A MILITARY AND INDUSTRY PARTNERSHIP PROGRAM: THE TRANSFER OF MILITARY SIMULATION TECHNOLOGY INTO COMMERCIAL INDUSTRY

A thesis presented to the Faculty of the U.S. Army Command and General Staff College in partial fulfillment of the requirements for the degree

MASTER OF MILITARY ART AND SCIENCE

by

WILLIAM T. McGUIRE, MAJ, USA

Fort Leavenworth, Kansas
1997

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	6 June 1997	Master's Thesis, 4 August 1996 - 6 June 1997

4. TITLE AND SUBTITLE
A Military and Industry Partnership Program: The Transfer of Military Simulation Technology Into Commercial Industry

5. FUNDING NUMBERS

6. AUTHOR(S)
Major William Thomas McGuire

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
U. S. Army Command and General Staff College
ATTN: ATZL-SWD-GD
Fort Leavenworth, Kansas 66027-1352

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSORING / MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE
A

13. ABSTRACT *(Maximum 200 words)*

This research thesis is a study through a military-commercial industry partnership to seek whether investments in military modeling and simulation can be easily transferred to benefit commercial industry. This document provides a methodology for evaluating military simulation models for potential use in commercial companies. The author uses this methodology to evaluate potential military simulation model transfer candidates for the commercial company Black and Veatch, a capital facility construction and engineering firm. Technological reasons prevented a suitable simulation product from being found for Black and Veatch. However, several models scored well in meeting requisite needs of the company. Because of the similarities in functional requirements for resource management, it appears that military software applications can convert to commercial use.

The contrast in military and civilian goals and the complex nature of software design is a challenge. The President and Congress provide directive authority for military technology transfer. Commercial industry may improve these products and DOD can realize savings from licensing agreements and cost sharing according to US Commerce and Trade Code and Federal Acquisition Regulations.

14. SUBJECT TERMS	15. NUMBER OF PAGES
Simulation, Comercial, Industrial, Modeling	86
	16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED

MASTER OF MILITARY ART AND SCIENCE

THESIS APPROVAL PAGE

Name of Candidate: MAJ William Thomas McGuire

Thesis Title: A Military and Industry Partnership Program: The Transfer of Military Simulation Technology Into Commercial Industry

Approved by:

____, Thesis Committee Chairman
MAJ Rickey E. Cox, M.B.A.

____, Member
James D. Johnston, M.S.

____, Member
COL Thomas J. Pawlowski III, Ph.D.

____, Member, Consulting Faculty
LTC John M. Rogers, J.D.

Accepted this 6th day of June 1997 by:

____, Director, Graduate Degree Programs
Philip J. Brookes, Ph.D.

The opinions and conclusions expressed herein are those of the student and do not necessarily represent the views of the U.S. Army Command and General Staff College or any other governmental agency. (References to this study should include the foregoing statement.)

ABSTRACT

A MILITARY AND INDUSTRY PARTNERSHIP PROGRAM: THE TRANSFER OF MILITARY SIMULATION TECHNOLOGY INTO COMMERCIAL INDUSTRY by MAJ William T. McGuire, USA, 86 pages.

This research thesis is a study through a military-commercial industry partnership to seek whether investments in military modeling and simulation can be easily transferred to benefit commercial industry. This document provides a methodology for evaluating military simulation models for potential use in commercial companies. The author uses this methodology to evaluate potential military simulation model transfer candidates for the commercial company Black and Veatch, a capital facility construction and engineering firm. Technological reasons prevented a suitable simulation product from being found for Black and Veatch. However, several models scored well in meeting requisite needs of the company. Because of the similarities in functional requirements for resource management, it appears that military software applications can convert to commercial use.

The contrast in military and civilian goals and the complex nature of software design is a challenge. The President and Congress provide directive authority for military technology transfer. Commercial industry may improve these products and DOD can realize savings from licensing agreements and cost sharing according to US Commerce and Trade Code and Federal Acquisition Regulations.

TABLE OF CONTENTS

LIST OF FIGURES

Figure | Page

CHAPTER 1

INTRODUCTION

Many factors indicate that the Department of Defense (DOD) should expand their efforts in transferring military computer simulation technology investments into United States commercial industry. This research thesis is a study, through a military-commercial industry partnership, to seek whether investments in military modeling and simulation can be easily transferred to benefit commercial industry. This document provides a methodology for evaluating military simulation models for potential use in commercial companies. The author uses this methodology to evaluate potential military simulation model transfer candidates for the commercial company Black and Veatch, a capital facility construction and engineering firm. Technological reasons prevented a suitable simulation product from being found for Black and Veatch. However, several models scored well in meeting requisite needs of the company. Because of the similarities in functional requirements for resource management, it appears that military software applications can convert to commercial use.

Technology transfer of military computer simulations to commercial industry complies with congressional law and presidential directive and may save the DOD money. The president has directed the Secretary of Defense to identify potentially useful technologies and make them readily available to US industry.[1] "Through technology transfer, the government shares the benefits of national investments in scientific progress with all segments of society."[2]

Congress states by statute that promoting technology transfer to the private sector enhances national security.[3] "It is the continuing responsibility of the Federal Government to ensure full use of the results of the Nation's Federal investment in research and development."[4]

The primary question is: Are military developed computer simulation models available that can be easily modified to improve the business resource management for commercial companies? Although the answer turns out to be no for the Black and Veatch case study, the question is important. The President and Congress provide directive authority for military technology transfer. Commercial industry may avoid research and development costs if they can cost-efficiently adapt existing military computer simulation model products to meet their requirements. Commercial industry may improve these products and offer the military an option to leverage the results of these improvements at a cost saving. DOD can realize savings from licensing agreements and cost sharing in accordance with US Commerce and Trade Code and Federal Acquisition Regulations.

The author developed a general methodology for evaluating military simulations for technology transfer and calls it the Military Simulation Transfer Process. The Military Simulation Transfer Process has five parts: literature review strategy, requirement determination, translating military requirements, simulation model candidate search method, and value analysis. The contrast in military and civilian uses for simulation models and the inherently complex nature of software design are challenges in finding suitable simulations for simulation technology transfer. Computer technology advancements may have made current military simulations in inventory obsolete. The evaluation approach may be used for any commercial company.

This document is the result of a research partnership between the United States Army, Command and General Staff College, Graduate Degree Programs, in coordination with Fort

Leavenworth's Department of Logistics and Resources Operations and the commercial company Black and Veatch. Black and Veatch is an example of U.S. commercial industry that would benefit from computer simulations.

Black and Veatch is an engineering and construction firm that specializes in the fields of energy, environment, processing and buildings. Headquartered in Kansas City, Missouri, they have offices worldwide in Europe, Australia, Africa, and several countries in the Far East. The firm provides complete engineering, procurement, construction, architectural, financial, and management consulting services for utilities, commerce, industry, and government agencies. It is an acknowledged leader in electricity generation, sewer-solid waste and environmental consulting contracts. Revenues in 1995 were $1.1 billion. They have a global information network to handle communications among its many offices and to maintain a global presence.[5] Black and Veatch is a commercial company that wants a viable military simulation model to help them. The search for a military product to meet Black and Veatch requirements is presented in this document's case study.

The significance of this study is that it provides a methodology for evaluating whether the military's simulation modeling technology is of value to commercial industry. The President and Congress direct those technology transfers to private industry if military simulations are of value for commercial use. The National Security Strategy states, "A central goal of our national security strategy is to promote America's prosperity through efforts both at home and abroad."[6] Additionally, this study considers the possibility for DOD to recover some of the costs of its simulation expansion from contractors that sell, lease, or license the resulting products of software development.[7] The military can possibly save money by using cost-sharing contracts with industry for future simulation developments.[8] Commercial industry and the military can cooperate for common objectives.

There are many similarities between a military operation of moving weapons and soldiers to a war zone and how a company like Black and Veatch move equipment and people to build a large facility. Both must transport materials and people (by specific skill) along with equipment and tools (by type) and use these resources within a specified land area. Comparable simulation products are not available to commercial industry. Black and Veatch wants to improve their competitiveness by simulating the variables that affect their business interests to engineer and build projects in the US and abroad. They need the "what if" analysis put into their plans and alternative strategies to improve efficiency, forecast requirements, and aspire to discover new opportunities.

Commercial industries want many of the same benefits as the military. Simulations can provide possible reductions in resource costs and improve acquisition efficiency and enhance the decision-making process for senior executives and their subordinates. Project plan scenarios are repeated for training and analysis. The company's information network distributes improved plan scenarios globally for interactive simulations between project teams. Simulations can experiment with the composition of project teams, work force structure, and production systems. This allows a project rehearsal to display on a "virtual" topography.[9]

The DOD and commercial industry seem to have parallel goals for simulations. The Department of Defense Modeling and Simulation Master Plan "endstate" describes a future simulation model product that commercial industry should be willing to invest in for their benefit. A commercial benefit is obvious when the description of this "end-state" simulation is reworded into commercial terminology. The "end-state" in modeling and simulations:

1. Become a primary tool to validate work (operational) requirements, structure, and tenets (doctrine) at industrial (strategic), corporate (tactical), and individual (entity) levels.

2. Simplify "what if" analysis for projects (missions).

3. Determine the likely impact of actions against specified work (operational) capabilities.

4. Support the cost, production, and maintenance assessment across collective (joint) capabilities.

5. Forecast the arrival time capability of resources (forces), the time required to build up construction potency (combat power), and how to sustain work (operations) to support a project (mission).

6. Test new concepts, designs, theory (doctrine), techniques (tactics), procedures, and systems into a synthetic environment (battlefield).

The scope of this thesis is to provide a general methodology for evaluating a military simulation model's value to a commercial company. Black and Veatch is being used as a case study. The rationale is if a military simulation model product is useful to them as a construction simulation system, it will also be useful to many other commercial industries. Research will use currently available military model simulations and will not involve those in development. Object-oriented modeling and design, described later, is the goal of software structure. This study will not include product testing or a "Proof-of-Concept" demonstration to validate identified software products. A detailed study of recent advances in simulation technology is not within the scope of this project.

The case study conclusion will consider each of three alternatives:

1. No, there are no military simulation models currently available that provide the functionality to transfer to commercial industry (Black and Veatch).

2. One or more simulation models provide limited capability to fulfill commercial industry (Black and Veatch) requirements.

3. Yes, there are one or more simulation models that have a high probability for transferal to commercial industry (Black and Veatch) purposes.

This document is the property of the US Army, Command and General Staff College. This document will not address any aspect of how a commercial company may obtain a military simulation model. All information will come from unclassified sources. Results of this research will be publicly available and will not provide Black and Veatch unfair competitive advantage over other commercial companies.

In summary of this introduction, the President's United States Security Strategy states:

> We are building on . . . other steps to improve American competitiveness: . . . assisting integration of the commercial and military industrial sectors. Structuring our research and development effort to place greater emphasis on dual-use technologies that allow the military to capitalize on commercial sector innovation for lower cost, higher quality and increased performance.[10]

Adapting military simulations into commercial industry sector complies with the President's guidance and may save the DOD money, improve domestic prosperity, and improve the quality of future simulation model design. It is important to see the feasibility, or the impossibility, for future inquiry in this field.

---

[1]Technology Innovation. Executive Order No. 12591, Facilitating Access to Science and Technology, Section 5.

[2]Technology Innovation, Federal Laboratory Consortium for Technology Transfer, III.

[3]Technology Innovation, The Code of Laws of the United States, Title 15, Commerce and Trade, Chapter 63--Technology Innovation, Congressional Findings and Declaration of Purpose; 1989 Amendment (b) (1).

[4]Technology Innovation, The Code of Laws of the United States, Title 15, Commerce and Trade, Chapter 63--Technology Innovation, Section 3710, (a) (1) Policy.

[5]Black and Veatch Homepage. http://www.bv.com 1995-96.

[6]National Security Strategy, 26.

[7]Federal Acquisition Regulation, Recoupment. 1996, 30,734.

[8]Federal Acquisition Regulation, Cost Sharing. 1996, 30,734.

[9]Based on Army Model and Simulation Office Goals, http://www.misma.army.mil:443/amso), 10 Dec. 96.

[10]National Security Strategy, 27.

CHAPTER TWO

RESEARCH METHODOLOGY

This chapter outlines in detail the specific research methods and techniques applied to answering whether there are military-developed computer simulation models available that can be modified for commercial companies. A description of the five parts of the Military Simulation Transfer Process research methodology helps understanding the investigative plan when used in the Black and Veatch case study. The author's understanding of the strengths and weaknesses of the methodology closes this chapter.

This methodology came from applicable portions of a Training and Doctrine Command (TRADOC) study guide, a military college student text for research and thesis writing, and personal experience in information systems management.[1] Relevant parts were collected together to form an applicable research methodology. The methodology for evaluating a military simulation model for commercial industry has five parts:

1. A literature review of how the military currently uses simulation models and current simulation technology.

2. Definition of commercial company's requirements.

3. Translation of the commercial company's requirements and work processes into military equivalents.

4. Identification of the simulation model candidates for evaluation.

5. Definition of value criteria and appraising of the data results for the company.

Military Simulation Transfer Process

Part One: Literature Review

The literature review focuses on updating the researcher on how the military uses simulation models now to meet its requirements. It assesses current simulation software development techniques available in the military and commercial markets. The purpose is to customize the research plan to the target company. Primary sources of information are Government official publications, textbooks, journal articles, and interviews with simulation model engineers employed by the military that develop and support simulation models. Secondary sources are articles that cover the target company's automated information system, industry publications, and product advertisements that promote new products.

The review familiarizes the investigator with the target company's business and the military equivalent occupational specialty. If the target company is a financial company that wants budgeting simulations as an example, the DOD financial offices, banking journals, and articles pertaining to new automated investment tools add more pertinent information and detail towards solving the target company's problem. A moving company would direct research into military logistic organizations and commercial transportation. This literature review should delve into the minute parts beyond the basics that apply to the target company's specific needs in modeling and design techniques, computer systems, and military simulation model design.

Part Two: Work Requirement Definition

The second part of the Military Simulation Transfer Process identifies the target commercial company's planning requirements for comparison to military planning requirements. After the problem is explained, tailoring the following secondary questions for the target company defines a set of criteria for measuring a product value.

What are the simulation requirements?

1. What does the company do?

2. Who is the target audience?

3. What is the environment that the company wants the simulation model to work within--land, sea, air, or other?

4. What are the technological limitations that the company must impose for the product to be useful?

The explanations of these questions follow:

The target company must express its simulation work requirements. This part of the process specifies what is done, who does it, and where the work is to be conducted. The four inquiry subject areas used to specify the who, what, and where are functional organization, audience, environment, and technology criteria. The functional organization, audience, and environment describe the employment characteristics. The technology defines the company's information system and its automation capability in terms of computer hardware, database design, and communication network.

The functional aspects of the company state what tasks are completed, who completes them and when. Questions are asked as to what product or service is produced for sale? Who performs the tasks and how is it done? The purpose is to find out the general objectives of the company and what processes are used to achieve them. These are later translated into military missions and processes. Since the company wants simulations to support their work, the researcher must know the detail of work that they want to model.

A moving company wants, as a general example, a simulation model to help solve a problem. Maybe they suffer problems in moving material on time. The goal is to move objects from point A to point B on a time schedule. Trucks, warehouses, loading docks and heavy equipment are used. Personnel are hired as truckers, managers, inventory clerks, and loaders. The processes are described by task and employee--from receiving a request to loading, moving, tracking and delivering the goods. This portion of the methodology locates the processes and participants in the problem area. The goal is to show the organizational works (Are they using a prescribed process?) and what level of the executive, supervisory or worker framework is involved.

The next step is to identify the target audience. The researcher first asks the question: Who is providing the data for the simulation and who gets the most benefit from the information? The target audience is usually the focus of the company's problem. For example, a commercial cruise line state that its problem is being unable to provide adequate food services during peak activity hours. The target audience is the kitchen employees who would provide data on planned meal attendance and times and receive back a simulation critique. The simulation results may have many audiences because the information benefits those who schedule, escort, and entertain passengers--and management who budgets, supervise and hire. However, the company's problem is solved by the target audience.

The environment simply states whether the work is performed on a geographic land mass and uses air, land and sea routes or needs to simulate a different medium. The environmental criteria asks what kind of outside unbiased influences must be part of the simulation model in order to provide a realistic perception to the user. A manufacturing company that uses water routes and land routes needs a model that takes these environmental factors into account. However, a financial company who wants to simulate investments may want a medium that simulates results from competing governments, weather, and natural disasters. Finding out the simulation setting provides criteria for the later search for products.

The computer system that runs a simulation model needs to be compatible to the company's information system. Target companies may propose a specific design structure easily accepted by automated systems already in place. Low-level technology requirements would allow non-computerized procedural simulations. The age of a simulation is a criterion because technology advances in software design has created generations of programs that require out-of-use computer systems. The age of the software should conform to the already established information system of the target company to fulfill performance expectations.

