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USING COMPUTER SIMULATION TO REENGINEER TRADITIONAL STOVE-PIPED ARMY STAFFS FOR INFORMATION OPERATIONS IN THE 21ST CENTURY

Michael L. McGinnis
Robert G. Phelan Jr.

Operations Research Center
United States Military Academy
West Point, New York 10996, U.S.A.

ABSTRACT

Recently, the US Army has been confronted by a wider range of military and peacekeeping operations. The future success of the Army on tomorrow's battlefields depends, in part, on how effectively our forces are able to fight and win the information war. We present a computer simulation approach being developed for the Army Digitization Office (ADO) for reengineering the current stove-piped organization of tactical Army staffs into staffs organized for information operations in the 21st century.

1 INTRODUCTION

World events of recent years have required the United States armed forces to respond to a much broader range of military operations involving both joint and coalition forces. Examples include Panama, Iraq, Somalia, Rwanda, Haiti and, most recently, Bosnia. Published accounts of the operations reveal at least two interrelated factors that combined to complicate the Army's command and control (C^2) processes (see, for example, Campen 1992, (Josephson and Macedonia 1994), (Sullivan 1994)). First, the infusion of communications, computer and information technology at all levels across the Army during the late 1980s and early 1990s increasingly overloaded commanders and staffs with battlefield information that bogged down the military decision making process. Second, both political and military considerations motivated commanders at all levels to accelerate the military decision making processes leading to military action that accelerated the operational tempo.

Former Army Chief of Staff, General Gordon R. Sullivan, recognized these problems and, in 1994, set a new course for the Army when he initiated an Army-wide effort supported by the Army Staff, branch schools, major commands and battle laboratories to design and field the Army of the early 21st century, or *FORCE XXI*. According to General Sullivan, *"FORCE XXI must be organized around information -- the creation and sharing of knowledge followed by unified action based on that knowledge which will allow commanders to apply power effectively* (Sullivan 1994)."

For Army commanders to win decisively on tomorrow's battlefields, they must make well-informed, timely decisions to give the land combat forces adequate guidance and sufficient time to carefully and thoroughly plan the military operation, and fight and win the battle. Winning decisively on tomorrow's high-technology battlefield will require reengineering the traditional, stove-piped tactical Army staffs from battalion through division into staffs organized for information operations that can win the information war.

We present a computer simulation approach under development for the Army Digitization Office (ADO), Headquarters, Department of the Army, for reengineering the way that staffs are currently organized into staffs organized for information operations in the 21st century. The major purposes of this paper are to:

1. overview work-in-progress on the development of a computer simulation model for this project; and
2. discuss preliminary simulation results comparing proposed FORCE XXI staffs organized for information operations based on the concepts of a *command and control system* (C^2 System), a *modular force structure* (MFS) and various levels of information and military technology.

By design, the simulation model will permit Army FORCE XXI developers to evaluate potential staff organization alternatives ahead of time and to examine the implications of these alternatives on officer professional development in terms of identifying future skills required of officers to properly man the FORCE XXI staffs. Attendant problems associated with developing and using the computer simulation approach to reengineer staffs for information operations are also discussed.

2 STRATEGIC CONSIDERATIONS FOR REENGINEERING ARMY STAFFS

During the Cold War, the United States national military strategy was oriented towards deterring, or fighting if necessary, general war in central Europe. However, recent changes to world order have led to a dramatic reduction in the United States' military force structure. The number of active Army divisions has been reduced from a high of twenty-one during the Cold War to ten 1997 that, for the most part, will be centrally-based within the continental United States. As we enter the next century, even a modest increase in world instability may lead to more frequent regional crises that erupt with little or no warning. Under these conditions, it is quite conceivable that FORCE XXI will continue to take on a broader range of land operations in different geographical environments than what US land combat forces have had to deal with in the past.

According to TRADOC Pam 525-5, *Force XXI Operations: A Concept for the Evolution of Full-Dimensional Operations for the Strategic Army of the Early Twenty-First Century*, (TRADOC 1994), the Army of the 21st century must be capable of conducting the five types of land operations listed below:

- Operations against complex, adaptive forces (CAF);
- Operations against complex, adaptive forces and armor-mechanized forces (CAF & AMF);
- Operations against armor-mechanized forces (AMF);
- Operations against infantry-based forces (IBF); and
- Operations Other Than War (OOTW).

Furthermore, it is also very likely that FORCE XXI will be further challenged by an equally broad range of geographical and climatic environments such as those listed in Table 1.

