIVITY;
        ASSIGN,ATRIB(2)=RNORM(0.7,0.3),ATRIB(3)=RNORM(0.3,0.1),ATRIB(4)=80,ATRIB(
        5)=3;
        ACTIVITY,,,BNAL;
;
ALL     GOON;
        ACTIVITY;
        COLCT,INT(1),ALLOST;
        ACTIVITY,,,TERM;
;
;BDE HEADQUARTERS
;
        CREATE,EXPON(170),,1;
        ACTIVITY;
        ASSIGN,ATRIB(2)=RNORM(0.3,0.1),ATRIB(3)=RNORM(0.2,0.12),ATRIB(4)=50;
        ACTIVITY,,,S3TOC;
;
S2TOC   AWAIT(6/9),TOCTACS2,BALK(OIL);
        ACTIVITY,ATRIB(3);
        FREE,TOCTACS2;
        ACTIVITY;
S3TOC   AWAIT(5/9),TOCTACS3,BALK(CMDL);
        ACTIVITY,ATRIB(3);
        FREE,TOCTACS3;
        ACTIVITY;
ZAAV    AWAIT(2),BNCMDNET,BALK(CMDL);
        ACTIVITY/4,ATRIB(2);
        FREE,BNCMDNET;
        ACTIVITY,,0.3,ZAAV;
        ACTIVITY,,0.7;
        GOON;
        ACTIVITY,,ATRIB(4).EQ.11;
        ACTIVITY,,ATRIB(4).EQ.20,ZAAW;
        ACTIVITY,,ATRIB(4).EQ.21,ZAAX;
        ACTIVITY,,ATRIB(4).EQ.22,ZAAY;
        ACTIVITY,,ATRIB(4).EQ.23,ZAAZ;
        ACTIVITY,,ATRIB(4).EQ.30,ZABA;
        ACTIVITY,,ATRIB(4).EQ.31,ZABB;
        ACTIVITY,,ATRIB(4).EQ.32,ZABC;
        ACTIVITY,,ATRIB(4).EQ.33,ZABD;
        ACTIVITY,,ATRIB(4).EQ.43,ZABE;
        ACTIVITY,,ATRIB(4).EQ.50,ZABF;
        ACTIVITY,,ATRIB(4).EQ.51,ZABG;
        ACTIVITY,,ATRIB(4).EQ.60,ZABH;
        COLCT,BET,INTEL11 TBC;
        ACTIVITY;
        COLCT,INT(1),INTEL11 DWNTIME;
        ACTIVITY,,,TERM;
ZAAW    COLCT,BET,EXORD20 TBC;
        ACTIVITY;
        COLCT,INT(1),EXORD20 DWNTIME;
        ACTIVITY,,,TERM;
ZAAX    COLCT,BET,EXORD21 TBC;
        ACTIVITY;
        COLCT,INT(1),EXORD21 DWNTIME;
        ACTIVITY,,,TERM;
ZAAY    COLCT,BET,EXORD22 TBC;
        ACTIVITY;
        COLCT,INT(1),EXORD22 DWNTIME;
        ACTIVITY,,,TERM;
ZAAZ    COLCT,BET,EXORD23 TBC;
        ACTIVITY;
        COLCT,INT(1),EXORD23 DWNTIME;
        ACTIVITY,,,TERM;
ZABA    COLCT,BET,FRAGO30 TBC;
        ACTIVITY;
        COLCT,INT(1),FRAGO30 DWNTIME;
        ACTIVITY,,,TERM;
ZABB    COLCT,BET,FRAGO31 TBC;
        ACTIVITY;
        COLCT,INT(1),FRAGO31 DWNTIME;
        ACTIVITY,,,TERM;
ZABC    COLCT,BET,FRAGO32 TBC;
        ACTIVITY;
```

```
        COLCT,INT(1),FRAGO32 DWNTIME;
        ACTIVITY,,,TERM;