A suitable simulation model for this study required flexibility to allow military entities, like tanks, to be replaced by industrial entities (cranes, bulldozers, etc.). The obvious logic is to build upon a confirmed system in contrast to a new unproved one. However, making changes to computer software involves risk of introducing inconsistencies and errors that affect the entire program.

Software development is expensive and tedious. Software product designs tend to be a series of interconnected components designed to do a single job, and do it well.[2] Computer software is inherently complex because it translates real events, equipment, circumstances and people into a mathematical domain of rules and equations. Advances in making computer programs "user friendly" has created an illusion of simplicity in what is really a complicated, labor intensive product.[3] Fixing one part often breaks many other parts. Seemingly slight changes often involve tedious correction of data links and retranslating source code (recompiling) into machine language.

This research focuses on finding find computer programs with independent interchangeable components introduced in software design in the early 1990s. This is critical because, the subroutines and math equations (algorithms) of an infantry platoon in the attack may not easily translate into a parallel structure in a corporate world.

Software developing companies and the government program managers both add human elements to the inherent complexity of simulation software development. Software developers want to be connected to their products. It is logical to assume that it would be in the developer's interest to fashion software to be fragile to change as a means to ensure future maintenance and upgrade contracts. Many of the most complex simulation programs in the military inventory are ones that have fulfilled requirements since the 1970s and 1980s. Government organizations saved money in enhancing functionality by adding onto older, preexisting software code rather than investing in a streamlined rewrite. All software programs older than ten years that required extensive processing power, existed on (now out of date) mainframe computers. Porting, or transferring the programs from an obsolete operating system to a UNIX type multi-processing language may add risk to product stability.

A desirable function in a software product is a graphical user interface for easy changing of objects, attributes and behaviors. The alternative method is changing the model objects by a time consuming process of rewriting the software code. The items of the data structure should be easily corrected or changed without negatively impacting other parts of the simulation model. This requires an analysis of the complexity of the system by scanning the linkages that thread the data paths throughout the system. Proposed products could not require that source code be recompiled after changes to the data files. Changing the data structure object's names, behaviors, and values should not require tedious reversed tracking of individual changes through algorithm modules.

In brief, as work requirements are documented, this process also establishes criteria for selecting simulation candidates and measuring value to the company. The target company's functional organization shows task requirements. The audience specifies the informational product needed. Environment defines the working space for functional and information activities. Technology tailors the product to the company's information system. The collection of the company's requirements makes finding a suitable model easier because the consolidated military simulation catalog identifies product functionality, target audience, environment and technical requirements for retrieval. The work requirements for the target company are translated into military equivalents in the next part of the Military Simulation Transfer Process.

Part Three: Translating Military Equivalents.

The process translates functional, audience, and environment into military equivalents. The military establishment has developed many regulated processes that support war missions. The Force Development Process designs the military capabilities, structure, and manpower.[4] Army training uses a planning process.[5] The Tactical Decision Making Process is used to plan operations for combat troops.[6] The Army Modeling and Simulation Office supports these processes with simulation products for leaders and soldiers.[7] The company's work process must be translated to match a military process in order to find a suitable product.

To translate military processes into the targeted commercial company's processes, a description of the organizational structure, the commercial product and the tasks to be simulated is required. The work that the company does is broken down into processes or tasks. These parts need to be represented into objects or events. Relationships are then linked from object to object. Then the purpose of the simulation is categorized into training or analysis. The difference between a training and an analytical simulation model primarily in the level of computational rigor to represent reality. A training simulation need only be real in the perception of the user, data accuracy is secondary to stimulating a mental process: an analytical model demands accurate data and a representative outcome.[8] The need for a training or analytical model is used later in part five of the Military Simulation Transfer Process, Value Criteria and Analysis.

A construction company is used to illustrate the translation into military equivalents. The company needs to simulate moving large numbers of people, equipment and materials to a distant country in order to build a large facility. They also want to simulate actions at the building site and use current data from their computer database so that the headquarters can analyze the results. It looks like these actions match the six operational phases of military Force Projection and the seven Battlefield Operating Systems for war. (See figure 1.) The target company's processes for their project planning converts into the five phases of Force Projection:[9]

1. Mobilization is the process where the active forces are augmented in preparation for war. The company hires people, buys/leases materials and equipment.

2. Deployment is the movement of resources into the area of operations. The company does the same.

3. Entry Operations in an unopposed environment involve arrival of resources through airfields, sea ports and road networks into a stable lodgment area. This process is the same for the target company.

4. Operations involve performing your mission. The company builds the building.

5. Post conflict/war termination is restoring of order, minimizing the confusion after combat operations, and preparing forces for redeployment. The company collects payment and leaves the site.

6. Demobilization is the process where augmented forces return to the premobilization state. The company returns to their headquarters site.

The company's functional/organizational structure for a project is then translated into the seven Battlefield Operating Systems.[10] The Battlefield Operating Systems appear to be similar to the construction company's operational components.

1. Command, Control, Communications, Computers and Information are the interacting processes that allow leaders to direct, supervise, receive and provide information. These processes form unity of command and direct effort toward common objectives. The company has the same functional requirements.

2. Intelligence gathers information on the enemy. Information on competition, weather, labor unions, budget shortfalls, and local populations are used for the company.

3. Maneuver gains operational results. Commanders maneuver their forces to create conditions for success. This matches a commercial company's needs.

4. Fire Support provides additional combat power in support of maneuver forces at the operational and strategic level. This system can be translated into special skills, heavy equipment, and additional funding.

5. Logistics sustains the force by feeding, manning, fixing equipment, and transporting resources. This system is the same for a construction company.

6. Mobility/Survivability ensures access and use of land routes and the hardening of facilities and mission areas for survivability. This is translated into road crews, site engineers, and civil engineering.

7. Air Defense provides protection from air attack. This system does not apply to the target company and can be dropped as an irrelevant system.

The phases of Force Projection and Battlefield Operating Systems will work for the example construction company. The links between the military processes (objects) are predefined when placed in a simulation model, these links must be verified so they match the construction company. Noting the military processes that match the civilian company's work process help narrow the search criteria for finding a suitable simulation model. Later, in the analysis, the simulation candidates are scored for worth in imitating the target company's work processes. The next step is to match the military and civilian personnel (object) job description. This compares the military rank structure to the civilian occupation.

A comparison of military rank hierarchy equates to target company work positions and responsibilities. One distinction in military and civilian work positions is that the function of rank in the military is vested in the person--the civilian's rank is vested in their work position.[11] This methodology uses the ranks of colonel, lieutenant colonel, captain, lieutenant, and sergeant to cover the range of work responsibilities and match the civilian audience categories. Lieutenant colonels are usually battalion commanders, and captains are either smaller unit commanders or staff officers. (See figure 2 for more detail on rank responsibilities.) The military has traditionally matched its rank structure to work positions. Identifying the target audience in a model candidate is simplified because military simulation models normally assign military rank positions for participant roles.

In summary, the third part of the Military Simulation Transfer process takes the civilian work processes and individual occupation status and compares them to predefined military mission processes and rank structure. With the results of the target company's translation to military equivalents for function, audience and environment, the researcher has narrows the search using criteria for selecting simulation model candidates in Part Four.

Part Four: Model Candidate Search

The fourth part of the Military Simulation Transfer Process is selecting prospective military simulation models. The following questions are asked to collect suitable military simulation products.

1. What simulation models are available for meeting the target company's functionality requirements?

2. Is there one simulation model that meets all of the target company's requirements?

   a. Can the requirements be met using several simulation model products?

   b. Is the purpose of this simulation for training, analysis or both?

   c. What is the goal of the simulation for the company based on the organizational, audience, environment, and technology criteria?

   d. Will the company need to add and change rules and parameters to simulation algorithms?

   e. Are there any special technology considerations?

Finding the sources of information that describe military simulation products and who sponsor them is critical to achieving this task. The Defense Modeling and Simulation Office (DMSO) is working toward consolidating defense simulation information. Updated information on military simulation inventory, design, functionality and sponsoring agencies is available through the Defense Modeling and Simulation Homepage and linked databases.[12] A sub-element of DMSO, the Defense Modeling, Simulations and Tactical Technology Information Analysis Center (DMSTTIAC) provides search engine capabilities of DOD and Service catalogs.[13] DMSTTIAC provides links to (among others):

1. Models and Simulations: Army Integrated Catalog (MOSAIC),
2. Special Operations Forces (SOF) Simulations,

3. C4I Modeling and Simulation Catalog (DISA/D8),

4. Navy Catalog of Models and Simulations, and

5. SMC/Aerospace Modeling and Simulation Tool Database.

The National Simulation Center, the Defense Information System Agency, and the Army Model and Simulation Office use World-Wide-Web technology to provide product information on simulations that they manage. DMSTTIAC also provides staffed research support for finding information about DOD simulations. The consolidation of all information on DOD simulation models is not complete. Although some products are not yet in the database, these centralized repositories are the best available resources for finding simulation products. The consolidated databases have query search engines permitting a survey of products based on targeted functional, audience, environment, and technology search parameters.

The simulation search process is complete when the investigator has used the consolidated military simulation repositories, World-Wide-Web internet access to program offices, and interview referrals within the time allotted. The process for model search is described in better detail when used for the case study (Chapter 4).

Part Five: Value Criteria and Analysis

The fifth part of the Military Simulation Transfer Process defines value criteria and conveys an appraisal of the data results for the company. Each criteria tailors value to the individual target company depending on the intended use. The target company must further define the criteria stated in part two (requirement definition) and prioritize importance. The investigator should ask the target company the following questions to further define company needs:

1. Is the purpose of this simulation for training, analysis or both?

2. What is the goal of the simulation for the company based on the collected organizational, audience, environment, and technology criteria from part two and three of the Military Simulation Transfer Process?

3. Will the company need to add and change rules and parameters to simulation algorithms?

4. Are there any special technology considerations that must be taken into account?

The answers to these questions provide more information to allocate a value score for the simulation model. These questions are outlined and explained for better understanding in Chapter Four's case study. These scores provide the basis for appraising the results.

The analysis of the collected data is a judgmental evaluation based on the information gained from the literature review, interviews, part two criteria and value scores. This evaluation results in one of the following conclusions:

1. No, there are no military simulation models currently available that provide the functionality to transfer to this commercial company.

2. Yes, one or more simulation models provide limited capability to fulfill this company's requirements.

3. Yes, there are one or more simulation models that have a high probability of meeting this company's requirements.

Strengths and Weaknesses

The strength of this methodology is that it uses both factual data and judgmental analysis in evaluating whether requirements are met. The Military develops software to specified requirements.[14] The methodology for creating search and value criteria provides simple yes and no answers that limit ambiguity. Military simulation models that meet any of the search criteria will provide a measure of value to the target company. The weaknesses of this methodology are in the measurement of value. Simulation products are evaluated by the number of positive responses to search criteria and the judgmental assessment of the product's engineers from interviews. There is no measure for product excellence. A simulation product that performs just one required task extremely well will have a lower value score than a marginal simulation that performs more than one required task. Finally, the Military Simulation Transfer Process lacks a cost effectiveness measurement that defines a level of worth to forecast the expense of changing the product to meet commercial needs.

In summary, the five part Military Software Transfer Process provides a methodology for searching for and evaluating the military simulation models for adaptability to commercial business. The literature review updates the investigator on current military and civilian simulation development and usage. Exploring and documenting the target company's requirements provides criteria for selecting a software candidate. Asking questions that explain the target company's functional needs, audience objective, environmental parameters and technological limitations define requirements and establish judgment criteria. Searching for simulation model nominees is the third part of the process. Scoring the software nominees against the target company's requirement criteria and judgmental analysis finishes the methodology. This methodology provides relevant information, measurable data and a valuation on the adaptability of military software products to commercial industry.

---

[1]TRADOC PAM 11-8 (Outline for Study Plan), Command and General Staff College Student Text 20-10.

[2]Stephen Coffin, <u>UNIX System V the Complete Reference</u>, (Osborne McGraw-Hill, 1990), 6.

[3]Grady Booch, <u>Object Oriented Design and Applications</u>, (Benjamin/Cummings Publishing Company, Inc., 1991), 4.

[4]U.S. Army Command and General Staff College Student Text C430, Resource Planning and Force Management, (Fort Leavenworth, Kansas, Jan. 1997), 30.

[5]U.S. Department of the Army, FM 25-100, Training the Force, (U.S. Army Combined Center, Fort Leavenworth, Kansas, Nov. 1988), 3-1.

[6]U.S. Army Command and General Staff College, ST 101-5 The Tactical Decision Making Process, (Fort Leavenworth, Kansas, 20 February 1996)..

[7]U.S. Army Model and Investment Plan for Fiscal Years 98-03.

[8]Denis Chrisman, National Simulation Center, Interview by author, (Fort Leavenworth, Kansas, 10 January 1997, and 9 April 1997)

[9]U.S Department of the Army, FM 100-5, Operations, (Washington DC: 14 June 1993), 3-9 to 3-12.

[10]Ibid., 2-5, 2-12, 2-13.

[11]U.S. Army Command and General Staff College Student Text C430, Resource Planning and Force Management, (Fort Leavenworth, Kansas, Jan. 1997), 313.

[12]Defense Modeling and Simulation Office, Information Library Search Engine, available: http://www.dmso.mil/systemsearch.html, 21 Jan 97.

[13]Defense Modeling, Simulation and Tactical Technology Information Analysis Center, Support Services, available: http://www.dmsttiac.hq.iitri.com, 8 Jan 96.

[14]U.S. Department of Defense, DOD Instruction 7935.1-STD, DOD Automated Data Systems Standards, (U.S. Government Printing Office, Washington, DC: 13 Sep 97), 3-3.

CHAPTER THREE

REVIEW OF LITERATURE

This review of literature describes and evaluates the existing literature on transferring military simulation technology to the commercial sector. This chapter will discuss the DOD's efforts to transfer military simulation models into other uses, such as computer automation and simulation modeling design and development. Also an explanation and evaluation of available information sources and their relevance to this study are given.

This study expands on a new area of government and commercial research and development. A survey of published literature lacks instances of military simulation models being adapted to commercial use from the original goals of simulating military operations in support of war. There is one case where the Training and Doctrine Command (TRADOC) Analysis Center (TRAC), a designated federal laboratory, has successfully transferred a military simulation to commercial industry. An interview with Ms. Cathy Corley, an Operations Research Analyst for TRAC, described a government built computer simulation called Combined Arms and Support Task Force Evaluation Model (CASTFOREM) that was transferred to Texas Instruments under a cooperative research and development agreement (CRADA).[1] The CRADA granted Texas Instruments the right to further develop the model with a view for further commercialization. It provided for both annual licensing fees and royalties on commercial sales payable to the U.S. Army. Texas Instruments learned of CASTFOREM from an separate government contract and wanted to enhance the capability for commercial sale. Texas

Instruments paid the government for the technolgy transfer and TRAC received a percentage of this money for its own operational budget and bonuses for government inventors.

In another interview, Mr. Kim Judd, of the Fort Leavenworth Staff Judge Advocate's Office, said that technology transfer has many advantages and the Army needs to become educated on the benefits.[2] Mr. Judd stated that the Cooperative Research and Development Agreement (CRADA) provides a relatively easy way for a commercial company to sign a contract with a government laboratory so the company can continue to develop the simulation model. The unique aspect of a CRADA is that it is not governed by the Federal Acquisition Regulation. The transferring government agency gets money from the industrial partner for their own operational budget. Army Regulation 5-11, Management of Army Models and Simulation governs the release of Army simulation technology. Additional information on the CRADA, and other governing regulations for simulation transfer are available through federal publications and Army regulations.[3]

Additionally, only published instance of a military simulation model transferred over and changed for local government was found.

The US Army Simulation, Training and Instrumentation Command (STRICOM) has adapted a military simulation for Orange County, Florida. Orange County uses it to train people in emergency management. PLOWSHARES is a program that trains government civilians on how to respond to large-scale disasters, such as hurricanes, fires, tornadoes, structure collapses, and hazardous material leaks.[4]

There is literature on the different parts that comprise information systems. These subjects support the investigative methodology by providing background on the complexity of automated systems, software design, simulation modeling, and object-oriented design. Computer system literature is available to provide the general information needed to identify

UNIX language detail and network basics.[5] The value of this information is to provide criteria for measuring simulation candidate complexity and to see if they would merge into the Black and Veatch computer network. Computer systems have the most extensive level of authoritative works but provided only indirect supporting background for this research document.

Articles and books provided information on simulation software design.[6] Research into current simulation model design provides background for measuring obsolescence in military simulation product candidates.[7] Searching for a military simulation model design technique that has been adapted from commercial industry may provide easier transition back for commercial use. The extent of work in simulation modeling is not large. The author believes that the authorities cited below are valid for two reasons. First, these documents describe successful techniques already used in commercial industry. Second, each of the articles references the same techniques for the basis of their successful application of simulation design. Secondary sources of information discussed past data structure design techniques and obsolete knowledge-based expert systems.