Table 1. FORCE XXI Geographical and Climatic Environments

Geographic Environments	Climatic Environments
urban/suburban	extreme cold
rural	moderate
mountains	extreme heat
desert	
jungle	

Previous work (McGinnis et al 1995) examining important strategic and operational considerations for FORCE XXI, such as mobility, versatility and sustainability given these operating, geographical and climatic environments led to the following possible organization for FORCE XXI:

- *generalization* of a C^2 System capable of providing effective command and control of military forces engaged in <u>any</u> of the land operation and operating environment listed above; and
- *specialization* of modular FORCE XXI combat forces by operation and geographical environment that tailors the modular forces ahead of time for different land operations and geographical environments (i.e., regions of the world) based on potential threats to U.S. national security.

Within this, the use of a computer simulation model to design the staffs of the C^2 System and the modular combat forces is discussed next.

3 BACKGROUND

To fight and win the information war, commanders and staffs at all levels must effectively manage both battlefield information and time for planning and executing the military operation. The FORCE XXI initiative includes the horizontal and vertical integration of new age information technology across the forces to enhance command and control of land combat forces. Information technology will unquestionably accelerate the operational tempo by compressing the C^2 cycle for military operations of Figure 1 where information operations feed military decision making resulting in military action.

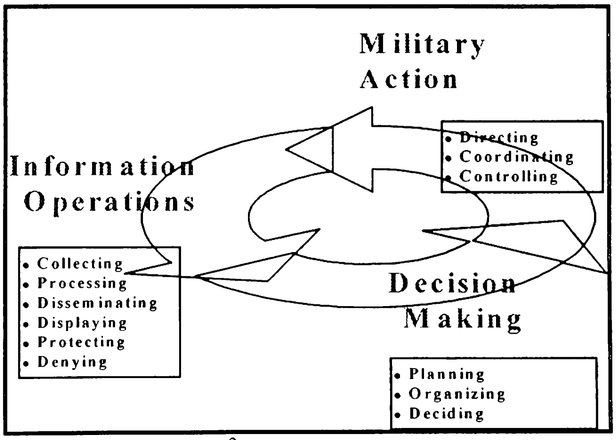

Figure 1. The C^2 Cycle for Military Operations

The implications seem obvious: the faster that information is collected, processed and disseminated to battle commanders, the faster that commanders will make decisions leading to military action, leaving less time for thinking about complex decision problems and making synchronization of fire and maneuver much more challenging.

From a military viewpoint, the responsibility for command and control rests with the commander. In practice, however, the commander relies extensively upon principal staff officers to accomplish many tasks associated with the command function. In general, the staff functions (and positions) include those activities that focus on controlling forces. Traditionally, the staff has been organized as follows: personnel and administration (G1/S1), intelligence (G2/S2), plans and operations (G3/S3) and logistics (G4/S4). In the past, commanders and staffs have relied upon written and verbal messages as well as voice radio traffic for military decision making, communicating orders and maintaining tactical control of forces. In addition, the battlefield situation, often referred to as the *relevant common picture* (RCP), is the commander's mental picture of the battlefield that he communicates verbally and in writing to his staff and subordinate commanders. In the past, commanders have generally relied on staffs to *manually* process battlefield information needed for updating their mental models of the battlefield and to keep abreast of the military situation. A "typical" Army division headquarters includes three command posts (CPs): Tactical, Main and Rear responsible for controlling all aspects of division operations. Until very recently, the vast majority of battlefield information at the tactical level (Division and below) was communicated by voice.

The Army is presently testing and, in some cases, fielding new communications and decision support systems for tactical level commanders (division and below). For example, the Army is fielding a Tactical Local Area Network, or TACLAN, for Division operations that provides electronic communications between the three command posts mentioned above as well as establishing links to senior and subordinate headquarters. Messages between different staff elements are transmitted over tactical switches. The system is supported by fifteen to thirty personal computers that serve as communications nodes for the staff sections of the various command posts. Messages are passed electronically between the nodes (i.e., within and between the command posts) and may be passed between outside elements as well. Additionally, the nodes may also receive communications from FM and satellite radio nets, telephone calls over tactical switches and hand carried messages. However, at the present time, all of the information must be *manually* processed before it is available for use by either the staff or the commander.

Clearly, as the operational tempo of future military operations increases and as vast amounts of battlefield information become instantly available to commanders through information technology, the traditional manual methods of updating the relevant common picture will not meet the future information processing needs of commanders. The simulation model approach for determining the size and composition of a 21st century tactical staff organized for information operations is discussed next.