ZABD    COLCT,BET,FRAGO33 TBC;
        ACTIVITY;
        COLCT,INT(1),FRAGO33 DWNTIME;
        ACTIVITY,,,TERM;
ZABE    COLCT,BET,INTDET43 TBC;
        ACTIVITY;
        COLCT,INT(1),INTDET43 DWNTIME;
        ACTIVITY,,,TERM;
ZABF    COLCT,BET,EXORD50 TBC;
        ACTIVITY;
        COLCT,INT(1),EXORD50 DWNTIME;
        ACTIVITY,,,TERM;
ZABG    COLCT,BET,FRAGO51 TBC;
        ACTIVITY;
        COLCT,INT(1),FRAGO51 DWNTIME;
        ACTIVITY,,,TERM;
ZABH    COLCT,BET,EXTDET60 TBC;
        ACTIVITY;
        COLCT,INT(1),EXTDET60 DWNTIME;
        ACTIVITY,,,TERM;
;
        CREATE,EXPON(170),,1;
        ACTIVITY;
        ASSIGN,ATRIB(2)=RNORM(5,1),ATRIB(3)=RNORM(10,2),ATRIB(4)=51;
        ACTIVITY,,,S3TOC;
;
        CREATE,EXPON(35),,1;
        ACTIVITY;
        ASSIGN,ATRIB(2)=RNORM(1,0.5),ATRIB(3)=RNORM(0.5,0.3),ATRIB(4)=60;
        ACTIVITY,,,S2TOC;
;
        CREATE,EXPON(35),,1;
        ACTIVITY;
        ASSIGN,ATRIB(2)=RNORM(0.7,0.3),ATRIB(3)=RNORM(0.3,0.1),ATRIB(4)=90;
        ACTIVITY,,,ALOC;
;
ALOC    AWAIT(7/9),ALOC,BALK(ALL);
        ACTIVITY,ATRIB(3);
        FREE,ALOC;
        ACTIVITY;
ZABI    AWAIT(4/10),BNALNET,BALK(ALL);
        ACTIVITY/5,ATRIB(2);
        FREE,BNALNET;
        ACTIVITY,,0.3,ZABI;
        ACTIVITY,,0.7;
        COLCT,BET,ALCOORD TBC;
        ACTIVITY;
        COLCT,INT(1),ALCOORD DWNTIME;
        ACTIVITY,,,TERM;
        END;
```

COMBAT SYNCHRONIZATION MODEL VER 1.4
BATTALION LEVEL MODEL NOTES

ATTRIBUTE NUMBERS

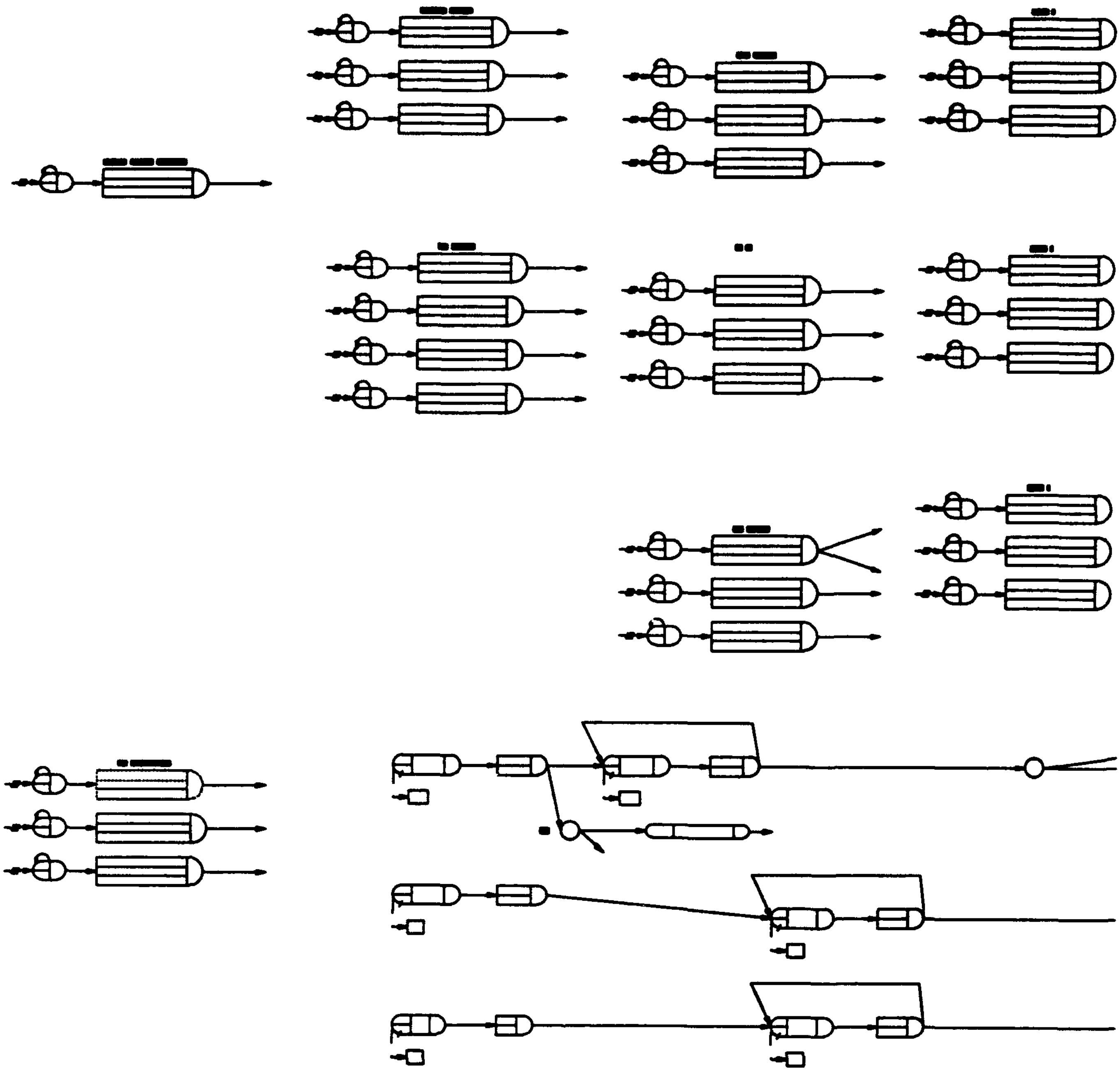
- 1=TIME OF CREATION
- 2=TRANSMISSION TIME
- 3=EVALUATION/PROCESSING TIME
- 4=MESSAGE TYPE/RELATIVE PRIORITY (1 IS HIGHEST)
    - SPOT REPORTS/CALL FOR FIRES
        - 10=FROM CDR'S PERSONAL OBSERVATION
        - 11=FROM SCOUTS
        - 12=FROM SUBORDINATE UNITS
    - CDR GENERATED EXECUTION ORDERS
        - 20=FROM CDR'S PERSONAL OBSERVATION
        - 21=FROM SCOUTS
        - 22=FROM SUBORDINATE UNITS
        - 23=FROM INTERNAL SENSORS
    - CDR GENERATED FRAGOS
        - 30=FROM CDR'S PERSONAL OBSERVATION
        - 31=FROM SCOUTS
        - 32=FROM SUBORDINATE UNITS
        - 33=FROM INTERNAL SENSORS
    - INTERNAL DETECTIONS/INTEL
        - 43=FROM INTERNAL SENSORS