Norman Nielsen's work on artificial intelligence provided the basics for representing decision-making actions into computer models.[8] Mr. Nielsen showed techniques on how object-oriented modeling can break down a person's knowledge of an occupational skill into a factual list of capabilities and behavioral procedures.[9]

Tuncer Oren provided information on how simulations process knowledge in his article "Dynamic Templates and Semantic Rules for Simulation Advisors and Certifiers." He broke simulation information processing into knowledge types of methodology, relevant representation, domain, and mathematical theorems. He recommended that each knowledge type be imbedded into a software product.[10]

Jeff Rothenburg, in his article for "Knowledge-based Simulations," and Jeffrey Esakov and Norman Badler in "An Architecture for High-Level Human Task Animation Control," described how military simulations are designed in comparison to non-military simulation models. Mr. Rothenburg defined a "Continuum of Stringency" that described the differing requirements of simulations built for analysis, gaming, and knowledge-based decision support.[11] This information was useful for grouping military simulation products and contrasting them to Black and Veatch requirements. Mr. Esakov and Badler emphasized the uncertainty of battle-planning software and some of its inherent flaws and introduced blackboard design concepts. Stated simply, blackboard design is where each part of the functionality has space on a hypothetical blackboard. These spaces on the blackboard represent an area of interest with a computation. The simulation user requests an action, and the computer scans the virtual blackboard for something it knows applies, the program erases old data, posts new data, and completes the action.[12] The value of blackboard design modeling is that it simplified the task of requesting an action and getting an answer.

Ben Wise and Richard Modjeski provided insight on the complexity of command and control simulations in their article "Uncertainty Management in Battle Planning Software." Monte Zweben, Brian Dunn and Michael Deal wrote an article called "Scheduling and Rescheduling with Interactive Repair," about simulating work schedules. It is difficult to define modeling components when simulating a continuously modified work schedule.[13] The mechanics of modeling command and control simulations explained what conflicts within a scenario would look like in a virtual computer environment.

The National Simulation Center, Fort Leavenworth, Kansas, provided literature and authoritative engineers for training simulations used by the DOD. The National Simulation

Center's student course textbook Training with Simulations is a comprehensive work for stating the practical use of computer simulations for training military leaders.

In the initial interviews, Black and Veatch directed that object-oriented modeling design was the goal structure to meet its needs. Objects in Action: Commercial Applications of Object-Oriented Technologies (Paul Harmon and David Taylor), Object-Oriented Modeling and Design (James Rumbaugh, et al.) and Object Oriented Design with Applications (Grady Booch) provided the author the information to define what object-oriented design meant and its importance to Black and Veatch.

Object-oriented design provides two benefits: better functionality and maintenance. An object is a software package that contains related data and procedures. Software objects depict real-world objects. In contrast to other design methods, the unique quality of object-oriented technology is that the software objects can interact with each other as their real-world counterparts do.[14] The object-oriented approach affects future maintenance change by providing a modular and thus more stable organizational structure to the software. The organization of object-oriented design allows changes to the software parts without damaging the integrity of the whole. Object-oriented system planning shifts much of the development into the early analysis phase. Data structure has emphasis over functions performed because data is less vulnerable to changing requirements than the operations performed on the data.[15] A typical software procedure using object-oriented techniques incorporates three modeling processes: object, dynamic, and functional. Data structure describes the object model. Sequencing the object in time uses a dynamic model. Transforming values uses the functional model.[16] Good object-oriented design isolates these three types of models and minimizes the coupling between them.[17]

Objects contain two types of knowledge encapsulated and protected from outside interference (see figure 3).[18] One is the factual characteristics, called attributes or data, that describe the object's identity, capabilities, current status, and parameters (boundaries). The other is the behavioral knowledge that describes how the entity will behave in certain circumstances.[19] The ease in changing object oriented modeling involves instituting an inheritance mechanism of obtaining attributes and behaviors among classes of objects. Superclasses contain features common to all. A subclass object inherits from the higher and each subclass continues refinement down to more detailed levels so any change in a higher class is automatically passed to its subclass objects. (See figure 4.)[20] All the characteristics of object-oriented modeling, encapsulated information, limited linkages, and inheritance, provides a more stable software product.

This research study is unique because there was little available literature found by the author for applying military simulations into the commercial market. This document fills this gap of knowledge for evaluating current military simulation model inventories for possible uses in the civilian world.

Relationship to Previous Studies

This thesis supplements previous work in military technology transfer, automating command and control, work scheduling, and object-oriented design. This document adds to related material in simulation development, software acquisition and automated management tools.

The PLOWSHARES initiative of adapting a military simulation model called JANUS for emergency disaster relief is an example of technology transfer outside the military domain. This is an example of one government agency helping another. The goal of the project was for training people in marshaling resources in response to disaster. The DOD used the JANUS simulation model for this program. This study expands the PLOWSHARES effort by documenting a more structured process in simulation transfer.

The article "Uncertainty Management in Battle Planning Software" (Ben Wise and Richard Modjeski) for command and control and the book Scheduling and Rescheduling with Interactive Repair (Monte Zweben, Brian Dunn and Michael Deal) in simulating work schedules shows interest in addressing the functional requirements discussed in this thesis for information systems. This document provides detailed research into military simulation modeling and available products where common functionality could be useful in commercial industry.

---

[1]Cathy Corley, Operations Research Analyst, TRADOC Analysis Center, interview by author, (Fort Leavenworth, Kansas, 22 Apr. 97).

[2]Kim Judd, Contract Lawyer, Staff Judge Advocate's Office, interview by author, (Fort Leavenworth, Kansas, 18 Apr. 97).

[3]Briefing Papers, *Technology Transfer*, No. 94-12, Federal Publications Inc. 1994. Department of the Army, *AR 70-57 Military-Civilian Technology Transfer,* Washington D.C. Army Material Command, *AMC Pamphlet 27-1 Cooperative Research and Development Agreements*, Alexandria, Virginia

[4]Plowshares Home Page http://www.stricom.army.mil/PRODUCTS/PLOWSHARES)

[5]Stephen Coffin, UNIX System V the Complete Reference. Orfali, Robert, Dan Harkey and Jeri Edwards, Essential Client/Server Survival Guide.

[6]Anandhi Bharadwaj, Ajay S. Vinze, and Arun Sen, *Blackboard Architecture for Reactive Scheduling.* Booch, Grady, Object Oriented Design with Applications, Fishwick, Paul, and Richard B. Modjeski, Knowledge-Based Simulation.

[7]Averill Law and W. David Kelton, Simulation Modeling and Analysis. Watson, Edward and Alan S. Wood, *Mixed-Model Production System Design Using Simulation Methodology.*

[8]Norman Niesen, "Artificial Intelligence (AI) Roles in Simulation Process," Fishwick, Paul, and Richard B. Modjeski, Knowledge-Based Simulation, Springer-Verlag New York, 1990.

[9]Norman Niesen, "Artificial Intelligence (AI) Roles in Simulation Process," Fishwick, Paul, and Richard B. Modjeski, Knowledge-Based Simulation, 4.

[10]Tuncer I. Oren, "Dynamic Templates and Semantic Rules for Simulation Advisors and Certifiers," 215.

[11]Rothenburg, 15.

[12]Jeffery Esakov, and Norman I. Badler, An Architecture for High-Level Human Task Animation Control, 170.

[13]Monte Zweben, Brian Daun and Michael Dele, Scheduling and Rescheduling with Interative Repair, 241.

[14]Paul Harmon, 2.

[15]Rumbaugh, Blaha, Premerlani, Eddy and Lorensen, 146.

[16]Rumbaugh, Blaha, Premerlani, Eddy and Lorensen, 17.

[17]Rumbaugh, Blaha, Premerlani, Eddy and Lorensen, 17.

[18]Taylor Harmon, Objects in Action, Illustrations 4, 5.

[19]Norman Nielsen, Application of Artificial Intelligence Techniques, Knowledge-based Simulations, 4.

[20]Rumbaugh, Blaha, Premerlani, Eddy and Lorensen, 146.

CHAPTER FOUR

BLACK AND VEATCH CASE STUDY

This is a case study for applying the Military Simulation Transfer Process methodology to a real world commercial company. Black and Veatch has reduced costs by using better business practices for building power plants by 50 percent.[1] They estimate that viable computer simulations can further reduce costs another 50 percent by improving their planning processes.[2] A 1 percent positive effect to Black and Veatch's one billion dollars yearly revenue equates to more than ten million dollars in added revenue and as much as ten times that in construction savings.[3] Black and Veatch wanted to use computer simulations to help solve some problems. The author noted the problem and the Military Simulation Transfer Process documented requirements, found simulation nominees, and evaluated each for value.

The research strategy applied the thesis problem to Black and Veatch: Are military developed computer simulation products or models available for Black and Veatch to modify for their business resource management? The research began with an interview with the company representative, Mr. John Voeller. Mr. Voeller, a senior partner in Black and Veatch, explained the company's problem. It appeared that the company's work schedules suffered from varying degrees of disruption at the construction sites. The company experienced work delays from missing equipment, parts, personnel, and unforeseen incidents that caused wasted work effort. The company uses detailed schedules for work, but their management needs improvement. The author compares it to the military philosopher Clausewitz's concepts called the "friction" and "fog" of war. Friction is the countless minor incidents that combine to lower the general level of performance, while fog is the uncertainty that wraps itself around every activity as well as the general unreliability of all information.[4]

Mr. Voeller wanted an evaluation of any available automated military simulations that would be of value to his company. A product that simulated actions of foremen performing tasks on the construction work site was of particular interest. He then gave a description of the company's functional organization, work environment, and stated that he wanted object-oriented modeling design as a favored technological parameter.

The Military Simulation Transfer Process is used in this case study to find a suitable simulation product for Black and Veatch. It starts with a literature review that collects information that directly applies to Black and Veatch's problem. The literature review states what DOD uses simulations for now and specific technology issues that concerned Black and Veatch. Black and Veatch's requirements are explained in better detail and their work is broken down into separate processes. These processes are compared with military processes for war missions. A search of the consolidated military simulation repository and DOD agencies find suitable simulation model candidates. These candidates are then evaluated against Black and Veatch's requirement criteria to find the most valuable product.

Military Simulation Transfer Process

Part One: Literature Review for Black and Veatch

The literature review provides an explanation of why and how DOD uses simulation models today and goes in more detail about object-oriented design. This material provides background information for collecting Black and Veatch requirements and translation of military and commercial work processes. This helped the author create relevant research questions and develop criteria for later requirement definition.

The DOD currently uses simulation models to train personnel, evaluate courses of action and allocate resources. The military compares its requirements towards specified mission success criteria--against planned actions for moving personnel, material, equipment and sustainment--to conduct war. Computer simulation models support planning analysis at all levels of the military organizational structure. For training, simulations provide a means to stimulate the thought processes and learn the skills of war without expensive deployment of men and material. The Army's Force XXI and digitization of the battlefield programs continue to raise the importance of computer simulations as a management tool. "Combat leaders will use simulations in peacetime training as they would for operational mission planning, mission rehearsal, and problem identification and resolution." (The Army Master Plan, "Army Strategic Modeling and Simulation Vision")

The following explanation of DOD simulation and modeling provides the structure of how the military designs its products. The answers to how the military uses simulation models and represents the processes for going to war were later used by the author in collecting Black and Veatch requirements, equating the military and commercial work structures, and searching for products. The author learned that DOD efforts in simulation and modeling will continue to grow in the future. Actions to consolidate DOD products eased the investigation burden for finding an appropriate simulation.

A definition of how the military uses computer simulations is required. The official DOD definition of the term Simulation is:

> A model that represents activities and interactions over time. A Simulation is an operation representation of selected features of real-world or hypothetical events and processes. It is

conducted in accordance with known or assumed procedures and data, and with the aid of methods and equipment ranging from the simplest to the most sophisticated.[5]

The military uses mathematical and physical models to create simulations for five types of uses. These are: research and development, test and evaluation, products and logistics, analysis, and eEducation and training.[6]

The military develops computer simulation software models for: (1) products and logistics, (2) analysis, and (3) Education and Training to recreate actions for war and on a battlefield environment to improve resource management. Research and development and test and evaluation simulators are used to evaluate weapons-equipment or pure science. The author did not evaluate Research and Development or Test and Evaluation simulation models because they are not used for resource management analysis.

To use a simulation, leaders formulate an operational plan-- then run the plan in these models, usually faster than real time--to see a forecast of results of many hours and days in a few minutes. A synchronized plan with available resources is the goal. These models identify conflicts when the plan is not providing the right results, with resources, with appropriate people, with the right equipment, tools and materials at a required location to do a multitude of tasks.

The Future Modeling and Simulation Guidance for Fiscal Years 1998-2003 outlines the DOD future plan for simulations. It directs the DOD to use an approach that provides strategic-level focus and end duplication of effort and resources between everyone in the DOD that uses modeling and simulation technologies. Operational C4I (command, control, communication, computers and intelligence) computer systems will interface with modeling and simulation products and move toward embedded capabilities.[7]

The DOD has recently made great strides in collecting its simulation resources and cross referencing them through the Defense Modeling and Simulation Office. Using the available search engine technology, military organizations have made available listings and descriptions of simulation models covering battlefield maneuver, operational planning, combat service support, transportation, logistical services, and analysis of force structure. The program offices provided literature on simulation products that they manage. Program offices provided information on military simulation's purpose, audience, computer hardware, and personnel using the simulation. A critical evaluation of these simulation products, of their shortfalls and adaptability to other than military use, is not available. Sources in the responsible agency must provide this information.

After the initial interview with Mr. Voeller, the author performed a technical study to gain detailed knowledge in object-oriented modeling and design. This was because Black and Veatch specifically requested object-oriented modeling design as part of the search criteria. The author performed a more detailed study of object-oriented technology.

Object-oriented modeling defines everything in self-contained entities called objects. The fundamental construct is that the object combines identification, relationships, interactions with other objects, and actions, called data transformation, into a single entity.[8] "Object oriented" means that designers organize the people, actions, and materials as a collection of independent objects that incorporate both data structure and behavior.[9] (See figure 3.) Object-oriented design is the goal structure because it is flexible, and shows promise for long-term cost-effective maintenance. Function-oriented design, an alternative to object-oriented design, is unacceptable for software reuse. Function-oriented, design the more conventional method of programming, connects data structure and functions to events (or objects) more loosely and makes it less flexible to change. Function-oriented design for complex simulation programs creates a maze of events and path to related events. Changing a single event can require changes to all related events and a tedious tracking down of their linked paths.

Black and Veatch was searching for a military simulation that also incorporated a modern isolated rule engine. The author found no published works describing isolated rule technology. Mr. Voeller of Black and Veatch and Mr. James D. Johnston of the TRADOC Analysis Center provided an explanation of this technology.[10] Software programmers define rules that govern how actions. Rules are often written throughout the software code within each program subroutine or object. An isolated rule engine is a program that is independent from the data. The logic rules, for example: If not A, then B is in a separate data file. Software programs access this file when they need a rule to perform a task. To change rules, the programmer needs to change only one rule file. Isolated rule engine technology emerged from expert system software programming. Expert software is also called inference and reasoning programs. Isolated rule engines were developed before object-oriented design techniques. Isolated rule engine technology has progressed farther than simply separating the rule file.

There are several commercial products that offer isolated rule engine technology.[11] An example is G2 produced by Gensym Corporation.[12] The G2 software works in an object-oriented environment to provide a system diagnoses and then graphically represents its results on the terminal screen. The same technology that is used for the isolated rule engine to show how objects are related to each other is used in network diagnostic tools.

Black and Veatch wanted an isolated rule engine to display how the software program's objects relate--a visualization of the dependencies. Diagnostic technology has been available for several years and is a standard software tool for any computer system administrator. An isolated rule engine in its basic form will be a separate file that has all of the program's rules. The advanced level provides a diagnostic tool that tracks down the objects and rules and graphically displays the interdependencies throughout the software structure. The advanced type is a recent capability for the technology.

There is an implied assumption that adapting a military simulation to commercial use will involve significant changes to the software. The amount of change required indicates a future cost to the company in money, time, and work hours. The amount of work to change the software has an impact on the judgmental evaluation of value in the Military Simulation Transfer Process methodology.

Part Two: Work Requirement Definition for Black and Veatch

From the basic question of whether military simulation products can transfer to industry, the author formed secondary questions for Black and Veatch's needs. The secondary questions helped to define search criteria as part of the Military Simulation Transfer Process methodology. After obtaining a working knowledge on simulation modeling and design and object-oriented structures, the author began the process of asking secondary research questions to define search criteria.

What are the simulation requirements?

1. What does the company do?

2. Who is the target audience?

3. What is the environment that the company wants the simulation model to work within--land, sea, air, or other?

4. What are the technological limitations that the company must impose for the product to be useful?

5. Is Black and Veatch using a prescribed process?

6. What product or service is produced for sale?

7. Who performs the tasks and how is it done?

The purpose is to find out the general objectives of the company: what processes are used to achieve them, who is providing the information for the simulation to react with, and who gets the most benefit from the information?