4 MODELING APPROACH

In early 1995, the Operations Research Center of the United States Military Academy at West Point, New York, and the Army Digitization Office (ADO), Headquarters, Department of the Army began a collaborative effort to develop a computer simulation model for conducting the types of studies described above in Section 1. The goal being to develop a robust simulation model for the ADO capable of performing repetitive analyses, in a timely manner, of dynamic issues supporting FORCE XXI Army Warfighting Experiments (AWEs).

The initial phase of model development has focused on establishing a general, baseline simulation model of some of the important tactical command and control functions, processes, procedures and systems currently being used by tactical units in the field. These have been identified through interviews with officers from division staffs, field operating agencies such as the US Army Communications and Electronics Command (CECOM) and the Army Battle Laboratories. For example, the TACLAN system briefly described serves as the baseline for modeling the electronic communication system for the division's information pipeline between commanders and staffs. This effort also includes collecting data on the type and quantity of messages routinely handled by tactical commanders and staffs during command post, field and real-world exercises. The reader is referred to (McGinnis et al 1995) for a discussion of commander's battlefield information requirements and a summary of recent literature related to this topic.

Following this, experiments will be conducted to reengineer the current division headquarters (commander and staff) into a FORCE XXI C^2 System that integrates four separate, yet highly interdependent components of C^2: (1) command and staff *functions*; (2) C^2 *processes*; (3) C^4I^2 *systems*; and (4) *people*. The C^2 System will be capable of conducting all of the military operations and all of the environments listed above in Section 2. Adjustments to the baseline computer simulation model will enable it to be used to study alternative communications and information technologies and to conduct tradeoff analyses on the type and number of staff personnel required for information operations given various distributions on the types and quantity of message traffic.

The initial simulation of a FORCE XXI C^2 System is based upon the concept of a Battle Command Team (BCT) as discussed in (McGinnis et al 1995). The shaded area of Figure 2 depicts a notional organization of a Battle Command Team for the FORCE XXI C^2 System.

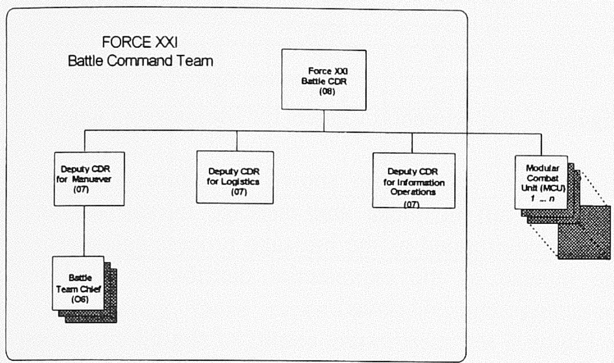

Figure 2. FORCE XXI C^2 System

The C^2 System proposed here will be commanded by a Major General who is supported by three Brigadier General Deputy Battle Commanders for Maneuver, Logistics and Information Operations (IO). These are organized around three critical battlefield functions of C^2, logistics and information operations. Directly subordinate to the Deputy Commander for Maneuver are three Battle Teams, each directed by a former Modular Combat Unit (MCU) commander. The teams are organized and staffed for continuous around the clock information operations to establish and maintain the relevant common picture of the battlespace.

A notional organization of the MCU Battle Team is shown below in Figure 3. The MCU is commanded by a Colonel and is similarly supported by a staff organized around the three battlefield functions of C^2, logistics and information operations.

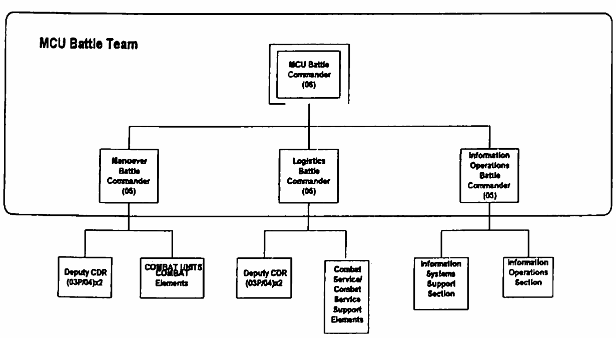

Figure 3. FORCE XXI Modular Combat Unit Battle Team

4.1 Assumptions and Modeling Distributions

The development of a baseline simulation model of the current command and control system accounts for some elements of the seven battlefield operating systems. These are: maneuver, fire support, mobility-countermobility-survivability, air defense, combat service support and command and control. Several examples illustrating how distributions for battlefield systems and processes were determined are given below.

Although TACLAN supports some command and staff functions, interviews with division staff officers and after action reviews (AARs) of recent training exercises revealed there is very little historical data available on tactical message traffic. Furthermore, the data that does exist is poorly documented and of questionable value. Officers recently interviewed from active duty divisions estimated between 3,000 and 3,500 electronic messages may be received within a 24 hour period at division main command posts during a "typical" tactical exercise. Many messages are generated from intelligence sources relaying information about enemy forces, dispositions, and possible intentions. For example, it was estimated that some intelligence sources generate as many as 100 messages per hour. Several after action reports documented approximately 6,000 unread messages left in queue at the end of a 72 hour division-level command post exercise. Obviously, some important information was not available to commanders for decision making.

Given these types of problems, several simplifying assumptions were needed in formulating distributions for modeling the C^2 nodes of the baseline simulation model. These included distributions for message inputs, the types of messages, message queues and message processing time. Based on the interview responses, ten message arrivals / staff node / hour was assumed. Obviously, some nodes will receive more messages per hour and others less, however, on average this seems to be fairly representative of most staff nodes observed. Identification of a real-world distribution of data flowing into a node has not been possible due to the lack of data. Therefore, in the absence of real-world data, the exponential distribution was chosen for modeling this process. Future efforts will focus on collecting actual interarrival data to accurately determine a more appropriate distribution.

Similarly, identification of a distribution for message processing time also suffers from a lack of real-world data. However, interviews with staff officers having recent real-world experience at processing messages at division command posts established a lower bound of twenty seconds for opening and processing electronic messages (i.e., e-mail). The average message processing time for the officers interviewed was approximately three minutes. However, there was much less certainty concerning the upper bound time for message processing. The interview values ranged from five to thirty minutes with the variability depending on the type of message and the type of staff position. Given this, a triangular distribution of T(0.33, 3.0, x) has been selected for message processing time where the maximum message processing time (x) in the distribution is an input parameter varying according to the type of message and staff function being modeled.

4.2 Building the Simulation Model

The baseline simulation model is being built, one C^2 node at a time, using *ProModel for Windows* simulation software. The commander and staff C^2 nodes are currently modeled as first-in first-out (FIFO) single servers with message interarrivals exponentially distributed and message processing time follows a triangular distribution as described above. Processing time delays are also incorporated into the model.

Building a baseline *meta-model* of the C^2 system one node at a time makes the task of verifying and validating the model more straightforward. Several performance measures have been selected for model verification and validation. These include the number of messages remaining in queue, processing time per message, total processing time and estimating various system costs (in dollars) such as the cost per message as a function message transactions and total system costs. These performance measures may be used in subsequent experiments to compare the FORCE XXI C^2 System alternatives against the current baseline system.

5 PRELIMINARY RESULTS

To date, approximately fifty two separate experiments have been conducted using the prototype simulation model. These experiments investigate various relationships between the system measures of performance and operating parameters. For example, the relationship between the number of messages left in queue and message arrival rate was studied by varying the mean interarrival time (from one to thirteen minutes) and maximum message processing time (from five to thirty minutes). Each experiment was replicated thirty times. Figure 4 graphs the results of this experiment, showing the average number of messages remaining in queue after seventy-two hours of simulated time. The results of this experiment are based on a maximum message processing time of thirty minutes for the various message interarrival times shown in Figure 4.

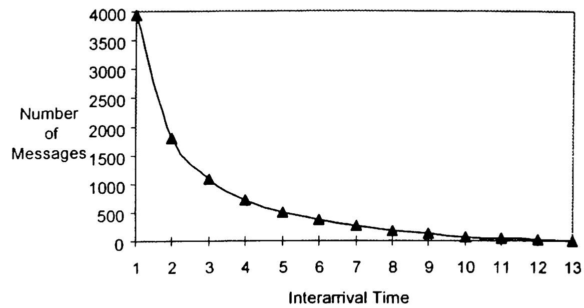

Figure 4. Experimental Results for Messages in Queue

The inverse relationship shown in Figure 4 between messages left in queue and message interarrival time may be interpreted as the message processing rate (i.e., the inverse of the exponential distribution used for message interarrival times).

Figure 5 summarizes the results of the 52 simulation experiments conducted thus far. The results show a linear relationship between message arrival rates and the number of messages remaining in queue.

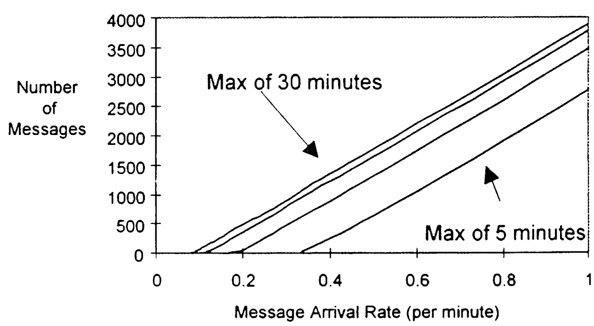

Figure 5. Linear Relationship Between Message Arrivals and Messages Remaining in Queue

From these results, it is possible to solve for the slope and y-intercept as a function of the message arrival rate and maximum message service time. These linear relationships can then be used to predict the number of remaining messages at a given node at the end of a simulated exercise.

$$\text{Number of Messages} = \frac{\Delta \text{Number of Messages}}{\Delta \text{Arrival Rate}} * \text{Arrival Rate} + f(\text{Max Service Time})$$

Future experiments will compare these results to real-world message traffic from command post exercises to validate the baseline model. Following this, the computer simulation model will be modified to depict possible configurations of the FORCE XXI C^2 system. Table 2 illustrates a possible C^2 system configuration.

Table 2. FORCE XXI C^2 Node Analysis Example

Battlefield Operating System	Number of Nodes	Inter-Arrival Mean	Max Service Rate	Remaining Messages
Maneuver	2	14.6	10	300
Intelligence	4	51.0	30	145
Fire Support	2	21.9	15	200
Air Defense	1	7.3	5	300
Logistics	2	29.2	20	150
Mobility/ Counter-Mobility	1	7.3	20	513
Command and Control	3	14.6	20	663

Automating these types of command and staff functions requires additional data that is not available at this time.

6 CONCLUSIONS AND FUTURE WORK

Future combat operations will rely more heavily upon information operations. As the Army continues its move towards a command structure organized around information, it is becoming clearer that the traditional staff organization is unsuitable. The work detailed in this paper demonstrates that a fundamental reorganization of the staff coupled with a simulation-based study of possible alternatives will be greatly beneficial to the Army in redesigning its C^2 structure for FORCE XXI. Upcoming tactical exercises should provide data to validate the baseline model.

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REFERENCES

Banks, J. and Carson, J.S. 1984. *Discrete-Event System Simulation*, Prentice-Hall, Englewood Cliffs, NJ.

Campen, A.D., 1994. *The First Information War*, AFCEA International Press, Fairfax, VA.

Josephson, E.H. and Macedonia, R.M. 1994. *Fighting Smarter: Leveraging Information Age Technology*, The Institute of Land Warfare, Association of the United States Army, Arlington, VA.

Law, A.M. and Kelton, W.D., 1991. *Simulation Modeling and Analysis*, 2nd Ed, New York: McGraw-Hill.

McGinnis, M.L., Barbero, M.P., Hull, G. and Caraccilo, D. J. 1995. *Strategic Framework For Organizing Force XXI For Future Operations*, Technical Report FY95-4, Operations Research Center, West Point, NY.

McGinnis et al 1995. *Critical Battlefield Information for FORCE XXI Commanders*, Technical Report FY95-5, Operations Research Center, West Point, NY.

McGinnis et al 1995. *A FORCE XXI C2 System and Modular Force Structure*, Technical Report FY95-6, Operations Research Center, West Point, NY.

Sullivan, G.R. and Dubik, J.M. 1994. *War in the Information Age*, Strategic Studies Institute, U.S. Army War College, Carlisle Barracks, PA.

Sullivan, G.R., 1994. Unpublished message to the US Army Training and Doctrine Command (TRADOC) Headquarters, Fort Monroe, VA.

TRADOC 1994. *Force XXI Operations: A Concept for the Evolution of Full-Dimensional Operations for the Strategic Army of the Early Twenty-First Century*, Pamphlet 525-5, Headquarters TRADOC, Department of the Army, Ft. Monroe, VA.

AUTHOR BIOGRAPHIES

MICHAEL L. MCGINNIS, the Director of the Operations Research Center at the United States Military Academy (USMA), West Point, New York, is currently attending the Naval War College at Newport, RI. He received a B.S. degree from USMA in 1977, an M.S. degree in Applied Mathematics and an M.S. degree in Operations Research from Rensselaer Polytechnic Institute in 1986, and a Ph.D. in Systems and Industrial Engineering from the University of Arizona in 1994. His current research interests are command and control, modeling and solving manpower requirement problems, and solving large-scale resource scheduling problems by exact methods and heuristic procedures.

ROBERT G. PHELAN JR. is assigned to the Operations Research Center at the United States Military Academy (USMA), West Point, New York. He received a B.S. from the University of Notre Dame in Aerospace Engineering in 1982, an M.E. in Manufacturing Engineering from Boston University in 1984, an M.B.A. from Boston University in 1993 and an M.S. in Systems Engineering from the University of Virginia in 1994. His current research interests are simulation of command and control systems and use of expert systems for resource scheduling.