    - HIGHER LEVEL ORDERS
        - 50=EXECUTION ORDERS
        - 51=SIGNIFICANT FRAGOS
    - EXTERNAL DETECTIONS/INTEL = 60
    - TACTICAL STATUS REPORTS = 70
    - LOGISTICAL STATUS REPORTS = 80
    - ADMIN/LOG COORDINATION = 90
- 5=NUMBER OF REPORTS IN "BATCH"

BATTALION LEVEL RESOURCE AND FILE NUMBERS

- 1=AWAITING BN CDR TO PROCESS
- 2=AWAITING BN COMMAND NET AVAILABILITY
- 3=AWAITING BN O&I NET AVAILABILITY
- 4=AWAITING BN A&L NET AVAILABILITY
- 5=AWAITING S-3 SECTION TO PROCESS
- 6=AWAITING S-2 SECTION TO PROCESS
- 7=AWAITING S-1/S-4 SECTION TO PROCESS
- 8=AWAITING FSE TO PROCESS

```
GEN,MAJ  WITSKEN,BDECOMMO CSM VER 1.0,7/23/1993,1,Y,Y,Y/Y,Y,Y/1,72;
LIMITS,6,6,800;
NETWORK;
PRIORITY/1,LVF(4)/2,LVF(4)/3,LVF(4)/4,LVF(4)/5,LVF(4)/6,LVF(4);
INITIALIZE,,720,Y;
FIN;
```

Brigade Model Control Statement



Brigade Network Schematic (3 pages)

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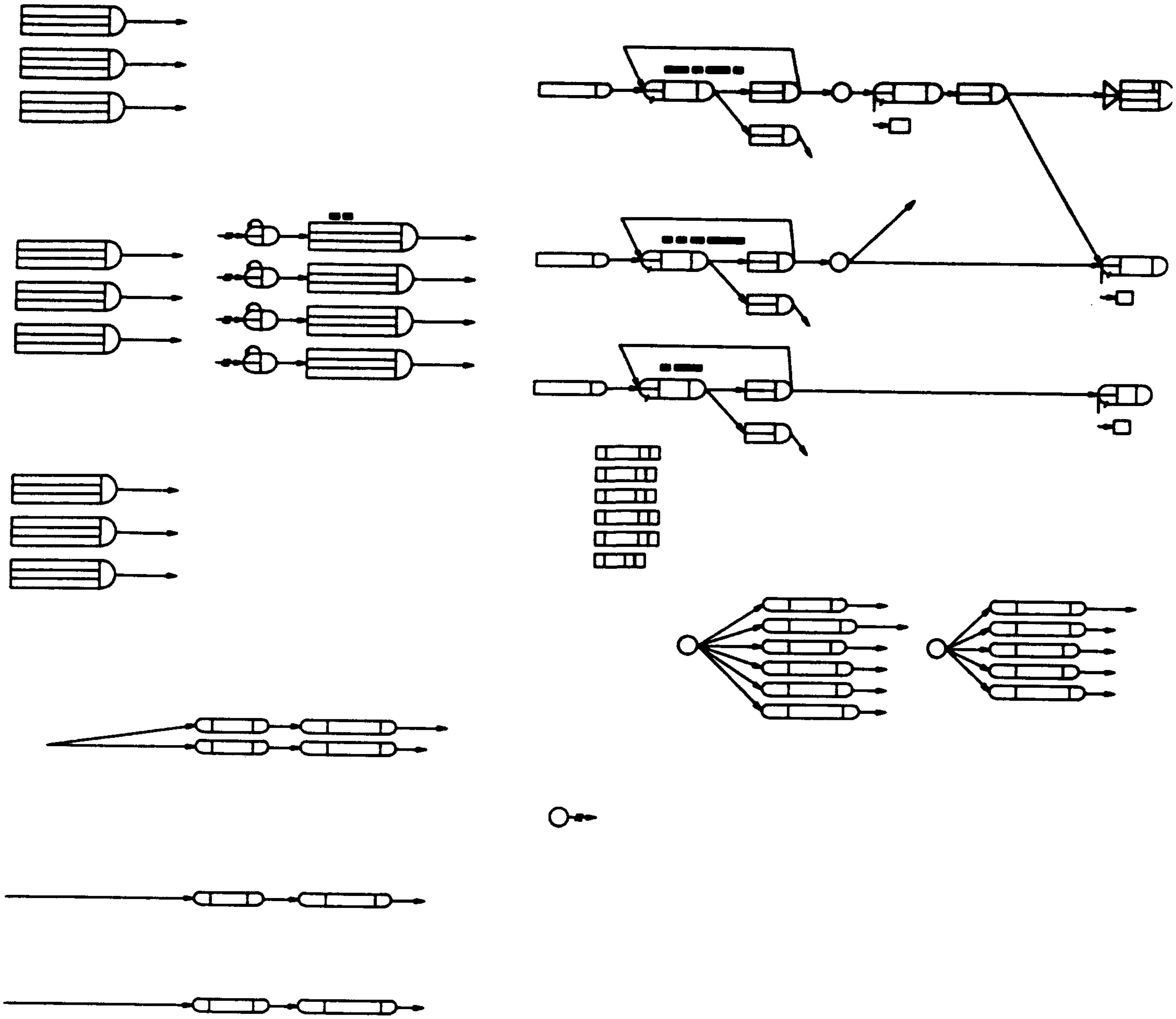

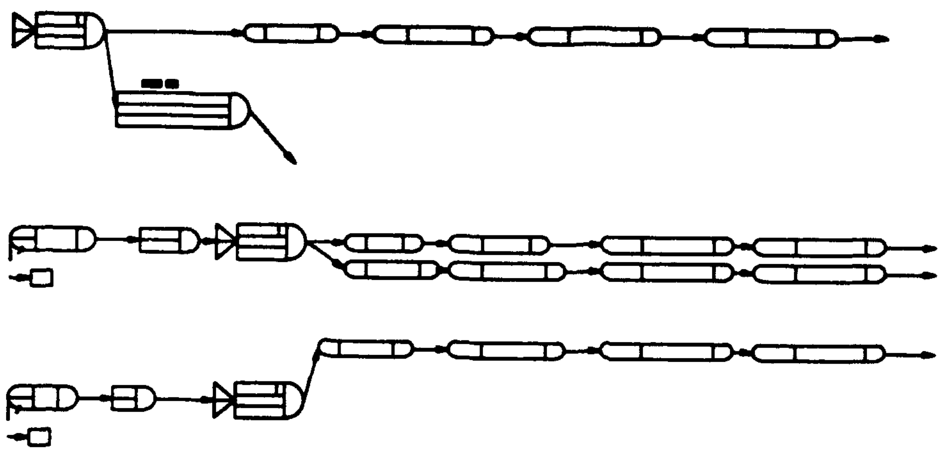

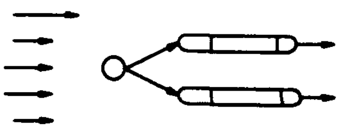

```
      RESOURCE/1,BDCMDNET,1;
      RESOURCE/2,BDOINET,2;
      RESOURCE/3,BDALNET,3;
      RESOURCE/4,TOCTACS3,4;
      RESOURCE/5,TOCTACS2,5;
      RESOURCE/6,ALOC,6;
;
;BN/TF A
;
;ENGINEER COMPANY
;
      CREATE,RNORM(15,9),,1;
      ACTIVITY;
      ASSIGN,ATRIB(2)=RNORM(1.1,0.5),ATRIB(3)=RNORM(1.7,0.5),ATRIB(4)=2,ATRIB(
      5)=3;
      ACTIVITY,,,BNCMD;
;
      CREATE,RNORM(35,12),,1;
      ACTIVITY;
      ASSIGN,ATRIB(2)=RNORM(0.3,0.2),ATRIB(3)=RNORM(0.2,0.12),ATRIB(4)=2,ATRIB(
      5)=3;
      ACTIVITY,,,BNCMD;
;
;NLOS BATTERY
;
      CREATE,RNORM(15,9),,1;
      ACTIVITY;
      ASSIGN,ATRIB(2)=RNORM(0.7,0.3),ATRIB(3)=RNORM(1.5,0.8),ATRIB(4)=6,ATRIB(
      5)=3;
      ACTIVITY,,,BNCMD;
;
;TOC/TAC AND COMMAND NET
;
      CREATE,RNORM(20,13),,1;
      ACTIVITY;
      ASSIGN,ATRIB(2)=RNORM(3.2,1.7),ATRIB(3)=RNORM(1.5,0.6),ATRIB(4)=6,ATRIB(
      5)=3;
      ACTIVITY,,,BNCMD;
;
      CREATE,RNORM(35,12),,1;
      ACTIVITY;
      ASSIGN,ATRIB(2)=RNORM(0.3,0.2),ATRIB(3)=RNORM(0.2,0.12),ATRIB(4)=2,ATRIB(
      5)=3;
      ACTIVITY,,,BNCMD;
;
BNCMD ASSIGN,ATRIB(6)=TNOW;
      ACTIVITY;