Additional interviews with Mr. John Voeller defined what simulation information would be valuable to the company. Simulation value measurements gained from these interviews provided levels of usefulness for target audiences in executive, middle-management, and field level work. The investigative methodology provided the following information:

Functional/Organizational

Black and Veatch builds capital facilities: power plants, refineries, sewage plants, etc. They currently use schedules to layout work at the building sites that they manage around the world. Black and Veatch continues to suffer from schedule conflicts, work stoppages and resource mismanagement at the work sites. They want to simulate the actions at a work site to address conflicts that are unforeseen in their building schedules. (See figure 5.) Black and Veatch foremen at the work site submit planning schedules for their work crews for one, two and three week increments. Simulations are modeled from these plans. Powrtrak © is the name of the company automated information system. It provides the manning, equipment, supply and sustainment data to the simulation. The database will also provide the current milestone plan and the work status for the project. A simulation is run against the many foreman-projected plans. Information showing schedule conflicts, course of action--"what if"--analysis, and a comparison against the planned milestone schedule is collected . The simulation is suppose to show any conflicts between the site foremen schedules for equipment, personnel and materials and the company milestone plan. The foremen (or higher level leaders) work out conflicts, shortfalls and schedule adjustments and update schedules to transfer back to the work site for execution.

Audience

The foremen are seen as the people who need to provide the information and act on the simulation feedback to solve the building site chaos. The target audience is the craft labor foreman, which is the lowest level of management control at the work site. Black and Veatch wants to have foremen at the work site submit planning schedules for their work crews for one, two and three week increments. Though the target audience is craft foremen, Black and Veatch wanted any military simulation that provided value at any audience level in the company. Simulation models that provide value to partners, project managers, and discipline engineers were a secondary goal.

Environment

The Black and Veatch model criteria sought models that would simulate groups of people performing tasks on geographic land masses. Logistical functions involving transportation could include air and sea environments, but this was of secondary importance.

Technology

Part of understanding the technology requirements is understanding the Black and Veatch information system capabilities. An explanation of the Black and Veatch information system defines their technology limitations. Powrtrak© is the name of the company information system and database. Powrtrak© is a centralized database that allows data sharing throughout the company with a goal to reduce costs in project execution. There are eight software applications that cover areas in operations, engineering and services. This database allows information sharing between one area, like project scheduling, to shared with cost control, construction control and procurement.[13] The eight supporting applications to Powrtrak© represent the company's effort to reduce duplication of effort and build a networked (virtual) management team.

Powrtrak© operational applications are project scheduling, 3D plant modeling, and construction control. Project scheduling creates a project milestone schedule that forecasts scheduling threats, such as weather, for planning. The 3D plant modeling provides space control and interference checking between work crews. Construction Control monitors and manages the construction site by tracking materials, status of work, equipment, and components. It organizes control of materials, quality, and loss and monitors project progress.

Automated engineering and engineering design are the engineering applications of Powrtrak©. These applications generate the design drawings and support the material and equipment procurement. Supporting services applications cover the project cost control, procurement control, and document management. The ability for these computer applications to share data allows instant retrieval of current data from the supporting offices of logistics, budget, and personnel into the operational and engineering areas. These applications would feed data into a potential military model to set the parameters and rules in a computer generated simulation on a represented work site.

Simulation models define rules that govern how to performed actions. Black and Veatch wanted an isolated rule engine. An isolated rule engine allows a computer system administrator to locate a program object and look at the governing rules. This provides a visualization of the object's interdependence on other rules and objects throughout the system. An isolated rule engine makes changes easier. The ease of change was a strong criterion because it directly affected the cost estimate for changing the software for Black and Veatch's use.

In summary, after collecting Black and Veatch's requirements, criteria now existed to search for simulation model candidates. Five criteria interpret Black and Veatch's requirements:

1. Simulation candidates must focus on collecting and moving resources to a land based geographic area. Selected models had to have functionality that involved manipulating resources in materiel, logistics, personnel, transportation from many locations to specified locations.

2. Simulation product age had to be within ten years of 1996. The author deemed the model too old if it was older than ten years old (unless the program office noted it for extensive upgrading) because object-oriented, networking, and isolated rule engine technology was not available. (Note: the first survey for candidates did not use this criterion.)

3. The program had to be able to draw data from a networked database. Products with their own self-contained databases are not viable candidates. Construction macro schedules and links with the company Powrtrak© databases provide a requirement for a networking capability.

4. Object-oriented design is the goal. Black and Veatch recommended object-oriented modeling and design as the one technology that had the greatest probability for success.[14] If there were no object-oriented simulation models available, this criterion would not apply. This was because Mr. Voeller (Black and Veatch) stated that he was looking for any automated military simulation model that would be of use to them.

5. An isolated rule engine would make a simulation model adaptable to change: The data structures and behaviors of the objects required changes without the source code being recompiled. (Note: this criterion advanced late in the research study and used in just the final analysis for product value.) A "user friendly" graphical interface feature for changing data structure is part of the value assessment.

Part Three: Translating Military Equivalents

A translation of Black and Veatch's organization with the military management structure showed similarities that could allow a simulation model developed by the military to support Black and Veatch requirements. Summit Solutions, Inc., Leavenworth, Kansas, assisted the author in evaluating military processes that compared to industrial construction.[15] The results of Summit Solution's work and the interviews with Mr. Voeller show that the processes in military force projection and battlefield operating systems match the processes for capital construction. (See figures 6 and 7.)

Black and Veatch uses eight processes to build a constriction project. As noted in figure 7, they can be matched to the six parts of Force Projection. A planning phase has been added to the Force Projection process because Black and Veatch develops a plan as new contracts are acquired. Military planning is a continuous process where contingency plans are prepared for any anticipated mission and is an assumed part of any operation. All of the supervisory positions in Black and Veatch are held by engineers.[16] However, the job related supervisory tasks were equivalent to military positions. The work positions for Black and Veatch compared with military positions in level of responsibility over personnel and organizational units. (See Figure 8.)

Part Four: Model Candidate Search

After gaining information on requirements and translating them into military processes, the fourth part of the Military Simulation Transfer Process began. From the military modeling and simulation program inventory, the author scanned lists of products and gave them a rapid evaluation for value potential. The author applied the following secondary question to the Black and Veatch problem and then added more supporting questions to guide the research process.

What simulation models are available for meeting Black and Veatch functionality requirements?

1. What construction-focused simulation products are in the military inventory?

2. Has the Military developed military simulation models using object-oriented modeling and design?

3. If there are no acceptable object-oriented models, what other viable military computer simulation programs are available?

The DOD Modeling and Simulation Office provided a internet link to a subordinate office called the Defense Modeling, Simulation and Tactical Technology Information Analysis Center (DMSTTIAC). DMSTTIAC provided access to current catalogs of DOD modeling products. DMSTTIAC also provided information services by way of search engines and staff support in finding object-oriented modeling products.

A search of military simulation catalogs provided listings and descriptions of military simulations for command and control, logistics and battle simulation. The simulation model catalogs update often. Initially, the author found only one simulation model developed using object-oriented design. The survey broadened to exempt object-oriented design as a criterion and find any simulation product that met the other functional, environmental and technical requirements. The audience criterion became part of the value assessment because Black and Veatch had a goal audience but wanted to cover all levels of management.

A survey of available military simulations found no construction specific models. Finding no construction models in DOD catalogs, the author interviewed Captain Davidson from the Engineering Force Simulations Center, Fort Leonard Wood, MI, and verified that the Engineer Corps does not currently maintain a simulation for constructing facilities. The first survey used the first criteria only (that covered functional, audience and environment requirements). The survey of the DOD simulation catalog maintained by the Modeling and Simulation Office brought forth the following simulations that promised functional (with and without object-oriented design) value to Black & Veatch (see figure 9 for detailed descriptions):

1. Battle Lab Reconfigurable Simulator Initiative (BLRSI)
2. Combat Analysis and Sustainability Model (CASMO)
3. Logistics Training Simulation System (CSSTSS)
4. C4ISR Combat Model
5. Deployment and Sustainment Model (DEPLOY)
6. EAGLE--Corps/Division Analysis Model
7. Enhanced Intra-theater Logistics Support Tool (ELIST)
8. Force Deployment Estimator (FDE)
9. JANUS
10. Logistics Data Network (LOGNET)
11. Logistics Sustainment Analysis and Feasibility Estimator (LOGSAFE)
12. Planning Resources of Logistics Units Evaluator (PROLOGUE)
13. Rand Strategy Assessment System (RSAS)
14. SPECTRUM--An Operations Other Than War Simulation
15. Urban Combat Assisted Training System (UCCATS) The name recently changed to JCATS/JTS.

The selected military simulation models appeared to meet Black and Veatch functional, audience, and environment requirements for actions on a geographic landscape. The level of detail for the simulations ranged from theater level to platoon. The fifteen initial candidates were then screened against the following criteria:

1. Simulation product age had to be within ten years of 1996.

2. The program had to be able to draw data from a networked database.

3. Simulation candidates must have been developed using object-oriented design.

4. The model design must have an isolated rule engine. (Note: this criterion did not reject candidates.)

After screening the list of simulations the following met the remaining criteria for further analysis.

1. Battle Lab Reconfigurable Simulator Initiative (BLRSI). BLRSI is a training tool that simulates driving a military vehicle over terrain. The contract for its employment was recently awarded, so this presumes that the program age is very recent. The simulation is network capable. The program uses object-oriented design technology. BLRSI does not have an isolated rule engine.[17]

2. C4ISR Combat Model. The Defense Information Agency C4ISR Combat Model graphically displays theater level operations over terrain maps. It was implemented in 1994. It was built for networked simulation gaming. It met the object-oriented design criteria. It does not have an isolated rule engine.[18]

3. EAGLE. EAGLE is a Corps and Division level simulator that displays the action of the units over geographic maps. It was built to be played over a network. It incorporates object-oriented programming techniques. The date of implementation is 1992. It does have an isolated rule engine.[19]

4. Enhanced Intra-theater Logistics Support Tool (ELIST). ELIST uses road maps to display transportation tasks. The program is about eight years old. The simulation is network capable. ELIST was built using object-oriented design. It does not have an isolated rule engine.[20]

5. SPECTRUM--An Operations Other Than War Simulation. SPECTRUM is a simulation of small units working on a geographical map display. It was implemented in 1995 and is being used to train leaders on Military Operations Other Than War. The software was build using object-oriented C++ programming language. The model contains its own database, however, the data fields may be filled from an outside networked database. The isolated rule engine provides information on the rule design but it does not give a description of object relationships between each other.[21]

Part Five: Value Criteria and Analysis

The author applied secondary questions to the Military Simulation Transfer Process methodology to Black and Veatch and added additional questions to guide the evaluation of simulation candidates.

1. Is there one simulation model that meets all of Black and Veatch requirements?

    a. Are requirements met using several simulation model products?

    b. What simulation model provides the best capability for Black and Veatch?

    c. What is the value of each simulation candidate to Black and Veatch?

        1 What functional processes does the model simulate?

        2 Does the model simulation provide information for the: Foreman? Additionally does it provide for:

            a. Project Manager?

            b. Staff Support?

            c. Partner?

        3 What technical features does it offer for:

            a. A Graphical User Interface for changing data?

b. Providing the lowest level of unit granularity?

c. An isolated rule engine?

The appraisals of the data results consist of counting the YES answers to the above questions and judgmental criticism based on the author's background in information systems and recommendations from interviewed experts. (See figure 10.) Black and Veatch defined requirements that involved moving personnel, material, and equipment within a geographical area and then applying various levels of space management, task priority and synchronization of resources.

There are no military simulation models that meet Black and Veatch requirements. This answers the primary research question of this case study. EAGLE scored the highest for providing the best available military simulation transfer candidate. However, the technical challenge to modify any existing models validated that developing a new product for Black and Veatch is a better option.

What follows is a critiqued and ranking of military simulation models from the most valuable to the least:

EAGLE (Criteria score: 13 Yes/1 No--see figure 11)

EAGLE is the best product surveyed for technology transfer to Black and Veatch. EAGLE provides simulations over geographic land masses from Corps to Battalion or Division to Company. Squad and platoon level are possible using database tricks. In a demonstration of EAGLE, the user interface was impressive in graphically representing units performing combat actions.[22] The mapping capability was able to show terrain maps from the National Mapping Agency and zoom in to ground level with the terrain features (hills, valleys, and rivers) displayed as an observer at ground level would see it. The author watched the simulation display a helicopter unit movement. It started as a terrain map showing a military unit symbol and then zoomed down into the cockpit of the helicopter (and even a side view as if we were flying beside the helicopters) as they attacked an enemy position.

A summarized description of EAGLE capabilities is taken from the consolidated simulation software repository product description file.[23] EAGLE is used as both a training and analysis simulation. That means it provides a realistic perception to stimulate the mental processes for combat and has a high level of data accuracy to produce representative output. EAGLE is an inference and reasoning program using expert (deductive reasoning) system technology. Its purpose is to provide course of action analysis, decision support, force requirements (to include mixing different forces) analysis, and scenario generation for staff training. The simulation was implemented in 1992. The object-oriented implementation used a programming language called Common Lisp Object System (CLOS) with the Knowledge Engineering Environment (KEE) frame system built on top. CLOS provided high resolution graphics and KEE provides the an inference engine and pattern matcher of an expert system. The human participation allows for stand alone where the simulations play out a plan or the play may be interrupted to change plans and orders for the units.

Simulations are played over a network where many participants can be involved in the scenario action. The isolate rule engine within KEE uses a separated file of rules, but does not have a diagnostic capability for validating change impact.[24]

In an analysis of the functionality for simulating Black and Veatch's work processes (matched with military Force Projection), EAGLE could represent each process except Resource Acquisition. EAGLE does not play logistics at all. The author judges that EAGLE would not be able to transfer unchanged to Black and Veatch. The actions in site preparation, infrastructure development, and construction would involve new program modules that act out the tasks of construction. EAGLE can support the Black and Veatch target audience of craft foreman, however, this would involve using database tricks to represent the smaller ten to thirty man unit.[25] EAGLE also met all of the technical criteria for Black and Veatch.

Though EAGLE is the best product for technology transfer, its technical shortcomings showed that Black and Veatch have a better option. Mr. Harry Jones, the Model Simulation Division Chief who oversaw EAGLE development, could not recommend EAGLE for transfer for the following reasons.[26] The biggest problem is that the CLOS programming language is considered old and better simulation programming languages are available. Mr. Jones is looking at reprogramming EAGLE into a better performing programming language (C++) to reduce the size of program code. The size of the current program makes it perform too slow. A simulation using 600 company and battalion sized units ran at "real-time" (this means no accelerated time). Mr. Jones also felt that the he would improve the isolated rule engine.

EAGLE was developed very quickly.[27] It took six people four months to plan the EAGLE design using software development tools (that Mr. Jones now considers old), and sixty days to produce a successful prototype. Considering the expected analysis, amount of changes and the ability to rapidly develop software, the author judged that developing a product from scratch is a better option for Black and Veatch.

SPECTRUM (Criteria score: 8 Yes/6 No--see figure 12)

SPECTRUM is rated second in the analysis. The SPECTUM Overview provided the following capabilities of the system.[28] SPECTRUM provides the cultural intelligence for conducting operations in another host country. It is used for training leaders for Operations Other Than War , meaning counter insurgency, humanitarian and peace missions. The simulation can show individual people working on a geographical map display. This map display can also show operational graphics displayed over the map. It was implemented in 1995 and is being used to train leaders on Military Operations Other Than War.

Mr. Dennis Chrisman provided more detail for final analysis.[29] The software was build using object-oriented C++ programming language. The model contains its own database, however, the data fields may be filled from an outside networked database. One terminal conducts play, so it is not set up for multiple users. The isolated rule engine provides information on the rule design but it does not give a description of object relationships SPECTRUM is a senior executive and staff officer tool. It uses a regional analysis model that simulates what the host country's culture will accept. The results hit a 75 to 80 percent accuracy rate now and with additional work this percentage could improve. For construction, it provides an indirect benefit by simulating host country support.[30]

The author judges that SPECTRUM could be able to recommend to Black and Veatch executives for evaluating local population hiring practices. It can provide some benefit for the planning, site preparation, resource acquisition and infrastructure development but it just simulates the relationships between the host country and the player. The limited scope of this program makes it only provide an indirect benefit to the company's actions at the construction site.

ELIST (Criteria score: 7 Yes/7 No--see figure 13)

The Enhanced Intra-theater Logistics Support Tool (ELIST) can provide value to Black and Veatch as a logistical planning aid for technology transfer. The ELIST evaluation data was provided by Mr. Van Groningen, an engineer who has been working on the program for eight years.[31] ELIST met the land-based, object-oriented, network and age criteria for Black and Veatch. The rule engine is not isolated. ELIST reads a Time Phased Force Deployment Data file (a standard DOD force mobilization report) which is a schedule that specifies the who, what, when, and where of resource transportation. This provides value to Black and Veatch for transportation aspects in Planning, Resource Acquisition, and Resource Release. These functions work through the database network and the model determines:

1. Did the units/cargo arrive on time?
2. What were the bottlenecks of the course of action?
3. Why could not some items move?
4. How did each item move? (history)

ELIST's primary drawback is that it provides transportation modeling only. The author asked Mr. Chuck Van Groningen, "Would it be better to modify the existing product or start new?" He responded: "We would take a lot of concepts and building blocks from our model, but I think the actual simulation engine would have to be rewritten. Many of the tools would be in place though."[32] The author judges that ELIST could provide valuable information on how Black and Veatch could develop this tool.

<u>C4ISR (Criteria score: 7 Yes/7 No--see figure 14)</u>

The C4ISR model is not recommended for Black and Veatch. The Program Manager for the C4ISR model provided an evaluation of the transfer value to Black and Veatch.[33] The C4ISR Model is a simulation that models campaign level conflicts at the theater level. C4ISR models units down to the company level. Major James Knowles states: "Since the units are aggregated, the amount of detail analyzed at the tactical level is limited. There is no logistical simulation." The simulated time period is 1-10 days. The time limitation does not meet Black and Veatch requirements. The author agreed with Major Knowles. The simulation could only provide value for the planning, infrastructure development and some resource release processes.

The target audience is the senior general ranks (three and four star). C4ISR does not meet Black and Veatch Requirements.

BLRSI (Criteria score: 2 Yes/12 No--see figure 15)

The Battle Lab Reconfigurable Simulator Initiative (BLRSI) does not meet Black and Veatch requirements. This simulation held promise of providing a simulation that could reflect individual action on a Black and Veatch construction site, but the evaluation found it unsuitable. BLRSI's capabilities were collected from their internet informational Homepage.[34] This product is a training simulation for vehicle drivers. This simulation involves a lot of specialized hardware that creates the perception of being in a military vehicle. The Product manager, Major Kyle Burke, assisted in analyzing BLRSI's potential use to Black and Veatch.[35] He offered that there is a constructive simulation product for BLRSI called Early Entry Operation and Service Support Analysis (EEOSSA) that moves and delivers resources up to platoon level. Major Burke stated that changing BLRS for commercial use would be a difficult task to complete. There is no data library for construction equipment, so this would have to be built. The author judged that BLRS did not help the foreman in course of action analysis. The limit of this simulation makes it have little value for Black and Veatch.

In summary, the author performed the Military Simulation Transfer Process on the construction and engineering company Black and Veatch. Company requirements were collected and translation into military simulation functionality. The author found suitable simulation candidates and evaluated them against developed criteria and interviewed authoritative experts who managed or developed these products. The results were that many products could provide functional value to Black and Veatch. However, the technical assessment finds that creating a new product would provide more value.

---

[1]John Voeller, Senior Partner, Black and Veatch, Interview by author, (Kansas City, Missouri, 29 August 1996).

[2]Ibid.

[3]John Voeller, Senior Partner, Black and Veatch E-mail (voellerjg@bv.com, 7 March 1997).

[4]Carl von Clausewitz, "On War," C610 Book of Readings, 217, 229

[5]U.S. Department of Defense, Joint Pubublication 1-02, DOD Dictionary of Military and Associated Terms, (Department of the ArmyWashington, DC:, 1989).

[6]U.S. Army, National Simulation Center, Training With Simulations, (Fort Leavenworth, Kansas, Aug. 1995), 7.

[7]Future M&S: Investment Guidance provided to all Program Evaluation Groups (PEGs) for POM FY 98-03.

[8]Rumbaugh, Blaha, Premerlani, Eddy and Lorensen, 1, 5.

[9]Jame Rumbaugh, et al, Object-Oriented Modeling and Design, (Prentice-Hall, Inc., 1991) 1.

[10]John G. Voeller, Senior Partner, Black and Veatch, telephonic interview by author 23 Apr. 97, and J.D Johnston, Chief Wargaming Analysis Division Training and Doctrine Command (TRADOC) Analysis Center Operations, telephonic interview by author 24 Apr. 97.

[11]John G. Voeller, Senior Partner, Black and Veatch, telephonic interview by author 23 Apr. 97. Isolated rule engine products: NEXPERT from Palo Alto, Intell Corporation PROCAPA, Automated Reasoning Tool, G2 by Gensym Corporation.

[12]Gensym Corporation, *Homepage* (on-line). Available: http://www.gensym.com/products/g2realtime.html

[13]Robert Calem, "Black & Veatch Power", Forbes ASAP, April 10, 1995.

[14]John G. Voeller, Senior Partner, Black and Veatch, interview by author (Kansas City, Missouri, 6 March 1997).

[15]Stephen Flannagan, Summit Solutions Inc., interview by author, (Leavenworth, Kansas, 10 Oct 96).

[16]John Voeller, , Senior Partner, Black and Veatch, interview by author (Kansas City, Missouri, 6 March 1997.

[17]Kyle Burke, (25 March 1997), Product Manager for BLRS, E-mail judgmental response to questions concerning BLRS capability. US Army, Simulation, Training & Instrument Command, *Battle Lab Reconfigurable Simulator Initiative (BLRSI)*, (on-line). Available: http://www.stricom.army.mil/PRODUCTS/BLRSI

[18]James Knowles, (10 March 1997), C4ISR Product Manager, Judgmental response to E-mail questions concerning C4ISR capability. Defense Information System Agency, C4ISR *Homepage*, 22 Apr. 97 (on-line). Available: http://www.disa.mil/d8/html/c4isr.html

[19]Harry Jones, Chief, Model Development Division TRADOC, Analysis Center-Operations Center, interview by author,(Fort Leavenworth, Kansas, 29 Jan. 97).

[20]Chuck Van Groningen, (11 March 1997), Engineer, Judgmental response to E-mail questions concerning ELIST capability.

[21]Denis, Chrisman, Software Engineer, National Simulation Center, interview by author, (Fort Leavenworth, Kansas, 10 Jan & 9 Apr. 97).

[22]Harry Jones, Chief, Model Development Division TRADOC, Analysis Center-Operations Center, demonstration conducted as part of interview by author, (Fort Leavenworth, Kansas 29 Jan. 97).

[23]DODIAC Modeling and Simulation Products, "Modeling and Simulation (M&S) Node for Directories", 21 Jan. 97 (on-line). Available: http://dmsttiac.hq.iitri.com/model/model

[24]James D. Johnston, Chief, Wargaming Analysis Division TRADOC, Analysis Center-Operations Center, interview by author, (Fort Leavenworth, Kansas 24 Apr. 97).

[25]Harry Jones, Chief, Model Development Division TRADOC, Analysis Center-Operations Center, E-mail, 14 March 1997.

[26]Harry Jones, Chief, Model Development Division TRADOC, Analysis Center-Operations Center, interview by author, (Fort Leavenworth, Kansas, 29 Jan. 97).

[27]James D. Johnston, Chief, Wargaming Analysis Division TRADOC, Analysis Center-Operations Center, interview by author, (Fort Leavenworth, Kansas 24 Apr. 97).

[28]National Simulation Center, *Introduction to SPECTRUM.*, Combined Arms Center (Fort Leavenworth, Kansas, 1995).

[29]Denis Chrisman, Software Engineer, National Simulation Center, interview by author, (Fort Leavenworth, Kansas, interview by author, 10 Jan. 97.

[30]Ibid.

[31]Chuck Van Groningen, E-mail,(vang@anl.gov) 11 March 1997.

[32]Ibid.

[33]Rick, Knowles, Product Manager for C4ISR, telephonic interview 19 Nov. 1997.

[34]US Army, Simulation, Training & Instrument Command, *Battle Lab Reconfigurable Simulator Initiative (BLRSI)*, (on-line). Available: http://www.stricom.army.mil/ PRODUCTS/BLRSI

[35]Kyle Burke, Productio Manager for BLRS, E-mail, (burkek@stricom.army.mil 25 March 1997).

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

The conclusion of this research answers the original research question about the availability of simulation technology for industry. There have been some information discoveries, and the author has three recommendations based on the results of this study. The research did not successfully find a military simulation model that transferred to the case study company, Black and Veatch. This chapter considers what the author learned and why Black and Veatch should consider developing their own simulation model.

During the research, the author made several discoveries. The Military Simulation Transfer Process will work better in the next repetition. The methodology description creates the appearance that the methodology executes sequentially one through four. In practice the parts, one, two and three, work concurrently. Secondary questions, in support of the primary question, increased and narrowed the focus specifically for Black and Veatch as the literature review brought up new insights.

As the author learned more about developing and using simulations, documenting the target company's requirements and value criteria continued into higher levels of detail. At the same time, the many military organizations that develop and maintain simulation models were yet undiscovered. Finding and evaluating military simulation products was a continuous process involving extensive search and subsequent interviews of program managers and engineers. The DOD Simulation and Modeling community is currently working to centralize its product resources. The author discovered products late in the study that were previously uncataloged as the updating process of military simulation catalogs progressed. The investigative process found formerly undiscovered simulation models up to the end of the research period. The internet access of DOD simulation documents, product descriptions, and the overall information consolidation effort is a valuable discovery in light of the expanding future role that simulations are to play in the future Army.

Most military simulation models are old. The vast majority of military simulations have a development date before 1990. These legacy systems were built with no intention of being transferred out of the military domain. The author found no indication that new simulation development is evaluating the benefit of technology transfer as part of the planning process. It appears that military simulation development will continue to design software that is limited to DOD use in the future. The author is assuming that rapid advances in computer technology will continue to make software programming easier and less expensive. This will make the majority of military simulations more expensive to maintain and update in contrast to newer models.

Another discovery was the technological importance of having an isolated rule engine. The isolated rule engine provides a visualization of the interdependencies between objects and the rules that govern their actions. In a military simulation model, historical data on recurring tasks can standardize the rules so that change is minimal. The importance of this feature governed the final analysis in determining product value for Black and Veatch. Though EAGLE met the statistical criteria for technology transfer, advances in software development tools changed value priorities from functional to present technology late in the research study.

But the answer to the primary thesis question of whether military developed computer simulation models can be easily modified for commercial companies is no. A search for a suitable simulation product with an isolated rule engine built (for frequent changes to logic rules) and able to show object dependency failed. Efforts to modify old code, that is no longer state of the art, is better spent developing a new program. Authoritative sources from each of the evaluated models recommend starting fresh. What the military has to offer is experience from past development and new ideas in expressing functionality and alternative techniques for problem solving.

For Black and Veatch, there are several simulation models that would provide some value to the corporate organization. Each of the selected object-oriented simulation models provide the potential for value to one or more of the Black and Veatch executive, middle management staff, or project manager audiences. From a cursory level, it would seem that Black and Veatch could accept one of these simulation model products for their own use.

One recommendation is to reevaluate the concept of software reuse. Reuse in this context is taking software code from an older program and adding it to a new one. For example, a software module that simulates a tank is taken from an old product and added to the new--or new plane and ship modules are added to an old program. Using portions of software code from previously made products may not be cost effective now. The author's experience, when working in the engineering office of the Global Command and Control System, showed that programmers spent as much time troubleshooting reused code as creating new. In the past, software reuse may have saved money. Developers can make software programs quickly now.

The rapid pace of improvement to software developing tools (for example, object-oriented design tools, automated software code generators and isolated rule engine programs) makes software development faster and less expensive. This situation questions the current logic that reusing older software code saves money. The DOD modeling and simulation community should examine the practice of upgrading simulation products when adding more code on obsolete programming languages.

There are development tools created for the DOD to build object-oriented modeling simulations. Advances in development tools have provided simulation model product managers an alternative for building over old programs to completely rewriting software code in the most improved programming languages. The concept of rewriting new code counters a popular assumption that building on an older--proven--product provides a more stable software at a savings. The significance of the object-oriented tool advances is that they could allow a complete rewrite for what would be spent in old software code maintenance.

Object-oriented tool advances simplify the software development process and the availability of automated software code generators no longer supports the assumption of cost savings in reuse of old software programs. The author's asked during interviews with simulation developers, whether they felt that Black and Veatch should reuse their military software code. The overwhelming consensus was for building a program for Black and Veatch from scratch. Harry Jones the Model Development Division Chief for TRADOC Analysis Center said, "By the time you figure out your own requirements and what to keep and throw out in the old code, you could have built one from scratch using the latest techniques and tools."

A second recommendation is to seek a broader customer base for simulations. A simulation initiative should fulfill a broader range of requirements to seek a larger customer audience. When the US military experiences reductions in funding and feels environmental law restrictions, out-of-garrison training exercises are reduced. Alternative solutions are to provide better training opportunities in the garrison environment and improve resource management. Simulations can fulfill this requirement. As the DOD consolidates its simulation resources, unit leaders can locate useful products in a one-stop shopping process. What the modeling and simulation community lack is a simulation tool that meets a range of requirements.

The third recommendation is to educate DOD simulation developers on the benefits of participating in commercial industry partnerships to develop useful products. The Cooperative Research and Development Agreement (CRADA) provides a cash incentive for the agency that transfers the technology to industry. In order to do this, the military simulation designer must use some foresight.

Another option is a cost sharing partnership. Creating a scheduling simulation that matches Black and Veatch requirements is a good candidate for a practicable simulation for commanders and staff officers. A cost-sharing venture between a commercial industry company and DOD to create a common simulation has potential benefits for all parties. There are challenges in cost sharing enterprises. The military and commercial sector must agree on how to implement requirements. A military and commercial partnership would have to agree to a common end state.[1] Though the perspectives of the military and industry are different, their requirements agree in reducing unforeseen events from stopping the work of their employees.

Significance of Study

The significance of this study is that it has shed light as to why military simulation products have not been transferred into commercial industry at this time. There is no value to the company procuring an older simulation to refurbish into current performance standards. The last ten years show that computer technology products do not stand the test of time. Repairing a ten year old computer (286 processor) costs more than the computer is worth retail. This study has evaluated military simulation models developed in more recent computer languages yet none have proven to be of value to commercial industry. This is because military simulation development continues with no intention for transfer outside the military.

Transferring military simulation model products would be possible with foresight in the early design phase of software development. The Army Model and Simulation Plan have a strategic sub-objective of investing in a new generation of models and simulations that "provide interoperability, reuse and commonality between systems."[2] But there is no discussion of sharing anything outside of the military.

A multi-functional simulation that generally modeled moving resources and performing tasks down to squad level would be beneficial to Black and Veatch and throughout the DOD. In peace time, training schedules submitted by commanders and run through a simulation may improve space management, timetable conflicts and logistical shortfalls. In war, a model may simulate building supply bases, area security, and facilitate land management and local training. The opposing argument for a universal simulation is that you sacrifice product excellence by limiting functions to create a mediocre product for many functions.

Suggestions for Further Research

There are three suggestions for further research as a result of this study. There is the continuation of the search for suitable simulation models for transfer into commercial industry. Studies may be pursued to follow-up on two of this thesis' recommendations: create a measurement standard for estimating cost effectiveness between building on old code or rewriting the program, and developing requirements for a general purpose simulation tool that would benefit a wide audience.

The search for suitable military simulation models that would apply to commercial industry is not complete because the consolidation of the military simulation inventory under the Modeling and Simulation Office is unfinished. The author had to end the search for simulation candidates in March 1997 to complete this thesis. An agency not investigated in depth was the

US Army Simulation, Training, and Instrumentation Command (STRICOM).[3] The Product Manager for BLRSI, Major Kyle Burke, recommended EEOSSA (Early Entry Operation and Service Support Model) and ModSAF (Modular Semiautomated Forces) as possible simulation candidates. The US Army Combined Arms Support Command (CASCOM) is another resource for simulation models for logistics.[4]

A second topic of study is to evaluate the merits of upgrading software over original code. Has software development technology reached a point where creating new code provides more benefits than reusing old code? Many legacy simulation models still meet requirements and continue maintenance with large support staffs. Creating a criteria for identifying inefficient legacy software for an updating rewrite may result in greatly improved simulation benefits to the user and save DOD money.

The last recommendation for further study is identifying the common simulation functions that would apply to a wider customer base. For example, the military police, engineers, and installation administration have requirements that closely match their civilian counterparts. Simulation products that meet these needs may benefit DOD and provide commercial opportunities for business.

In summary, the author recommends three areas of study for future research. Surveying more military simulation models for applicability for commercial industry can be more thorough. Evaluating the true value of software reuse in contrast to advances in software development tools may show that developing software from scratch has more advantages than keeping old software code. Identifying common functions between the military and civilian organizations can offer new opportunities for new simulation products that cover a larger customer base.

---

[1] Rick Jimenez, Available E-mail: jimenezr@stricom.army.mil, 25 March 1997.

[2]United States. Department of the Army, Army Model and Simulation (M&S) Investment Plan for Fiscal Years(FY) 98-03 (draft), (Department of the Army, Washington, DC:, 1995). 9, 15.

[3]STRICOM, Available: http://www.stricom.army.mil.