ZAGA  AWAIT(1),BDCMDNET;
      ACTIVITY/1,ATRIB(2),TNOW-ATRIB(6).LE.10;
      ACTIVITY,,TNOW-ATRIB(6).GT.10,ZAGD;
      FREE,BDCMDNET;
      ACTIVITY,,0.3,ZAGA;
      ACTIVITY,,0.7;
      GOON;
      ACTIVITY;
      AWAIT(4),TOCTACS3,BALK(CMDL);
      ACTIVITY,ATRIB(3);
      FREE,TOCTACS3;
      ACTIVITY,,ATRIB(4).EQ.2;
      ACTIVITY,,ATRIB(4).EQ.6,ZAGC;
      BATCH,1/4,ATRIB(5),,FIRST/2,3;
      ACTIVITY,,0.75;
      ACTIVITY,,0.25,HONC;
      COLCT,BET,CDR REP TBC;
      ACTIVITY;
      COLCT,INT(1),CDR REP UPTIME;
      ACTIVITY;
      COLCT,ATRIB(2),CDRREP TRANSTIME;
      ACTIVITY;
      COLCT,ATRIB(3),CDRREP PROCTIME;
      ACTIVITY,,,TERM;
HONCH ASSIGN,ATRIB(2)=RNORM(0.3,0.2),ATRIB(3)=RNORM(0.2,0.12),ATRIB(4)=2,ATRIB(
      5)=1;
      ACTIVITY,,,S3TOC;
ZAGC  AWAIT(5),TOCTACS2,BALK(OIL);
      ACTIVITY,ATRIB(3);
```

Brigade Network Statement (6 pages)

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```
      FREE,TOCTACS2;
      ACTIVITY;
      BATCH,2/4,ATRIB(5),,FIRST/2,3;
      ACTIVITY,,ATRIB(4).EQ.3;
      ACTIVITY,,ATRIB(4).EQ.6,ZAGB;
      COLCT,BET,DET TBC;
      ACTIVITY;
      COLCT,INT(1),DET UPTIME;
      ACTIVITY;
      COLCT,ATRIB(2),INTDET TRANSTIME;
      ACTIVITY;
      COLCT,ATRIB(3),INTDET PROCTIME;
      ACTIVITY,,,TERM;
ZAGB  COLCT,BET,TACSTAT TBC;
      ACTIVITY;
      COLCT,INT(1),TACSTAT UPTIME;
      ACTIVITY;
      COLCT,ATRIB(2),TACSTATTRANSTIME;
      ACTIVITY;
      COLCT,ATRIB(3),TACSTATPROCTIME;
      ACTIVITY,,,TERM;
ZAGD  FREE,BDCMDNET;
      ACTIVITY,,,CMDL;
;
      CREATE,RNORM(17,11),,1;
      ACTIVITY;
      ASSIGN,ATRIB(2)=RNORM(0.7,0.3),ATRIB(3)=RNORM(1.3,0.6),ATRIB(4)=7,ATRIB(
      5)=3;
      ACTIVITY,,,BNAL;
;
      CREATE,RNORM(17,11),,1;
      ACTIVITY;
      ASSIGN,ATRIB(2)=RNORM(0.7,0.3),ATRIB(3)=RNORM(1.1,0.5),ATRIB(4)=7,ATRIB(
      5)=3;
      ACTIVITY,,,BNAL;
;
      CREATE,RNORM(20,13),,1;
      ACTIVITY;
      ASSIGN,ATRIB(2)=RNORM(3.2,1.7),ATRIB(3)=RNORM(1.5,0.6),ATRIB(4)=6,ATRIB(
      5)=3;
      ACTIVITY,,,BNCMD;
;
;BN/TF CDR
;
;FORWARD SUPPORT BATTALION
;
      CREATE,RNORM(17,11),,1;
      ACTIVITY;
      ASSIGN,ATRIB(2)=RNORM(0.7,0.3),ATRIB(3)=RNORM(1.1,0.5),ATRIB(4)=7,ATRIB(
      5)=3;
      ACTIVITY,,,BNAL;
;
      CREATE,RNORM(16.7,10.8),,1;
      ACTIVITY;
      ASSIGN,ATRIB(2)=RNORM(0.7,0.3),ATRIB(3)=RNORM(1.1,0.5),ATRIB(4)=7,ATRIB(
      5)=3;
      ACTIVITY,,,BNAL;
;
;BDE RSE
;
;FA BN
;
;BN/TF B
;
;BDE O&I NET/ TAC/TOC/S-2
;
      CREATE,RNORM(35,12),,1;
      ACTIVITY;
      ASSIGN,ATRIB(2)=RNORM(0.3,0.2),ATRIB(3)=RNORM(0.2,0.12),ATRIB(4)=2,ATRIB(
      5)=3;
      ACTIVITY,,,BNCMD;
;
;ADA BATTERY
;
      CREATE,RNORM(15,9),,1;
      ACTIVITY;
```

```
      ASSIGN,ATRIB(2)=RNORM(1.1,0.5),ATRIB(3)=RNORM(1.7,0.5),ATRIB(4)=2,ATRIB(
      5)=3;
      ACTIVITY,,,BNCMD;
;
      CREATE,RNORM(35,12),,1;
      ACTIVITY;
      ASSIGN,ATRIB(2)=RNORM(0.3,0.2),ATRIB(3)=RNORM(0.2,0.12),ATRIB(4)=2,ATRIB(
      5)=3;
      ACTIVITY,,,BNCMD;
;
BNOI  ASSIGN,ATRIB(6)=TNOW;
      ACTIVITY;
ZAGE  AWAIT(2),BDOINET;
      ACTIVITY/2,ATRIB(2),TNOW-ATRIB(6).LE.10;
      ACTIVITY,,TNOW-ATRIB(6).GT.10,ZAGF;
      FREE,BDOINET;
      ACTIVITY,,0.3,ZAGE;
      ACTIVITY,,0.7;
      GOON;
      ACTIVITY,,ATRIB(4).EQ.3,HONCH;
      ACTIVITY,,,ZAGC;
ZAGF  FREE,BDOINET;
      ACTIVITY,,,OIL;
;
      CREATE,RNORM(3.3,2.9),,1;
      ACTIVITY;
      ASSIGN,ATRIB(2)=RNORM(0.3,0.2),ATRIB(3)=RNORM(0.2,0.1),ATRIB(4)=2,ATRIB(
      5)=3;
      ACTIVITY,,,BNCMD;
;
      CREATE,RNORM(14,7),,1;
      ACTIVITY;
      ASSIGN,ATRIB(2)=RNORM(1, 0.5),ATRIB(3)=RNORM(0.5,0.3),ATRIB(4)=3,ATRIB(5)=
      3;
      ACTIVITY,,,BNOI;
;
      CREATE,RNORM(15,9),,1;
      ACTIVITY;
      ASSIGN,ATRIB(2)=RNORM(0.7,0.3),ATRIB(3)=RNORM(1.5,0.8),ATRIB(4)=6,ATRIB(
      5)=3;
      ACTIVITY,,,BNCMD;
;
      CREATE,RNORM(19,7),,1;
      ACTIVITY;
      ASSIGN,ATRIB(2)=RNORM(2.9,0.8),ATRIB(3)=RNORM(1.6,0.5),ATRIB(4)=3,ATRIB(
      5)=3;
      ACTIVITY,,,BNOI;
;
      CREATE,RNORM(20,13),,1;
      ACTIVITY;
      ASSIGN,ATRIB(2)=RNORM(3,1.7),ATRIB(3)=RNORM(1.5,0.6),ATRIB(4)=6,ATRIB(5)=
      3;
      ACTIVITY,,,BNCMD;
;
      CREATE,RNORM(35,12),,1;
      ACTIVITY;
      ASSIGN,ATRIB(2)=RNORM(0.7,0.3),ATRIB(3)=RNORM(0.3,0.1),ATRIB(4)=6,ATRIB(
      5)=3;
      ACTIVITY,,,BNCMD;
;
      CREATE,RNORM(20,13),,1;
      ACTIVITY;
      ASSIGN,ATRIB(2)=RNORM(2.2,1.2),ATRIB(3)=RNORM(0.9,0.2),ATRIB(4)=6,ATRIB(
      5)=3;
      ACTIVITY,,,BNCMD;
;
      CREATE,RNORM(17,11),,1;
      ACTIVITY;
      ASSIGN,ATRIB(2)=RNORM(0.7,0.3),ATRIB(3)=RNORM(1.3,0.6),ATRIB(4)=7,ATRIB(
      5)=3;
      ACTIVITY,,,BNAL;
;
      CREATE,RNORM(17,11),,1;
      ACTIVITY;
      ASSIGN,ATRIB(2)=RNORM(0.7,0.3),ATRIB(3)=RNORM(1.1,0.5),ATRIB(4)=7,ATRIB(
      5)=3;
```

```
      ACTIVITY,,,BNAL;
;
;A&L NET/ALOC
;
      CREATE,RNORM(70,24),,1;
      ACTIVITY;
      ASSIGN,ATRIB(2)=RNORM(0.7,0.3),ATRIB(3)=RNORM(0.3,0.1),ATRIB(4)=7,ATRIB(
      5)=3;
      ACTIVITY,,,BNAL;
;
      CREATE,RNORM(70,24),,1;
      ACTIVITY;
      ASSIGN,ATRIB(2)=RNORM(0.7,0.3),ATRIB(3)=RNORM(1.3,0.6),ATRIB(4)=7,ATRIB(
      5)=3;
      ACTIVITY,,,BNAL;
;
BNAL  ASSIGN,ATRIB(6)=TNOW;
      ACTIVITY;
ZAGG  AWAIT(3),BDALNET;
      ACTIVITY/3,ATRIB(2),TNOW-ATRIB(6).LE.10;
      ACTIVITY,,TNOW-ATRIB(6).GT.10,ZAGH;
      FREE,BDALNET;
      ACTIVITY,,0.3,ZAGG;
      ACTIVITY,,0.7;
      AWAIT(6),ALOC,BALK(ALL);
      ACTIVITY,ATRIB(3);
      FREE,ALOC;
      ACTIVITY;
      BATCH,1/4,ATRIB(5),,FIRST/2,3;
      ACTIVITY;
      COLCT,BET,LOGSTAT TBC;
      ACTIVITY;
      COLCT,INT(1),LOGSTAT UPTIME;
      ACTIVITY;
      COLCT,ATRIB(2),LOGSTATTRANSTIME;
      ACTIVITY;
      COLCT,ATRIB(3),LOGSTATPROCTIME;
      ACTIVITY,,,TERM;
ZAGH  FREE,BDALNET;
      ACTIVITY,,,ALL;
;
;BN/TF C
;
      CREATE,RNORM(15,9),,1;
      ACTIVITY;
      ASSIGN,ATRIB(2)=RNORM(1.1,0.5),ATRIB(3)=RNORM(1.7,0.5),ATRIB(4)=2,ATRIB(
      5)=3;
      ACTIVITY,,,BNCMD;
;
;UAV SECTION
;
      CREATE,RNORM(15,9),,1;
      ACTIVITY;
      ASSIGN,ATRIB(2)=RNORM(0.7,0.3),ATRIB(3)=RNORM(1.5,0.8),ATRIB(4)=6,ATRIB(
      5)=3;
      ACTIVITY,,,BNCMD;
;
      CREATE,EXPON(14),,1;
      ACTIVITY;
      ASSIGN,ATRIB(2)=RNORM(1, 0.5),ATRIB(3)=RNORM(0.5,0.3),ATRIB(4)=3,ATRIB(5)=
      3;
      ACTIVITY,,,BNOI;
      ACTIVITY,,,S2TOC;
;
      CREATE,RNORM(17,11),,1;
      ACTIVITY;
      ASSIGN,ATRIB(2)=RNORM(0.7,0.3),ATRIB(3)=RNORM(1.3,0.6),ATRIB(4)=7,ATRIB(
      5)=3;
      ACTIVITY,,,BNAL;
;
      CREATE,RNORM(35,12),,1;
      ACTIVITY;
      ASSIGN,ATRIB(2)=RNORM(0.7,0.3),ATRIB(3)=RNORM(0.3,0.1),ATRIB(4)=6,ATRIB(
      5)=3;
      ACTIVITY,,,BNOI;
;
```

```
         CREATE,RNORM(70,24),,1;
         ACTIVITY;
         ASSIGN,ATRIB(2)=RNORM(0.7,0.3),ATRIB(3)=RNORM(0.3,0.1),ATRIB(4)=7,ATRIB(
         5)=3;
         ACTIVITY,,,BNAL;
;
CMDL     GOON;
         ACTIVITY,,ATRIB(4).EQ.1;
         ACTIVITY,,ATRIB(4).EQ.2,ZAGI;
         ACTIVITY,,ATRIB(4).EQ.3,ZAGJ;
         ACTIVITY,,ATRIB(4).EQ.4,ZAGK;
         ACTIVITY,,ATRIB(4).EQ.5,ZAGL;
         ACTIVITY,,ATRIB(4).EQ.6,ZAGM;
         COLCT,INT(1),CMDLOST CFF;
         ACTIVITY,,,TERM;
ZAGI     COLCT,INT(1),CMDLST CDR ORD;
         ACTIVITY,,,TERM;
ZAGJ     COLCT,INT(1),CMDLOST DET;
         ACTIVITY,,,TERM;
ZAGK     COLCT,INT(1),CMDLOST FRAGO;
         ACTIVITY,,,TERM;
ZAGL     COLCT,INT(1),CMDLOST INTEL;
         ACTIVITY,,,TERM;
ZAGM     COLCT,INT(1),CMDLOST TACSTAT;
         ACTIVITY,,,TERM;
;
ALL      GOON;
         ACTIVITY,,ATRIB(4).EQ.7;
         ACTIVITY,,ATRIB(4).EQ.8,ZAGN;
         COLCT,INT(1),ALLOST LOGSTAT;
         ACTIVITY,,,TERM;
ZAGN     COLCT,INT(1),ALLOST AL COORD;
         ACTIVITY,,,TERM;
;
OIL      GOON;
         ACTIVITY,,ATRIB(4).EQ.2;
         ACTIVITY,,ATRIB(4).EQ.3,ZAGO;
         ACTIVITY,,ATRIB(4).EQ.4,ZAGP;
         ACTIVITY,,ATRIB(4).EQ.5,ZAGQ;
         ACTIVITY,,ATRIB(4).EQ.6,ZAGR;
         COLCT,INT(1),OILOST CDR ORD;
         ACTIVITY,,,TERM;
ZAGO     COLCT,INT(1),OILOST DETECTS;
         ACTIVITY,,,TERM;
ZAGP     COLCT,INT(1),OILOST FRAGO;
         ACTIVITY,,,TERM;
ZAGQ     COLCT,INT(1),OILOST INTEL;
         ACTIVITY,,,TERM;
ZAGR     COLCT,INT(1),OILOST TACSTAT;
         ACTIVITY,,,TERM;
;
S3TOC    AWAIT(4),TOCTACS3,BALK(CMDL);
         ACTIVITY,ATRIB(3);
         FREE,TOCTACS3;
         ACTIVITY;
         ACTIVITY,,ATRIB(4).EQ.2,ZAGU;
ZAGS     AWAIT(1/10),BDCMDNET,BALK(CMDL);
         ACTIVITY/4,ATRIB(2);
         FREE,BDCMDNET;
         ACTIVITY,,0.3,ZAGS;
         ACTIVITY,,0.7;
         GOON;
         ACTIVITY,,ATRIB(4).EQ.2;
         ACTIVITY,,ATRIB(4).EQ.4,ZAGT;
         COLCT,BET,CDRORD TBC;
         ACTIVITY;
         COLCT,INT(1),CDRORD DWNTIME;
         ACTIVITY,,,TERM;
ZAGT     COLCT,BET,HGHORD TBC;
         ACTIVITY;
         COLCT,INT(1),HGHORD DWNTIME;
         ACTIVITY,,,TERM;
ZAGU     GOON;
         ACTIVITY,,0.33;
         ACTIVITY,,0.67,TERM;
         COLCT,INT(1),CDR DIR CFF TIME;
```

```
        ACTIVITY,,,TERM;
;
;BDE HEADQUARTERS
;
        CREATE,EXPON(170),,1;
        ACTIVITY;
        ASSIGN,ATRIB(2)=RNORM(4.8,1.4),ATRIB(3)=RNORM(8.6,2.9),ATRIB(4)=4;
        ACTIVITY,,,S3TOC;
;
        CREATE,EXPON(35),,1;
        ACTIVITY;
        ASSIGN,ATRIB(2)=RNORM(1.1, 0.5),ATRIB(3)=RNORM(0.6,0.3),ATRIB(4)=5;
        ACTIVITY,,,S2TOC;
;
TERM    TERMINATE;
;
;FSE
;
        CREATE,EXPON(35),,1;
        ACTIVITY;
        ASSIGN,ATRIB(2)=RNORM(0.7,0.3),ATRIB(3)=RNORM(0.3,0.1),ATRIB(4)=8;
        ACTIVITY,,,ALOC;
;
S2TOC AWAIT(5),TOCTACS2,BALK(OIL);
        ACTIVITY,ATRIB(3);
        FREE,TOCTACS2;
        ACTIVITY;
ZAGV    AWAIT(2/10),BDOINET,BALK(ALL);
        ACTIVITY/5,ATRIB(2);
        FREE,BDOINET;
        ACTIVITY,,0.3,ZAGV;
        ACTIVITY,,0.7;
        COLCT,BET,INTEL TBC;
        ACTIVITY;
        COLCT,INT(1),INTEL DWNTIME;
        ACTIVITY,,,TERM;
;
ALOC    AWAIT(6),ALOC,BALK(ALL);
        ACTIVITY,ATRIB(3);
        FREE,ALOC;
        ACTIVITY;
ZAGW    AWAIT(3/10),BDALNET,BALK(ALL);
        ACTIVITY/6,ATRIB(2);
        FREE,BDALNET;
        ACTIVITY,,0.3,ZAGW;
        ACTIVITY,,0.7;
        COLCT,BET,ALCOORD TBC;
        ACTIVITY;
        COLCT,INT(1),ALCOORD DWNTIME;
        ACTIVITY,,,TERM;
        END;
```

COMBAT SYNCHRONIZATION MODEL VER 1.0
BDE LEVEL NOTES

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    1=SPOT REPORTS/CALL FOR FIRES
    2=CDR GENERATED ORDERS
    3=INTERNAL SENSOR DETECTIONS/INTEL
    4=HIGHER LEVEL ORDERS (SIGNIFICANT FRAGOS)
    5=EXTERNAL DETECTIONS/INTEL
    6=TACTICAL STATUS REPORTS
    7=LOGISTICAL STATUS REPORTS
    8=ADMIN/LOG COORDINATION
5=NUMBER OF REPORTS IN "BATCH"

BRIGADE LEVEL FILE NUMBERS

1=AWAITING BDE COMMAND NET AVAILABILITY
2=AWAITING BDE O&I NET AVAILABILITY
3=AWAITING BDE A&L NET AVAILABILITY
4=AWAITING S-3 SECTION TO PROCESS
5=AWAITING S-2 SECTION TO PROCESS
6=AWAITING S-1/S-4 SECTION TO PROCESS

Brigade Model Notes
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