[4]CASCOM, Available: http://www.cascom.army.mil.

The Force Projection phases are:	The Battlefield Operating Systems are:
1. Mobilization, 2. Deployment, 3. Entry Operations, 4. Operations, 5. Post Conflict/War Termination, 6. Demobilization.	1. Command, Control, Communications, Computers and Information 2. Intelligence 3. Maneuver 4. Fire Support 5. Logistics 6. Mobility/Survivability 7. Air Defense

Fig. 1. List of Force Projection Process and Battlefield Operating Systems. United States. Department of the Army, FM 100-5, Operations (Washington, DC: 14 June. 93), 3-7 to 3-12, 2-12.

Military Position	Unit	Task
General	Division, Corps and Theater size of 6,000 or more people	Supervises many large and complex organizations
Colonel	Brigade/2,000-4,000 people	Supervises one large complex organization of multiple groups
Staff Officer	In All organizations -- may be technical or supervisor	Provides technical and planning expertise
Lieutenant Colonel	Battalion/600-1000 people	Supervises one organization of multiple groups
Captain	Company/100 people	Supervises completion of multiple tasks by multiple groups
Lieutenant	Platoon/30 people	Supervises single tasks completed by multiple groups
Sergeant	Squad-Platoon/10-30 people	Supervises single tasks in one group and is told what and when to do them.

Fig. 2. Responsibilities Associated with Military Rank. Figure by author.

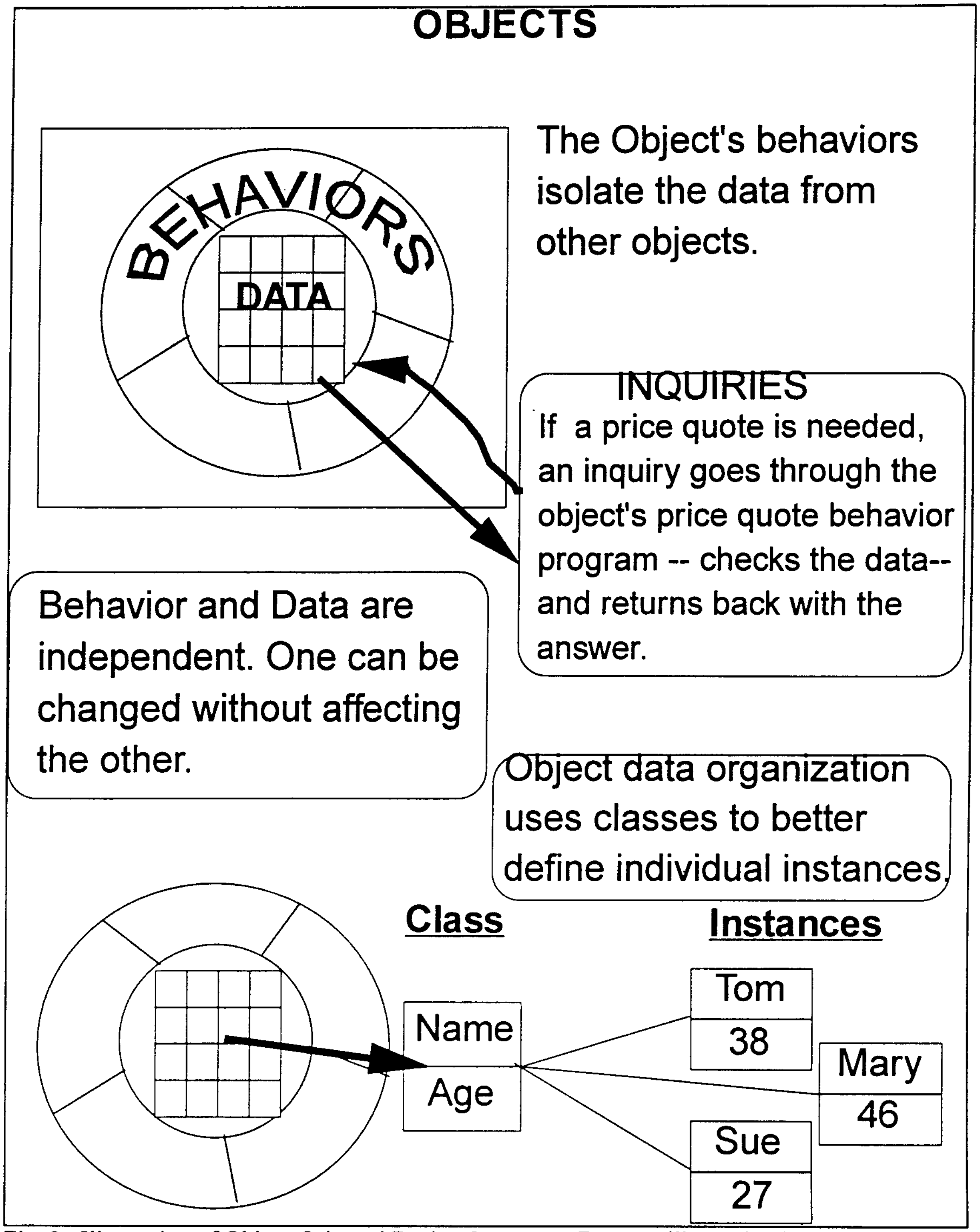

Fig. 3. Illustration of Object-Oriented Design Structure. From an illustration by Paul Harmon and David Taylor, Objects in Action: Commercial Applications of Object-Oriented Technologies (Addison-Wesley Publishing Co., 1993)., 5, Exhibit 1.3.

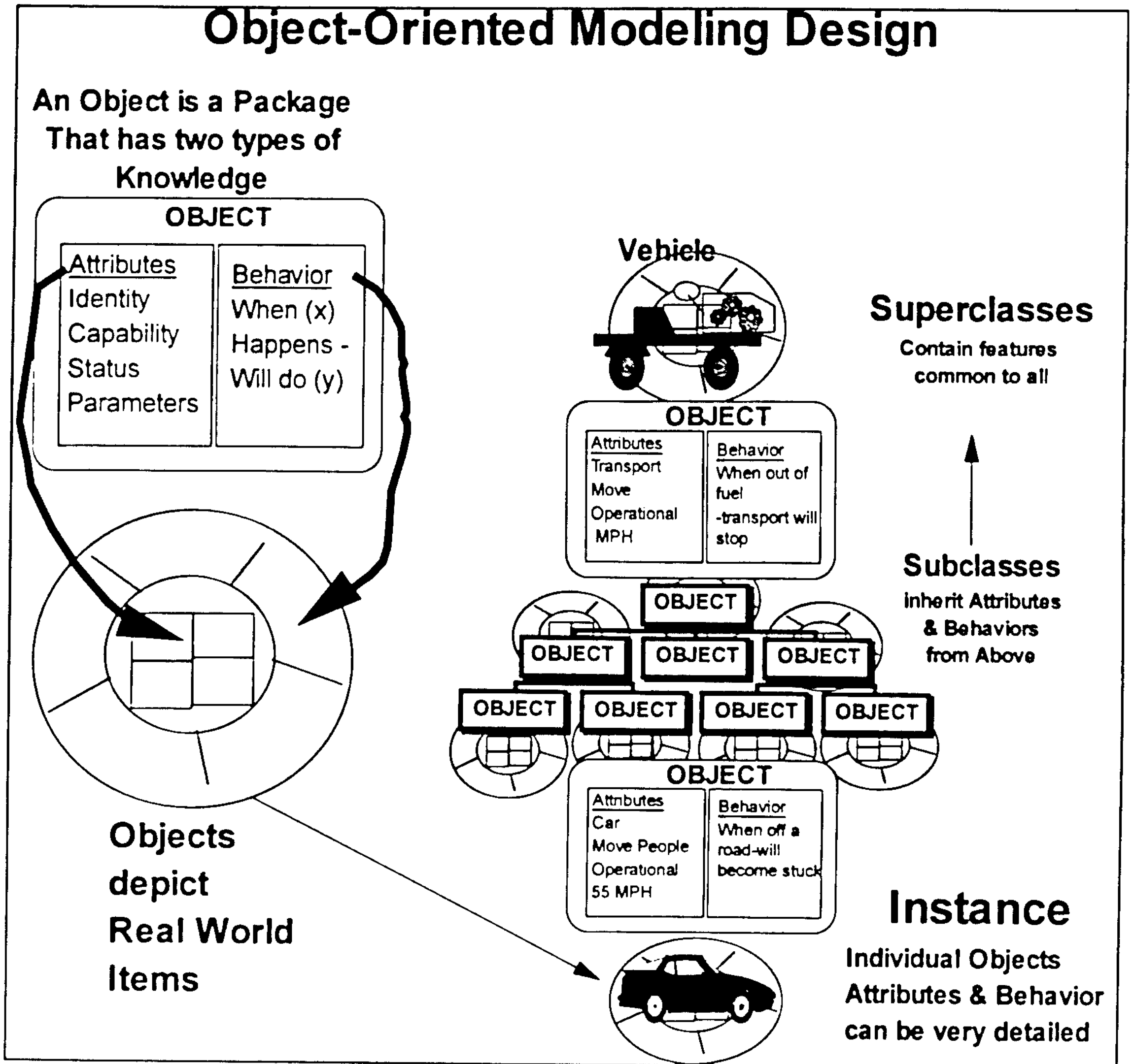

Fig. 4. Object-Oriented Data Organization. Figure by author.

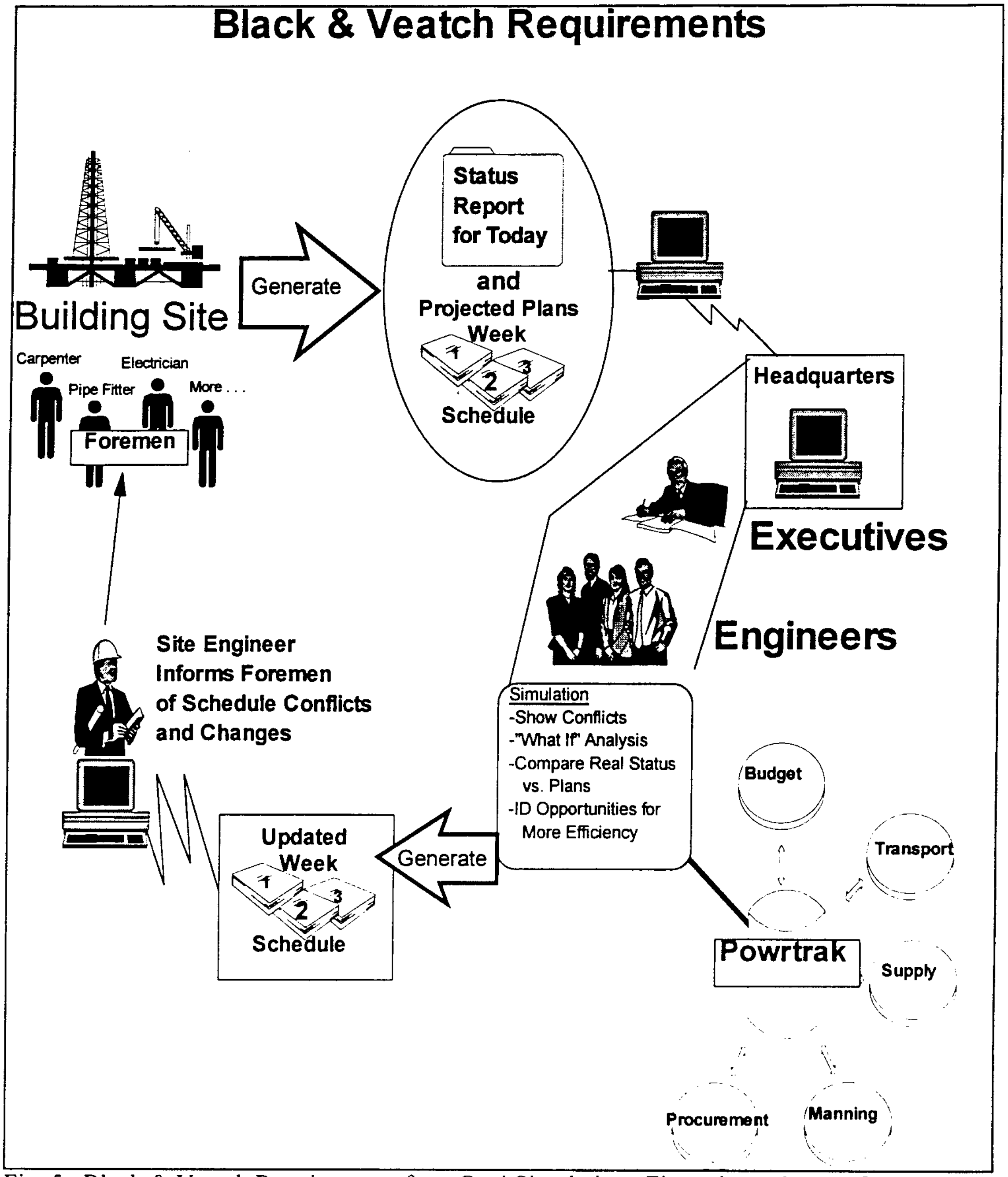

Fig. 5. Black & Veatch Requirements for a Goal Simulation. Figure by author. Information collected from Mr. John G. Voeller, Black and Veatch Senior Partner, interview by author, 29 August 1996.

Military	Black and Veatch	
Planning (Note: The military planning process is continuous. It is added for Black and Veatch because they do not prepare contingency plans.)	Project Planning	This is the collection of all require documents and plans from the construction disciplines Mechanical, Electric, Structural, Civil, Chemical, and Environmental.
Mobilization	Acquisition	This is the hiring of personnel -- construction companies, local hiring, and procuring materials/logistics.
Deployment	Site Preparation	The company performs a site survey-- surface and sub-terrainian analysis, and builds the needed roads to enter the construction site.
Entry Operations	Infrastructure Development	The construction of sewers, water base, structure base (pound pilings), retaining walls and docks.
Operations	Construction	Building the facility.
Post Conflict/War Termination	Start Up and Site Tear Down	Tests the operation of the facility against performance guarantee. Tear down removes temporary structures and heavy equipment.
Demobilization	Resource Release	Workers are layed off. Leased equipment is returned. Salvage is disposed of.

Fig. 6. Force Projection Process Compared to Project Construction Process. Black and Veatch information collected from Mr. John G. Voeller, interview by author, 6 March 1997.

Military	Black and Veatch
Command, Control, Communication, Computers, and Information	Management, Powrtrak, Project Status
Intelligence	Financial, Socio-Political, Competition
Maneuver	Labor, Trades, Sub-Contracting
Fire Support	Heavy Equipment
Logistics	Construction Services
Mobility/Survivability -- Engineering	Engineering -- Design, Redesign, Inspect
Air Defense	N/A

Fig. 7. Battlefield Operating Systems Compared to Industrial Construction. Data from Mr. Stephen Flanagan, interview by author, 10 October 1996. Summit Solutions, Inc., Leavenworth, Kansas.

Military Position	Construction Position	Job Description
General	Partner in Charge	Planning-Oversight over multiple projects
Colonel	Project Manager	Planner/Supervisor Responsible for one project
Lt. Colonel/Staff Officer	Discipline Engineers	Planner- in one of six construction disciplines Mechanical, Electric, Structural, Civil, Chemical, and Environmental
Captain	General Foreman Hired for project from outside of Black & Veatch.	Supervises between 4 to 50 Foremen. Minimum project will have foremen for carpentry, millwrights, steel/iron worker, pipe fitter
Lieutenant	Site Engineer	Black & Veatch Representative. Receives and transmits information, ensures foremen follow plan
Sergeant	Foreman	Works for General Foreman. Is told what and when to perform task.

Fig. 8. Comparison of Military and Construction Positions and the Commercial Job Description. Figure by author. Black and Veatch information collected from Mr. John G. Voeller, interview by author, 6 March 1997, and Mr. Stephen Flanagan, interview by author, 10 October 1996. Summit Solutions, Inc., Leavenworth, Kansas.

Simulation Model	Description
1. Battle Lab Reconfigurable Simulator Initiative (BLRSI)	Model Type: Training. BLRSI is a virtual, man-in-the-loop simulator which may be rapidly and easily reconfigured to represent, to varying levels of fidelity, a multitude of configurations (either current or future) of a given vehicle or weapon system platform. Date Implemented: Unknown
2. Combat Analysis and Sustainability Model (CASMO)	Model Type: Analytical. CASMO is used to analyze division level operations of maintenance and logistics in peace and war. Date Implemented: 1989
3. Logistics Training Simulation System (CSSTSS)	Model Type: Training and education. CSSTSS provides exercise play for commanders and staff in command, control, and communications. Simulates supply consumption and resupply, equipment repair, transportation, personnel, medical, Petroleum, and Ammunition. Date Implemented: Unavailable.
4. C4ISR Combat Model	Model Type: Analysis. The C4ISR Model is a set of interacting simulations that can be used to analyze joint force campaigns including air, ground and naval operations down to battalion level Date Implemented: 1994
5. Deployment and Sustainment Model (DEPLOY)	Model Type: Training and education. DEPLOY illustrates logistical constraints in deployment and employment planning. The model provides feasibility checks and tradeoff analysis for moving supplies by air and sea. Date Implemented: 1983
6. EAGLE - Corps/Division Analysis Model	Model Type: Analysis and Training. EAGLE is used by combat development studies for simulating new doctrine, scenario development, and future concept analysis for forces in land and air. Date Implemented: 1991
7. Enhanced Intra-theater Logistics Support Tool (ELIST)	Model Type: Analysis. ELIST is an analytical tool that simulates, from a transportation perspective, the deployment of forces within theater. It helps planners

	analyze and develop courses of action that require forces to arrive at particular in-theater destinations on specific dates. Date Implemented: Unknown
8. Force Deployment Estimator (FDE)	Model Type: Analysis. FDE is designed to provide a first cut estimate of the feasibility of a planned deployment by ground, sea and air -- and their sustainment world wide. Date Implemented: 1991
9. JANUS	Model Type: Analysis. JANUS provides a simulation of the battlefield to battalion level. This model assesses the impacts of logistical support and sustainablility on the combat unit. Date Implemented: Original Version 1970's
10. Logistics Data Network (LOGNET)	Model Type: Analysis. LOGNET assesses material requirements and shortfalls in theater-level plans. Calculations of sustainment requirements and shortfalls are simulated over time. Date Implemented: 1987
11. Logistics Sustainment Analysis and Feasibility Estimator (LOGSAFE)	Model Type: Analysis. LOGSAFE provides logistic sustainment modeling capability to assist logistic planners in determining the sustainment requirements of a proposed Course of action (Course of Action) using integrated data report graphs. Date Implemented: 1994
12. Planning Resources of Logistics Units Evaluator (PROLOGUE)	Model Type: Analysis. PROLOGUE evaluates the logistical aspects of operation plans time-phased at the theater, above corps, and offshore base levels. Date Implemented: 1985
13. Rand Strategy Assessment System (RSAS)	Model Type: Analysis. RSAS provides a laboratory for analysis of military strategy for nuclear and conventional combat down to brigade. Date Implemented: 1988
14. SPECTRUM -- An Operations Other Than War Simulation	Model Type: Training. SPECTRUM simulates political, economic, and socio-cultural activities conducive to regional environments where missions and

	operations other than war (OOTW) are conducted. Focus is towards the political and psychological resolve of the societal groups of the region being simulated. Date Implemented: 1995
15. Urban Combat Assisted Training System (UCCATS) The name has recently been changed to JCATS/JTS.	Model Type: Training. UCCATS is a derivative of JANUS, intended to be used by platoon leaders to battalion commanders to simulate operational plans in urban terrain. Date Implemented: 1991

Fig. 9. Data collected from DMSTTIAC Defense Modeling, Simulations & Tactical Technology Information Analysis Center database search, Homepage, 12 Feb. 97 (on-line). Available: http:dmsttiac.hq.iitri.com

Black & Veatch Requirements	Military Models **Yes** Shading is **No**				
	BLRSE	C4ISR	EAGLE	ELIST	SPECTRUM
Functional Score	2 Yes/12 No	7 Yes/7 No	13 Yes/1 No	7 Yes/7 No	8 Yes/6 No
Type	Training	Analysis	Analysis &Training	Analysis	Training
Focus	Vehicle Driving Skills	Theater Operations	Combat at Corps to Squad	Theater Operations	Social, Civil - Operations Other Than War
Planning	[redacted]	Yes	Yes	Yes	Yes
Site Prep	[redacted]	[redacted]	Yes	[redacted]	Yes
Resource Acquisition	[redacted]	[redacted]	[redacted]	Yes	Yes
Infrastructure Development	[redacted]	Yes	Yes	[redacted]	Yes
Construction	Yes	[redacted]	Yes	[redacted]	[redacted]
Start-Up	[redacted]	[redacted]	Yes	[redacted]	[redacted]
Site Tear Down	Yes	[redacted]	Yes	[redacted]	[redacted]
Resource Release	[redacted]	Yes	Yes	Yes	[redacted]
Environment: All simulation models met the environment criteria.					
Audience					
Foreman	[redacted]	[redacted]	Yes	[redacted]	[redacted]
Project Mgr.	[redacted]	Yes	Yes	Yes	[redacted]
Staff Support	[redacted]	Yes	Yes	Yes	Yes
Partner	[redacted]	Yes	Yes	Yes	Yes
Technical					
Data Changed by Graphic User Interface	[redacted]	Yes	Yes	Yes	Yes
Lowest Level of unit granularity	Individual	Company	Squads	Item for Transport	Individual
Separate Rule Engine	[redacted]	[redacted]	Yes	[redacted]	Yes

Fig. 10. Statistical Summary of Simulation Model Analysis. Figure by author.

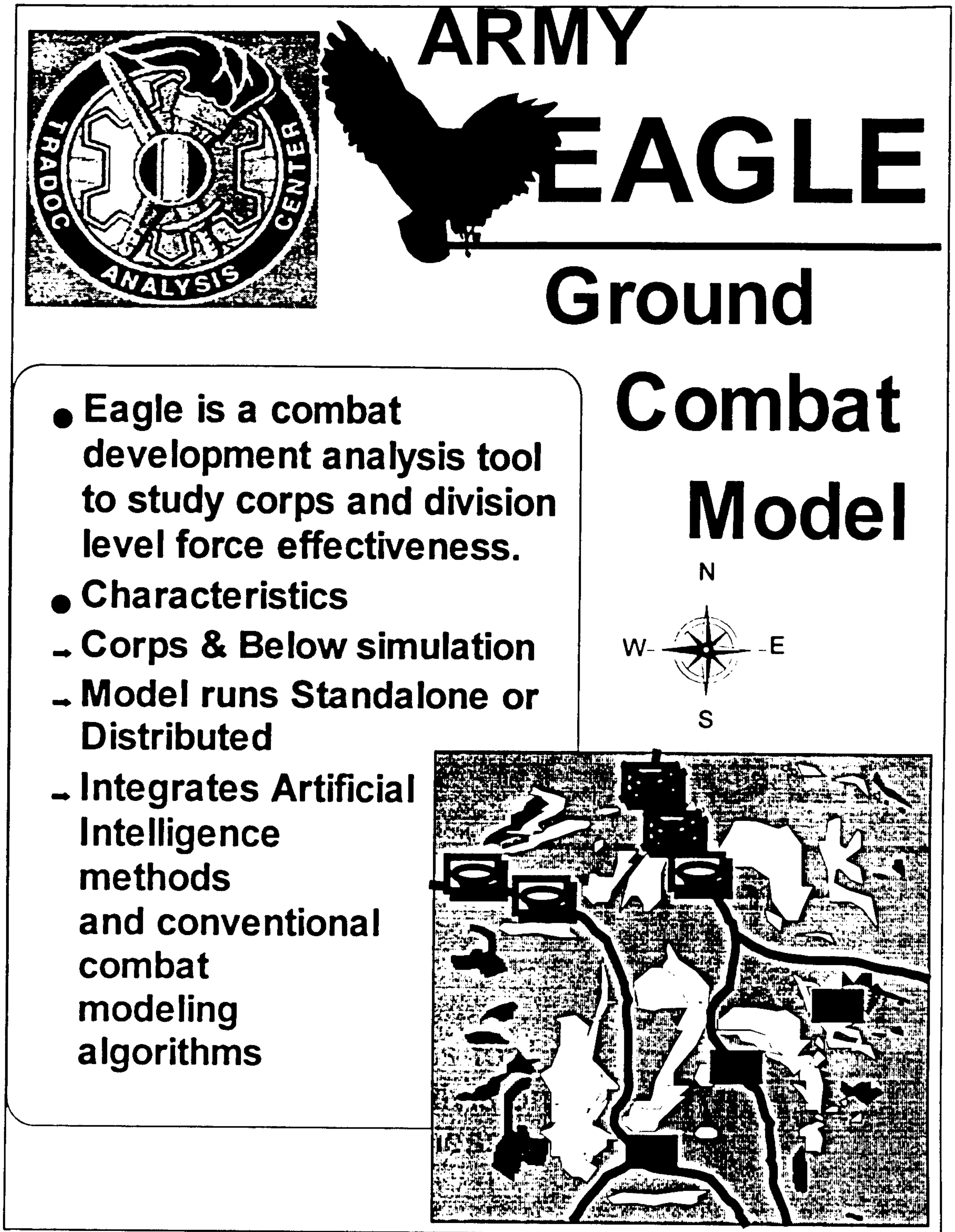

Fig. 11. EAGLE Simulation Model. Figure by author. Data from briefing slides provided by Mr. Harry Jones, interview by author, 29 January 1997, Model Development Division Chief, Training and Doctrine Command (TRADOC) Analysis Command-Operations Center, Fort Leavenworth, Kansas.

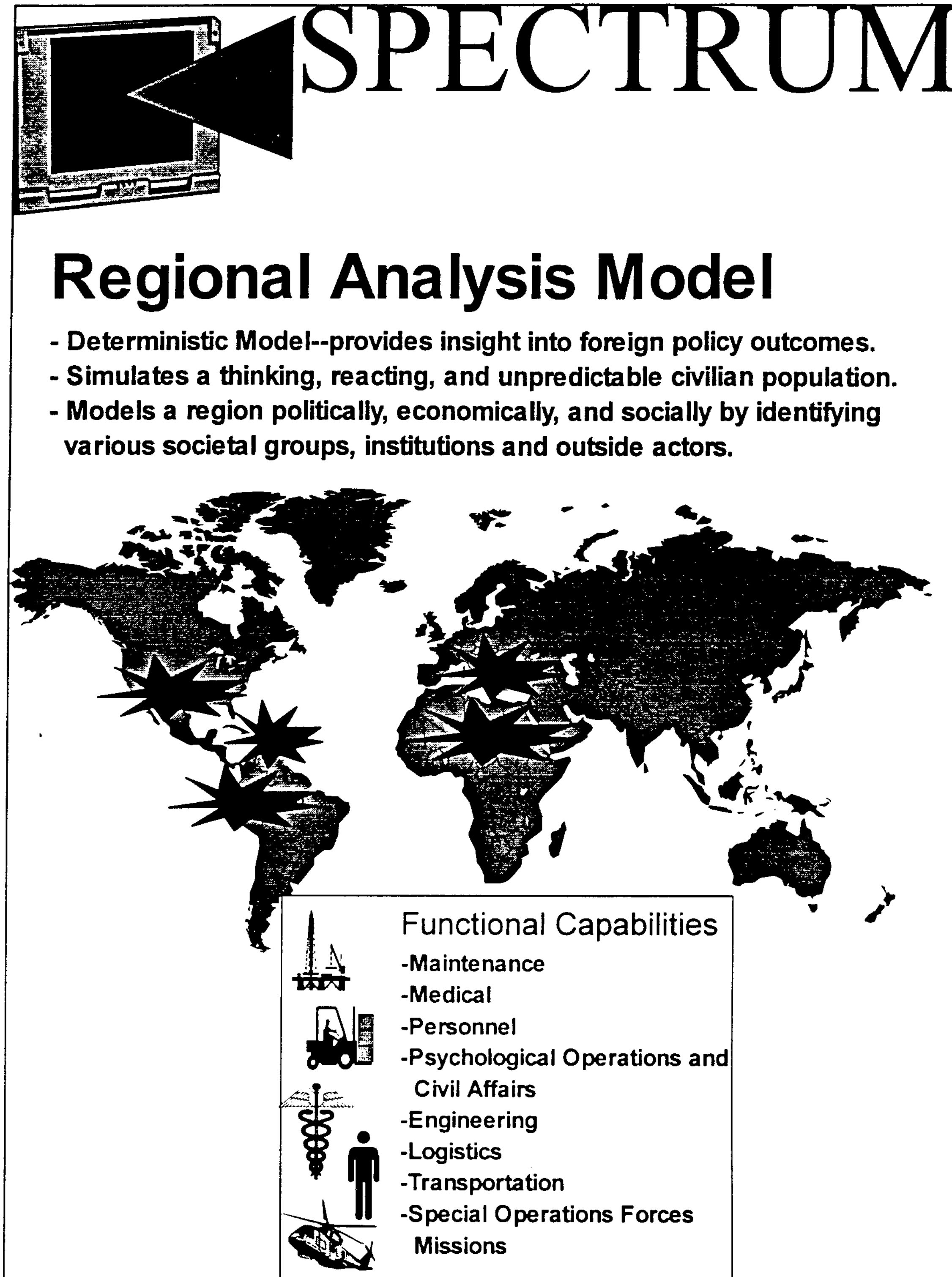

Fig. 12. SPECTRUM. Figure by author. Data provided by Mr. Denis Chrisman, interview by author, 10 January 1997, National Simulation Center, Software Engineer, Fort Leavenworth, Kansas.

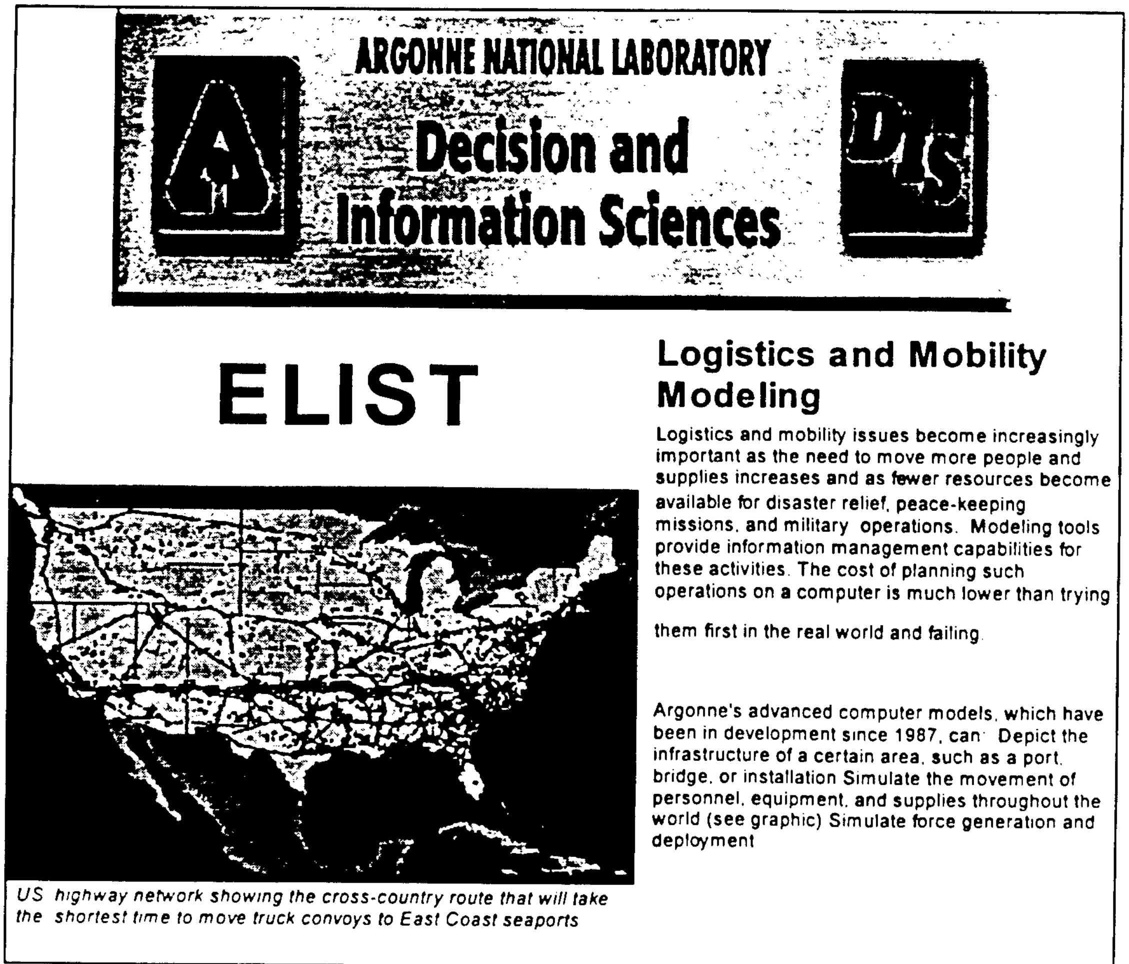

Fig. 13. Enhanced Intra-Theater Logistics Support Tool (ELIST). Figure by author. Data and map from Department of Energy, Argonne National Laboratory, Decision & Information Sciences, *Homepage* (on-line). Available: http://www.dis.anl.gov

C4ISR Model [Federation]

Command and Control, Communication, and Computers (C4) Intelligence, Combat Model runs an hour of combat and publishes command situation reports (SITREPS), H+1. The SITREPS and contact reports are sent to the Command and Control Model. The Information Model, based upon the phase of combat, creates background technical information objects which will be used to seed the Communications and Computer Model. As the simulation event clock progresses, messages are released. Decisions are made and processed before being released into the Combat Model.Surveillance, and Reconnaissance (ISR)

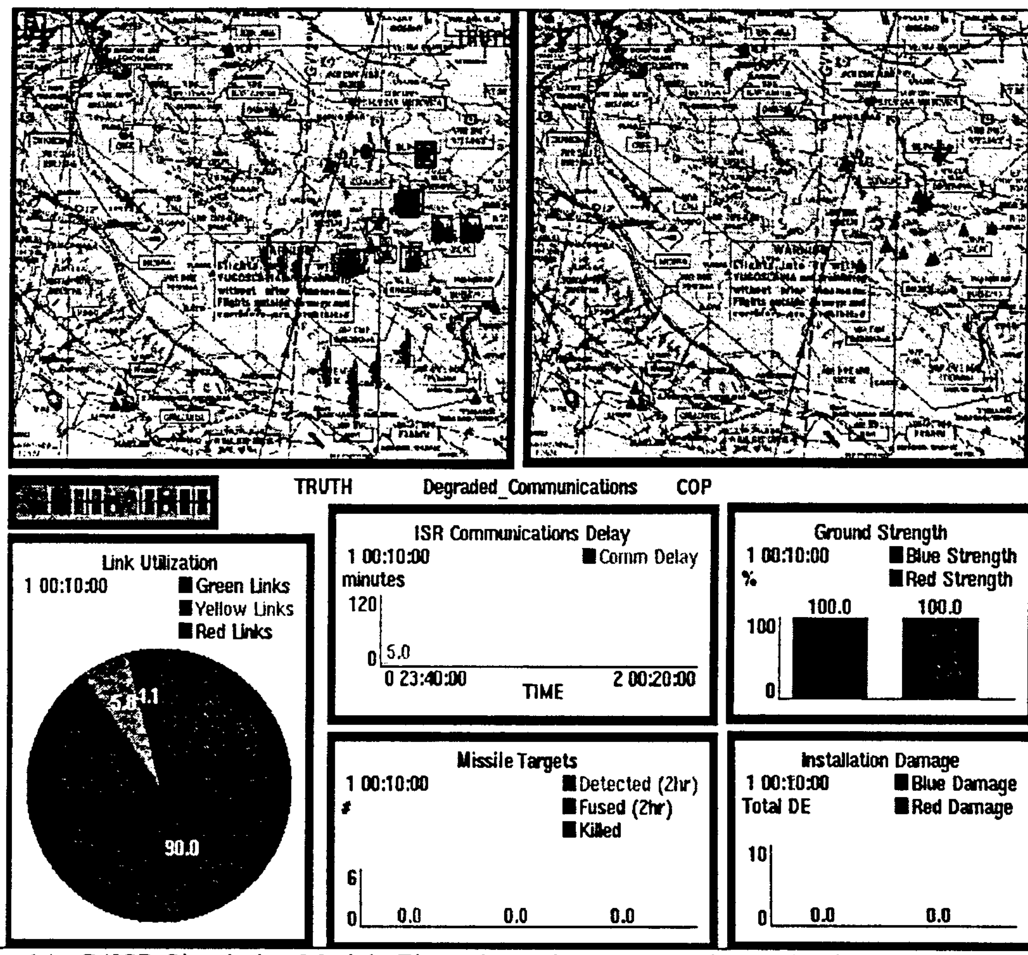

Fig. 14. C4ISR Simulation Model. Figure by author. Data and graphics from Defense Information System Agency, C4ISR *Homepage,* 22 Apr. 97 (on-line). Available: http://www.disa.mil/d8/html/c4isr.html

Battle Lab Reconfigurable Simulator Initiative BLRSI

The Battle Lab Reconfigurable Simulator Initiative (BLRSI) project represents the U.S. Army Training and Doctrine Command (TRADOC) Battle Labs' pursuit of reconfigurable simulator technology.

Specifically, a BLRSIM is a virtual, man-in-the-loop simulator which may be rapidly and easily reconfigured to represent, to varying levels of fidelity, a multitude of configurations (either current or future) of a given vehicle or weapon system platform.

BLRSIM provides simulator functionality that has been segregated into five simulator configurations with deliverables as follows: track and wheel Ground Vehicles (BLRSIM_GV) (shown left); rotary wing Aircraft (BLRSIM_AV); Command, Control, Communication, Computer and Intelligence systems (BLRSIM_C4I); Dismounted Infantry soldiers (BLRSIM_DI); and Early Entry Operations and Service Support Analysis systems (BLRSIM_EEOSSA).

Fig. 15. BLRSI. Figure by author. Data and graphics from US Army, Simulation, Training & Instrument Command, *Battle Lab Reconfigurable Simulator Initiative (BLRSI)*, (on-line). Available: http://www.stricom.army.mil/PRODUCTS/BLRSI

BIBLIOGRAPHY

Articles

Bharadwaj, Anandhi, Ajay S. Vinze and Arun Sen. "Blackboard Architecture for Reactive Scheduling." Expert Systems With Applications, 7. Pergamon Press, 1994. 55-65.

Calem, Robert E. "Black & Veatch Power." Forbes ASAP. 10 April 1995.

Watson, Edward, and Alan S. Wood. "Mixed-Model Production System Design Using Simulation Methodology." Production and Inventory Management Journal. Fourth Quarter, 1995.

Books

Booch, Grady. Object Oriented Design with Applications. Benjamin/Cummings Publishing Company, Inc., 1991.

Coffin, Stephen. UNIX System V the Complete Reference. Osborne McGraw-Hill, 1990.

December, John, and Neil Randall. The World Wide Web UNLEASHED. Indianapolis, IN: SAMS Publishing, 1994.

Fishwick, Paul, and Richard B. Modjeski. Knowledge-Based Simulation. New York: Springer-Verlag 1990.

Harmon, Paul, and David Taylor. Objects in Action: Commercial Applications of Object-Oriented Technologies. Addison-Wesley Publishing Company, 1993.

Law, Averill, and W. David Kelton. Simulation Modeling and Analysis. McGraw-Hill Book Company, 1982.

Orfali, Robert, Dan Harkey and Jeri Edwards. Essencial Client/Server Survival Guide. John Wiley & Sons, Inc. 1994.

Rumbaugh, James., et al. Object-Oriented Modeling and Design. Prentice-Hall Inc. 1991.

Computer Program

National Simulation Center, Introduction to SPECTRUM, , Ft. Leavenworth, KS: Combined Arms Center. 1995.

Electronic Database

Defense Modeling and Simulation Office, Information Library Search Engine 21 January 1997. Available: http://www.dmso.mil/systemsearch.html.

Defense Modeling, Simulation and Tactical Technology Information Analysis Center, Support Services. 8 January 1996. Available: http://dmsttiac.hq.iitri.com.

DODIAC Modeling and Simulation Products. Modeling and Simulation (M&S) Node for Directories, 21 January 1997. Available: http://dmsttiac.hq.iitri.com/model/model.

Modeling and Simulation Resources Repository, 9 April 1997. Available: http://mercury-www4.nosc.mil/msrr.

Electronic Media

Army Model and Simulation Office, Homepage, 31 March 1997. Available: http://www.amso.army.mil:443/amso2.

Black and Veatch, Homepage. Available: http://www/bv.com.

Defense Link, Homepage. Available: http://www.dtic.mil/defenselink.

Defense Information System Agency, Homepage, 22 April 1997. Available: http://www.disa.mil.

Defense Information System Agency, C4ISR Homepage, 22 April 1997. Available: http://www.disa.mil/d8/html/c4isr.html.

Defense Modeling and Simulation Office, Homepage, 4 April 1997. Available: http://www.dmso.mil.

DMSTTIAC Defense Modeling, Simulations & Tactical Technology Information Analysis Center. Homepage, 12 February 1997. Available: http:dmsttiac.hq.iitri.com.

Department of Energy, Argonne National Laboratory, Decision & Information Sciences, Homepage. Available: http://www.dis.anl.gov.

Gensym Corporation, Homepage (on-line). Available: http://www.gensym.com/products/g2realtime.html.

US Army, Homepage, 26 March 1997 (on-line). Available: http://www.army.mil.

US Army, Corps of Engineers, Homepage, 3 February 1997. Available: http://www.usace.army.mil.

US Army, Simulation, Training & Instrument Command, Battle Lab Reconfigurable Simulator Initiative (BLRSI), (on-line). Available: http://www.stricom.army.mil/PRODUCTS/BLRSI.

Government Publications

Combat Studies Institute. C610 Term I Syllabus Book of Readings, The Evolution of Modern Warfare. Ft. Leavenworth, KS: U.S. Army Command and Staff College. August 1996.

Federal Acquisition Regulation. CCH Inc., Chicago IL, 1996.

National Simulation Center, Training with Simulations. Ft. Leavenworth, KS: Combined Arms Center. 1995.

Simulation, Training & Instrumentation Command. JANUS Operator's Manual Version 6.0 UNIX Model. Orlando FL.

Simulation, Training & Instrumentation Command. JANUS Database Manager's Manual Version 6.0 UNIX Model. Orlando FL.

Simulation, Training & Instrumentation Command. JANUS Software Users Manual Version 6.3 UNIX Model. Orlando FL.

Technology Innovation, Federal Laboratory Consortium for Technology Transfer, United States Code, Title 15 Commerce and Trade. St. Paul, MN: West Publishing Company. 1991).

U.S. Army Material Command, AMC Pamphlet 27-1 Cooperative Research & Development Agreements. 5001 Eisenhower Avenue, Alexandria, VA: 14 September 1995.

U.S. Army Command and General Staff College C430, Resource Planning and Force Management. Ft. Leavenworth, KS: January 1997.

U.S. Army Command and General Staff College 101-5, The Tactical Decision Making Process. Ft. Leavenworth, KS: 20 February 1996.

U.S. Briefing Papers. Technology Transfer, No. 94-12. Federal Publications, Inc. 1994.

U.S. Department of the Army. Army Model and Simulation (M&S) Investment Plan for Fiscal Years(FY) 98-03 (DRAFT). Washington, DC: Department of the Army. 1995.

U.S. Department of the Army. AR 5-11 Management of Army Models and Simulation. Washington, DC: Department of the Army. 1995.

U.S. Department of the Army. AR 70-57 Military-Civilian Technology Transfer. Washington, DC: Department of the Army. 25 July 1991.

U.S. Department of the Army. AR 350-38 Training Aids, Devices, Simulations and Simulators. Washington, DC: Department of the Army. 1995.

U.S. Department of the Army. FM 100-5, Operations. Washington, DC: 14 June 1993.

U.S. Department of the Army. FM 25-100, Training the Force. Ft. Leavenworth, KS: US Army Combined Arms Center. November 1988.

U.S. Department of Defense. Catalog of Wargaming and Simulation Models. Vol. 12, 2 October 1992.

U.S. Department of Defense. DOD Directive 5000.59, DOD Models and Simulations (M&S) Management. Washington, DC: U.S. Government Printing Office. 4 January. 1994.

U.S. Department of Defense. DOD Instruction 7935.1-STD, DOD Automated Data Systems Standards. Washington, DC: U.S. Government Printing Office. 13 September 1979.

U.S. Department of Defense, Joint Publication 1-02, DOD Dictionary of Military and Associated Terms. Washington, DC: Department of the Army. 1989.

U.S. Department of Defense. National Military Strategy of the United States of America. Washington, DC: U.S. Government Printing Office.1995.

United States White House. A National Strategy of Engagement and Enlargement. Washington, DC: U.S. Government Printing Office. February 1996.

Interviews

Corley, Cathy, interview by author, 22 April 97, TRADOC Analysis Center, Operations Research Analyst, Ft. Leavenworth, Kansas.

Chrisman, Denis, interview by author, 10 January 97, National Simulation Center, Software Engineer, Ft. Leavenworth, Kansas.

Chrisman, Denis, interview by author, 9 April 97, National Simulation Center, Software Engineer, Ft. Leavenworth, KS.

Davidson, William, Captain, US Army. Telephonic Interview. 21 February 1997. Engineer Force Simulation Center. Ft. Leonard Wood, MI.

Flanagan, Stephen. Interview by author. 10 October 1996. Summit Solutions, Inc. Leavenworth, KS.

Johnston, James D. Interview by author. 24 April 1997. Chief, Wargaming Analysis Division. Training and Doctrine Command (TRADOC) Analysis Center-Operations Center. Ft. Leavenworth, KS.

Jones, Harry. Interview by author, 29 January 1997. Chief, Model Development Division, Training and Doctrine Command (TRADOC) Analysis Center-Operations Center. Ft. Leavenworth, KS.

Judd, Kim., Interview by author, 18 April 1997. Contract Lawyer, Staff Judge Advocate's Office, Ft. Leavenworth, KS.

Knowles, James, Major, US Army. Telephonic interview 19 Nov. 1997. Defense Information System Agency, Combat Model for C4ISR, Washington, DC

Voeller, John G., Senior Partner. Interview by author, 29 August 1996. Black and Veatch, Kansas City, MO.

Voeller, John G., Senior Partner. Iinterview by author, 19 November 1996. Black and Veatch, Kansas City, MO.

Voeller, John G., Senior Partner. Interview by author, 6 March 1997. Black and Veatch, Kansas City, MO.

Electronic Media

Burke, Kyle, (25 March 1997), Product Manager for BLRS, Judgmental response to questions concerning BLRS capability [5 paragraphs]. Available E-mail: burkek@stricom.army.mil

Jimenez, Rick, (25 March 1997), Engineer, Judgmental response to questions concerning BLRS capability [4 paragraphs]. Available E-mail: jimenezr@stricom.army.mil

Jones, Harry (14 March 1997), Chief, Model Development Division, Judgmental response to questions concerning EAGLE capability [5 paragraphs]. Available E-mail: jonesh@tfs.net

Knowles, James, (10 March 1997), C4ISR Product Manager, Judgmental response to questions concerning C4ISR capability [9 paragraphs]. Available E-mail: knowlesj@ncr.disa.mil

Voeller, John G., Senior Partner, (7 March 1997), Judgmental response Black & Veatch documented description [23 paragraphs]. Available E-mail: voellerjg@bv.com

Van Groningen, Chuck, (11 March 1997), Engineer. Judgmental response to questions concerning ELIST capability [9 paragraphs]. Available E-mail: vang@anl.gov

INITIAL DISTRIBUTION LIST

Combined Arms Research Library
U.S. Army Command and General Staff College
1 Reynolds Avenue
Fort Leavenworth, KS 66027

Defense Technical Information Center
ATTN: DTIC/OCA
8725 John J. Kingman Road
Fort Belvoir, VA 22060-6218

James D. Johnston
Chief Wargaming Analysis Division
255 Sedgwick Avenue
Fort Leavenworth, KS 66027

Mr. John G. Voeller
Black & Veatch
11401 Lamar
Overland Park
Kansas City, MO 64114

Mr. William F. Lawson III
Business Executives for National Security
114 West 11th Street
Kansas City, MO 64105-1804

Colonel Pawlowski
National Simulation Center
410 Kearney Street
Fort Leavenworth, KS 66027

LTC John M. Rodgers
1380 Strawberry Lane
Lexington, KY 40502-2719

Major Rickey E. Cox
Department of Logistics and Resource Operations
U.S. Army Command and General Staff College
1 Reynolds Avenue
Fort Leavenworth, KS 66027

Mr. And Mrs. Joseph J.McGuire
1620 Marlowe Avenue
Indianapolis, IN 46201

CERTIFICATION FOR MMAS DISTRIBUTION STATEMENT

1. Certification Date: 6 June 1997

2. Thesis Author: Major William T. McGuire

Thesis Title: A Military and Industry Partnership Program: The Transfer of Military Simulation Technology Into Commercial Industry

4. Thesis Committee Members

Signatures:

5. Distribution Statement: See distribution statements A-X on reverse, then circle appropriate distribution statement letter code below:

(A) B C D E F X SEE EXPLANATION OF CODES ON REVERSE

If your thesis does not fit into any of the above categories or is classified, you must coordinate with the classified, you must coordinate with the classified section at CARL.

6. Justification: Justification is required for any distribution other than described in Distribution Statement A. All or part of a thesis may justify distribution limitation. See limitation justification statements 1-10 on reverse, then list, below, the statement(s) that applies (apply) to your thesis and corresponding chapters/sections and pages. Follow sample format shown below:

S----------SAMPLE--------SAMPLE----------SAMPLE------------SAMPLE------------S

	Limitation Justification Statement	Chapter/Section	Page(s)	
A				A
M				M
P	Direct Military Support (10)	Chapter 3	12	P
L	Critical Technology (3)	Sect. 4	31	L
E	Administrative Operational Use (7)	Chapter 2	13-32	E

---------SAMPLE---------SAMPLE----------SAMPLE------------SAMPLE-------------

Fill in limitation justification for your thesis below:

Limitation Justification Statement	Chapter/Section	Pages(s)

7. MMAS Thesis Author's Signature: