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THESIS

**REVOLUTIONIZING ARMY USAGE
OF MODELING AND SIMULATION AS AN
ELEMENT OF ACQUISITION REFORM**

by

Craig H. Carson

December, 1995

Principal Advisor:

John T. Dillard

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**REVOLUTIONIZING ARMY USAGE OF MODELING AND
SIMULATION AS AN ELEMENT OF ACQUISITION REFORM**

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Captain, United States Army
B.A., University of Virginia, 1984

Submitted in partial fulfillment
of the requirements for the degree of

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from the


NAVAL POSTGRADUATE SCHOOL

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ABSTRACT

This thesis examines the use of modeling and simulation (M&S) technology in streamlining the Army's acquisition process by comparing it to commercial use of M&S. It establishes that the Army views M&S as anything short of combat and that it plays an integral part as a tool in mitigating risk in the acquisition process. The Army has recognized some areas for improving its use within the current acquisition framework. In comparison, the best businesses in the commercial sector have adopted M&S technology as a cornerstone to improving their entire acquisition process. They use M&S not just as a tool but as a foundation, linking a variety of functions together. This integrated M&S system linked with a horizontal management structure and a flexible, three-phase process provides the synergy to field new products in less time and cost than previously. The Army could use M&S technology to improve acquisition practices if it adopted a three-phase acquisition process and a linked M&S system.

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I. INTRODUCTION

A. PURPOSE

The purpose of this thesis is to examine the use of models and simulations (M&S) in the Army's acquisition process as a whole and how M&S can be used to streamline the acquisition process. The examination consists of three distinct elements. The first element is a qualitative analysis of current Army regulations and practices regarding M&S usage. The second element is a qualitative analysis of selected M&S practices of commercial enterprises. The final element entails a comparison of the M&S practices of the Army with those of commercial enterprises. From these elements, a set of recommendations on how to use M&S to leverage acquisition streamlining are formulated and offered.

B. BACKGROUND

Within the last decade, industry has learned to leverage emerging technologies to create a more seamless and quicker acquisition for many commercial projects. In the same period, the Army has considered numerous recommendations on how to streamline, redefine, revamp, and otherwise improve its acquisition process, but it still uses the same acquisition life-cycle model developed to produce the "Big Five" systems of the 1980's. The Army has tried to continually meld

technologies and techniques into a process based on concepts over two decades old.

The Boeing Company instituted a revolutionary approach to designing, producing, and fielding its newest airplane. Part of this revolution involved the total integration of simulations and models into their acquisition process. While the Army uses M&S in almost all phases of its acquisition cycle, it does not use it as extensively and consistently as Boeing and other manufacturers have. While the Army may not achieve the same cost and time savings as Boeing, it might realize savings and maximizations that would far outweigh minor adjustments to the acquisition process.

The ex-Chief of Staff of the Army, General Gordon R. Sullivan, stated that in order to maintain our technical advantages into the next century, we must create a dynamic process where the requirement is allowed to evolve throughout the acquisition process (Sullivan, 1993). Better use of M&S, coupled with changes to the acquisition life-cycle process, would allow the Army to accomplish this goal. Boeing and other companies have shown that the seamless use of M&S makes an important difference.

C. THESIS OBJECTIVE

This thesis proposes a new concept of how the Army could

best use M&S as part of the Secretary of Defense's move to reform the acquisition process. It examines current uses of M&S in both the Army and the commercial world. In looking at commercial practices, it concentrates on businesses that manage large industrial or complex projects. The thesis recommends changes to the Acquisition Life-Cycle Model to best utilize the capabilities that these two technologies provide for streamlining, reducing costs, and maximizing efficiency with Army acquisitions.

D. RESEARCH QUESTIONS

The primary research question of this thesis is:

- How can the Army better utilize the advantages of modeling and simulation to create a more streamlined acquisition process?

The four subsidiary research questions are:

- What is modeling and simulation as the Army currently defines it?
- How does the Army currently use modeling and simulation and what are some of the problems with it?
- What are the current best practices of industry in the use of modeling and simulations?
- What planned reforms does the Army currently have regarding modeling and simulations and how will they affect the acquisition life-cycle model?

E. SCOPE AND LIMITATIONS

This thesis proposes a new concept on how the Army could best use M&S as leveraging technologies to meaningful reform of the Department of Defense acquisition process. It examines the current use of M&S in both the Army and the commercial world as a basis for comparison.

Since M&S can have the largest impact on high priority and high cost acquisitions, it will focus on the use and impact of M&S in acquisition category I (ACAT I) programs for the Army. For comparison purposes, it will examine how businesses use M&S in large industrial or complex projects. This ensures that the analysis compares apples to apples and not apples to oranges.

Finally, the thesis recommends changes to the Acquisition Life-Cycle Model that enables utilization of these two technologies to reduce costs, reduce time, and maximize effectiveness. These recommendations are based on a qualitative analysis of the benefits of M&S.

F. RESEARCH LITERATURE AND METHODOLOGY

Research data were obtained from official Government directives and policies, journals, previous theses, United States Code, Department of Defense (DoD) and Army regulations and manuals, and personal interviews. Information on current

Army M&S practices and initiatives to change was obtained from Army Training and Doctrine Command Analysis Centers (TRACs), the Army Materiel Command (AMC), the Army Tank-Automotive Research, Development, and Engineering Center (TARDEC), the Defense Systems Management College (DSMC), and the DoD Task Force on Acquisition Streamlining. Information on current commercial practices was obtained from various published articles, General Dynamics Land Systems (GDLS), Lockheed Martin, Boeing, and DSMC.

Research was conducted via personal and telephone interviews with knowledgeable M&S and program management personnel. Throughout this research, interviewees provided many previously unpublished copies of briefing charts that they had presented.

Interviews with Government M&S personnel centered on the current process and usage of M&S. They were also questioned as to what paradigms were present impeding better usage and integration.

Discussions with commercial personnel focused on what their current state of the art was and how M&S had saved them time or money. Further, they provided information on how M&S could maximize effectiveness, with either cost or performance as constraints.

G. ACRONYMS

A listing of acronyms associated with both M&S and acquisition in general is presented in the Appendix.

H. ORGANIZATION OF THESIS

Chapter II of this thesis addresses the current guidance and initiatives on M&S. It defines what M&S are and what current laws, regulations, directives, and policies govern them. Further, it will identify initiatives being undertaken to modify the Army's current usage.

Chapter III looks at the current state of M&S usage and the impediments to change. This chapter examines how the Army actually employs M&S and what systemic structures prevent more extensive usage.

Chapter IV provides an overview of current commercial practices. It looks at how companies working on large, complex projects employ M&S. It also examines the cost, time, and performance benefits these companies reaped from using M&S as opposed to their previous methods.

Chapter V compares commercial and Army practices with regard to M&S use. It pays special attention to why the commercial world is using M&S more extensively and in multiple modes, while the Army continues to use M&S for distinct and finite purposes.

Chapter VI contains the conclusions from the comparison and recommendations for reforms to the acquisition process to better utilize M&S.

II. M&S GUIDANCE AND INITIATIVES

A. GENERAL

When looking to reform any system, one must first define the basis of the system. Currently, the Army's acquisition process is based on a life-cycle development model that was created to facilitate the development and fielding of the "Big Five" systems of the seventies and eighties. This model was developed to take advantage of both the technological and regulatory environments of those times.

Since the thrust of this paper is to recommend changes to the existing acquisition system, it is key to any further discussion and analysis that it define what exactly is meant by M&S. It must further define the framework, the acquisition life-cycle model, in which M&S must currently operate.

B. THE LIFE-CYCLE MODEL AND M&S

As mentioned previously, the acquisition life-cycle model and M&S are interrelated. While the acquisition life-cycle model can operate without M&S, M&S cannot currently operate within the acquisition process unless it is somehow tied to the life-cycle model. From this relationship, we can clearly see that an understanding of the life-cycle is essential to

any further discussion of M&S.

1. Life-cycle Model Defined

The acquisition life-cycle model is a five-phase process, illustrated in Figure 1. Each phase is preceded by a

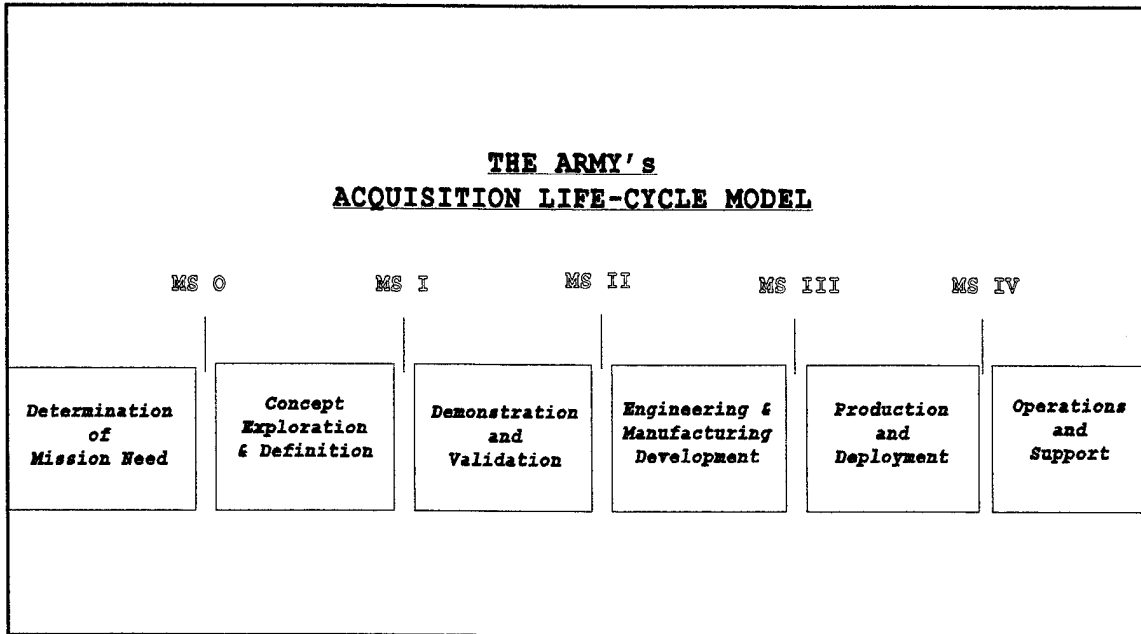


Figure 1 Acquisition Life-cycle Model

milestone that effectively acts as a gate into the milestone and an exit from a previous event or phase.

a. Milestone 0

Milestone 0 is the first milestone and entry into the first phase, Phase 0. Prior to this milestone, the Army determines the mission requirement and need for solution. This milestone marks the start of the search for a materiel

solution to a threat. Phase 0, Concept Exploration and Definition, is fairly self-explanatory. The purpose of this phase is to explore alternative materiel solutions to the need. The information from this phase applies directly to the next milestone. (DODI 5000.2, 1991, pp. 3-6 & 3-7)

b. Milestone I

Milestone I, the second milestone, actually marks the beginning of a new program. Passage through this gate signifies the requirement to develop and field a materiel solution to a user need. This milestone also starts Phase I, Demonstration and Validation (Dem-Val). In this phase the concepts from Phase 0 begin to take shape. Normally, this is the point when the program office first begins to "bend metal" and conduct developmental testing (DT). (DODI 5000.2, 1991, pp. 3-10 & 3-14)

c. Milestone II

Milestone II signals the end of the Dem-Val phase and the start of the Engineering and Manufacturing Development (EMD) phase. Phase II, or EMD, is the point where designs get firmed up and actual testing with troops takes place. Successful completion of EMD is required for a system to reach production and the field. (DODI 5000.2, 1991, pp. 3-19 & 3-22)

d. Milestone III

Milestone III heralds the start of full production of a system. A successful Milestone III will result in initiation of Phase III, Production and Deployment. This is the point where the user finally gets the system needed to combat the threat identified prior to Milestone 0. (DODI 5000.2, 1991, pp. 3-24 & 3-27)

e. Milestone IV

Milestone IV, the fifth milestone, is similar to Milestone III. Its purpose is to get approval for modifications to an existing system. It is the only Milestone that does not act as a gate into its accompanying phase, Phase IV. All fielded systems have a Phase IV, Operations and Support, even if there is no Milestone IV. This phase encompasses supporting the day to day operations of a system, and the continual checking to ensure it can still meet its mission need. (DODI 5000.2, 1991, pp. 3-29 & 3-30)

2. M&S Defined

M&S encompasses a broad range of methods and capabilities. When first thinking about M&S, most people immediately think about computer-based systems, but M&S is not just limited to such systems. M&S actually exist whenever you evaluate or use a system in an environment that is not the one

in which it was designed to perform. In the Army's eyes, anything short of actual combat is a simulation (Mercer, et.al., 1994, p. 4-4).

By definition, a model is a physical, mathematical, or otherwise logical representation of a real world system, entity, phenomenon, or process (Garcia, 1993, p. D-3). To put this definition in laymen's terms, one would say that anything short of a full production run system would be a model. The overall objective of M&S is to provide the Army with information and data to evaluate the potential performance of a system, man and machine, in combat.

The Army further classifies M&S types into three distinct categories. These categories are defined as constructive, virtual, and live. As you progress from one category to the next, you get a corresponding increase in resource cost and realism. Figure 2 illustrates this paradigm. (US AMC TF - Draft, 1994, p. 4)

a. Constructive

Constructive M&S systems are the most widely used in the acquisition cycle. They encompass things such as war games, models (physical and virtual), and analytical tools. This category of M&S is the least expensive to use overall but also provides the least amount of fidelity. Examples of this

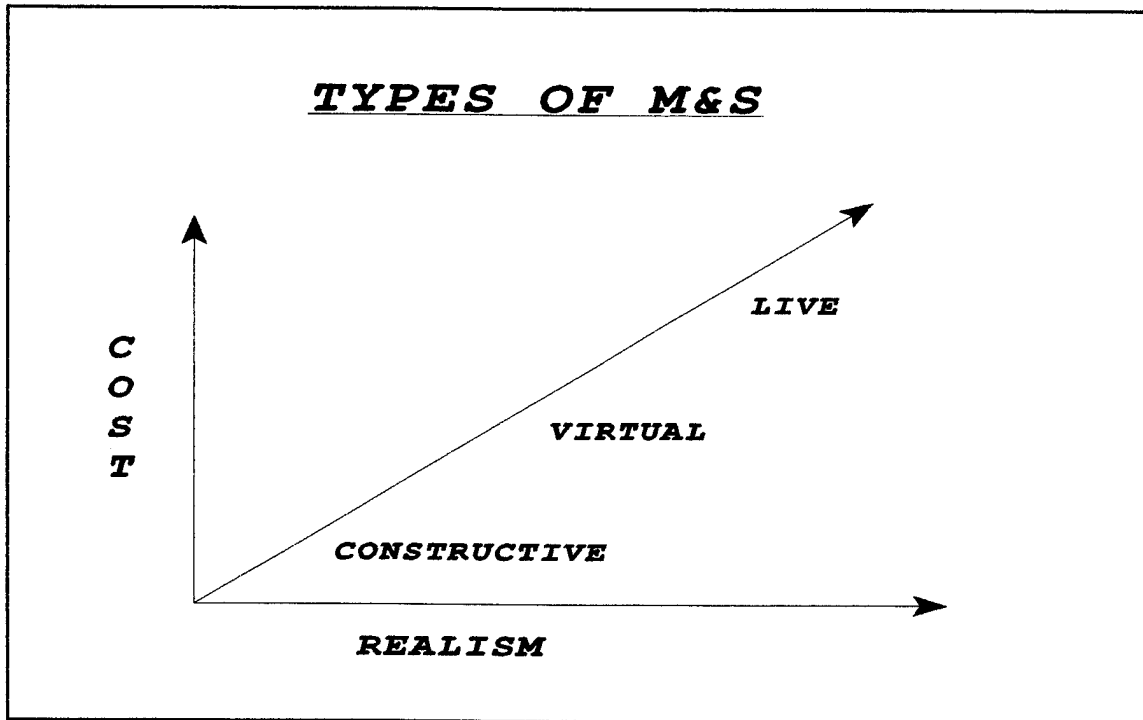


Figure 2 M&S Cost vs Realism Paradigm

category include Computer Aided Design/Manufacturing (CAD/CAM) tools, JANUS (force-on-force), and CASTFOREM (movement on a variety of terrains).

b. Virtual

Virtual M&S systems, while not currently used as widely by the Army as constructive systems, are becoming more prevalent. This category bridges the gap between constructive and live systems. As a result of this unique position, it provides a fair degree of realism at a medium cost. This category is normally associated with either troops in physical mockups or using computer models on a computer based,

synthetic, battlefield. Examples of these systems are MANPRINT labs (reconfigurable mockups), Close-Combat Test-Bed (networked developmental mockups), and SIMNET (linked tactical trainers).

c. Live

Live M&S systems provide the highest degree of realism but at the highest cost. They involve the use of actual soldiers with actual systems, either pre-production or production models. Examples of this type of M&S include such events as operational tests, field training exercises, and training center rotations.

C. CURRENT POLICY ON M&S

The tone for the Army's policy on M&S has changed dramatically over the last decade as the budget has shrunk. The Army currently sees M&S as a means to maximize both the cost effectiveness and operational effectiveness of its acquisition of systems in the future. This tone is exhibited by this statement by then Army Chief of Staff, General Gordon Sullivan:

You need to know that we will use simulation techniques throughout the Army's acquisition process. We will determine needs in large-scale, simulation supported exercises that allow us to

consider alternative solutions that meet our needs. We will use drawings, diagrams, and 3-dimensional models generated by computers, put them in constructive or virtual environments, and compare alternatives both technically and tactically. The most promising technologies will be tested by real soldiers, first in reconfigurable crew stations, then in full scale simulations. Final designs, production, and assembly steps will also be simulated in virtual factories before actual prototypes are made. Then the actual and virtual prototypes will be exercised simultaneously to discover potential problems before the production begins. Tactics, techniques, and procedures are also developed along with the system so that the system is fully ready for use when produced. (Sullivan, 1993)

1. Department of Defense Policy

As with all aspects of Army acquisition, the Department of Defense Instruction 5000.2, Defense Acquisition Management Policies and Procedures, also has an impact on M&S (DODI 5000.2, 1991, p. 16-6). While this is not the only DOD publication affecting M&S, it is the key document that affects M&S use in acquisition. DODI 5000.2 discusses the use of M&S in three specific areas. It mentions using models for Cost and Operational Effectiveness Analyses (COEA), in validating the survivability of systems under some extreme conditions, and it specifies how extensively M&S can be used in operational testing and evaluation.

2. Army Policy

General Sullivan's vision was reinforced by the Office of the Assistant Secretary of the Army (Research, Development, and Acquisition) (OASA(RDA)) in May 1993. At that point Lieutenant General (LTG) William Forster, the ASA(RDA)'s military deputy, issued a memorandum directing that all ACAT I and II programs, Advanced Technology Demonstrations (ATD) and Top Level Demonstrations (TLD) include a Simulation Support Plan (SSP) in their acquisition strategies. This directive effectively laid the responsibility for identifying the requirements of M&S to support engineering and combat developments, test and evaluation, and training and military exercises on the program manager (PM). The PM also had to develop an acquisition strategy to procure the M&S to support the requirements. (Forster, 1993)

In addition to the directive for SSPs, there are a number of other Army policy documents that impact on M&S. The most important of these documents is the Army Model and Simulation Master Plan. This plan guides Army investment in M&S and how it meshes with other DOD initiatives.

The second most important document to the Army acquisition community is the Department of the Army Pamphlet (DA PAM) 5-11. This pamphlet is the instructional manual

associated with Army Regulation (AR) 5-11, *Army Model and Simulation Management Program*. This pamphlet describes the procedures to verify, validate, and accredit (VV&A) M&S. These steps are key to establishing the formal validity of data resulting from M&S.

The third piece of policy that has an influence on M&S in Army acquisitions is DA PAM 70-XX. This is the instructional manual that accompanied LTG Forster's policy letter and gives guidance on how to prepare and submit the SSP. (Mercer, 1994, p. 3-9)

D. CHANGE INITIATIVES

As part of the Army's efforts to maintain its technological edge in an environment of shrinking acquisitions budgets, the AMC, as the Army's acquisition agency, has taken the lead in initiating change regarding M&S policy. The AMC recognized that M&S could be a key leveraging technology to increase cost and performance effectiveness. In order to determine how to fully realize the benefits of M&S, the AMC Commanding General formed a task force (TF) to prepare a strategy to accomplish this. The vision of the TF is "to field better and affordable (sic) combat materiel in the shortest time by integrating world class modeling and

simulation tools throughout the acquisition cycle" (US AMC TF - Final, 1994).

The TF had only ninety days to accomplish its mission. It was composed of members from all phases of the acquisition cycle, TRADOC, the Operational Test and Evaluation Command (OPTEC), and technical and acquisition personnel from all the AMC subordinate commands. At the conclusion of the ninety-day period, the TF presented seven recommendations to the AMC CG's Principal Deputy for Acquisition (AMC-PDA).

The AMC-PDA assigned these recommendations to subordinate agencies for action in 30 November 1994. The agencies were to have submitted draft implementation plans by 30 December 1994 (Oscar, 1994). The agencies have currently not submitted adequate responses to the AMC-PDA (Chamblee, 1995). Despite a lack of draft implementation plans, valuable insight can still be gained by examining the recommendations themselves.

1. Recommendation 1

The TF recognized a shortfall in current policy. The current policy does not adequately address M&S planning prior to MS 0, use of M&S to reduce costs in testing and development, and provide sufficient guidance on preparing SSPs. This TF recommendation contained three parts to overcoming this shortfall in policy. The first was to change

policy so that it would specifically state goals for test and development cost reduction, promote the use of the latest M&S tools, and encourage meaningful SSPs. The second was to update existing M&S related regulations to address these changes. The final part of the recommendation was to circulate good examples of SSPs.

2. Recommendation 2

The TF found that the Government was not specifying Government funded, contractor developed, M&S tools as deliverables to the Government. The TF realized the Government could get some reuse and cost savings if it required the contractor to deliver these items. They recommended that policy be revised to include language in RFPs making these tools discrete deliverables to the Research Development and Engineering Centers (RDECs).

3. Recommendation 3

The third recommendation dealt with the current emphasis on live or constructive simulation to meet test and evaluation (T&E) requirements. The TF felt that T&E should make more extensive use of the M&S tools developed at the RDECs. They recommended developing broader guidance on using M&S. They went so far as to recommend changing the name of the Test and Evaluation Master Plan to the Test, Simulation, and Evaluation

Master Plan as well as changing the Test Integration Working Group into the Test and Simulation Integration Working Group to mark the new emphasis.

4. Recommendation 4

The TF recommended that RDECs and the Simulation, Training, and Instrumentation Command (STRICOM) work together to develop reconfigurable Man-in-the-Loop (MITL) simulators. Accomplishing this would address the RDEC's shortfall in this area. This action would also allow the user-developer early access to simulators for low cost evaluation of designs.

5. Recommendation 5

This recommendation called for development of an overarching plan that addressed policy, vision, strategy, framework, and responsibilities for using M&S. This plan would tie together information currently found in three different plans, the M&S plan, the Distributed Interactive Simulation Master plan, and the Modernization plan.

6. Recommendation 6

This recommendation addresses the knowledge shortfall in the acquisition community. The TF recognized a need for a method to update the community on what the current state of the art is in M&S. They saw a need for a "road show" to visit AMC, TRADOC, and PEO/PMs to tout the successes of M&S. They

also saw a need to update the Defense Acquisition University's curricula in this area.

7. Recommendation 7

The final issue dealt with updating the M&S catalog. They recommended that PMs and RDECs be required to submit information on current M&S to the catalog maintained by the Deputy Under-Secretary of the Army for Operations Research. This action would allow the acquisition community a ready reference of M&S for potential reuse and cost savings.

E. SUMMARY

This chapter has laid a foundation for further discussion on how M&S is used. It showed how the Army acquires systems based on an acquisition life-cycle model. It has also shown that M&S can be anything short of combat. In the acquisition field, M&S is governed by both DOD guidance and Army policy, regulations, and guidance. The Army has recognized that M&S will be a key enabling tool to maintaining its technological edge in the future. To fully realize the benefits of M&S, the Army's acquisition command, AMC, commissioned a TF to make recommendations on how to maximize the benefits of M&S. The fact that the TF was formed means that the Army's leadership recognizes its current M&S usage is not all that it can be.

To fully understand this, one must next have an understanding of how the Army uses M&S in its acquisition process.

III. M&S USAGE AND CHANGE BARRIERS

A. INTRODUCTION

The Army's current milestone-based system of acquisition generates numerous M&S requirements in each phase. Each phase has its own requirements for M&S. In order to see how M&S can be used as a leveraging technology in acquisition reform, one must understand how the Army uses M&S in each phase. This chapter will examine how M&S is applied at each phase of the acquisition life-cycle. It will also identify systemic barriers to more extensive use of M&S in the acquisition life-cycle.

B. M&S USE BY PHASE

The Army uses M&S widely throughout the entire acquisition life-cycle. The use of M&S early in the life-cycle can be characterized as widespread but fairly simple. As the system continues through the process, the use of M&S tools will decrease but the complexity and cost of these tools will increase. As a program progresses through the life-cycle and its specifications become more complex, the PM needs M&S tools that better reflect the state of the system. This need for higher fidelity tools causes the PM to spend more money on

fewer tools.

Despite this cost growth and usage decrease, PMs continue to use M&S in all phases of acquisition. M&S provides the program with a means to reduce risk. Risk is mitigated by providing the program with a tool to study various alternatives, both cost and performance based, in a rapid manner across all phases. (US AMC TF - Final, 1994, p. 22)

1. Pre-Concept Exploration & Definition

The Army uses M&S extensively at this stage of the acquisition cycle. At this stage the initial decisions are made as to whether a program should even be initiated to defeat a new threat. A wide variety of M&S is used to determine the mission area analysis (MAA). The MAA is instrumental in defining the ability of existing systems to defeat a new threat and examining potential capability enhancements to overcome it. (Mercer, 1994, p. 5-2)

During this phase of the acquisition cycle, most M&S types are constructive in nature with some limited use of virtual types of M&S. The constructive models allow evaluation of various engineering and design proposals. The data from these models are used as input for simulations of the probable materiel solutions in force on force engagements. These simulations replicate engagements between units from

platoon all the way up to theater size.

The data from these simulations are correlated with results from virtual types of M&S. Virtual M&S, such as the Close Combat Test-Bed facility at Fort Knox, Kentucky, allows humans to input changes to tactics as the situation develops. It also allows combat developers, the requirements generators of the acquisition process, to evaluate new tactics and techniques against the new threats.

Thus, M&S at this stage is significant in determining the requirements to begin the acquisition process. The lowest level of models provides data on a system's ability to survive given a new threat. The next level of simulation builds upon that data to examine the impact of units equipped with the modeled items in an operational environment. The highest level of simulations identifies the war fighting factors to be stated in the mission need statement (MNS). (Mercer, 1994, p. 5-2)

2. Concept Exploration and Definition

In this phase many of the same types of M&S tools are used again. The major difference here is that the materiel developer (Mat/Dev) is using the M&S. He uses M&S to further refine the potential solutions to the mission need as well as project the costs associated with each potential solution.

The Mat/Dev uses M&S to examine specific materiel alternatives for their performance characteristics. The examination can range from the engineering level through to the theater level. These models allow the conduct of trade off analysis of various configurations in an operational environment.

Coupled with these analyses are a variety of other studies facilitated with M&S. Logistics models assist in developing the support plan and the operations and support (O&S) costs associated with fielding the system. Cost models allow the Mat/Dev to conduct cost estimates for a variety of concepts in a short period of time. The cost information resulting from the M&S is a key component of the cost and operational effectiveness analysis (COEA), an important deliverable from this phase.

The other two important documents arising from this phase, the operational requirements document (ORD) and draft system specifications, are aided by M&S usage. Constructive and virtual M&S tools allow analysis of the mission effectiveness of each alternative. M&S allows the Mat/Dev to test numerous different solutions on a variety of battlefields in a short period of time. Through the use of some simplistic virtual M&S tools, the Mat/Dev integrates the user into the

examination of potential solutions at an early stage in the development.

The final element that M&S facilitates at this stage is program consistency. M&S allows the Mat/Dev the opportunity to apply the same measures of effectiveness (MOE), measures of performance (MOP), and critical system characteristics between the various program documents at this stage. M&S facilitates this by applying these standards consistently as each potential solution is modeled or simulated. (Mercer, 1994, p. 5-4)

Data from M&S contribute to every document resulting from this phase. The cost analysis not only impacts the COEA but also plays a role in the acquisition program baseline (APB). Results from operational M&S contribute to MOEs and MOPs in the ORD, COEA, and test and evaluation master plan (TEMP). Finally, the data from constructive engineering M&S help frame the specifications of the system. (Beck, 1992, p. 35)

3. Demonstration and Validation

M&S at this stage of a program begins to become more complex and system specific. As the program matures, the PM uses higher fidelity M&S tools that more truly reflect the parameters of the system. The PM uses M&S to model components of the end system. This allows him the opportunity to try out

various alternatives prior to writing the detailed design specifications. It is also at this stage that some developmental testing occurs using M&S. (Beck, 1992, p. 35)

The M&S tools at this point also allow testing and designing of actual hardware and software in the loop at integration labs. These labs allow the PM to see the progress of various component prototypes and how they operate within the framework of the whole system early in the development. These labs can be extremely beneficial in reducing risk by identifying and correcting problems before any components, software or hardware, are produced.

As the components of a system become better defined at this stage, logistics models and simulations are also developed. These M&S tools provide a reasonably accurate prediction of how well the logistics support plan will facilitate the operation of the system. M&S tools allow the logistician to see how various configuration changes will affect reliability and maintainability. (Mercer, 1994, p. 5-6)

Virtual M&S tools increase in frequency of use at this time. These tools allow the PM to place the eventual user of the system in early designs of the system. This has the effect of providing the user an avenue for input on the system design prior to any actual manufacture. This input assists in

precluding expensive design modifications to the system after it is fielded.

During this phase computer aided design and manufacture (CAD/CAM) tools are used. CAD/CAM supports early producibility planning, factory facilitization, and design planning. CAD/CAM also provides the user and PM an opportunity to review and update specifications while seeing the effects these changes will have on the schedule and cost.

M&S assists in further refining cost estimates at this point in the acquisition life-cycle. The PM uses cost models to incorporate engineering cost estimates to arrive at more reliable estimates for the proposed system. These cost estimates are in turn used in evaluating contractor proposals for the next phase of the acquisition.

4. Engineering and Manufacturing Development

Use of M&S in the engineering and manufacturing development phase has declined in volume but the complexity of M&S tools being used has increased dramatically. Accompanying this increase in complexity is a commensurate increase in cost associated with M&S use. By this phase, the majority of the M&S tools are either virtual or live.

Although the majority of the M&S tools are virtual and live at this point, some constructive M&S tools are used.

They are employed to assist designers with final configuration management of components. They also provide a final insight into how large units of the final system will perform and impact at the theater level of combat.

Virtual M&S tools provide the largest role at this point. They allow the program manager to review how well the systems have been designed with the soldier in mind. They also provide needed feedback on how well hardware and software components operate together via trials in integration labs.

M&S tools are instrumental in mitigating risk associated with the milestone tests of this phase. These tests are both operational and development tests. They represent the final hurdle to exiting this phase. M&S provides the PM an opportunity to "model-test-model" his system prior to actual live testing. The results from these simulations are used by the PM to confirm his testing parameters and point out areas that will need additional emphasis to succeed. (Barbara, 1994)

Model-test-model represents a departure from previous methods of testing. Prior to the widespread use and acceptance of computer-driven M&S, the primary means of testing was accomplished via the process of "build-test-break-fix". This method was extremely expensive and time consuming. This method is still used and is a form of M&S itself. It is

the live form of M&S.

This method is still the only method of successfully completing the required operational testing for this phase and some legally mandated development test, such as live fire survivability/maintainability tests. By integrating the model-test-model methods into the live simulation, the PM now has a new tool for controlling costs.

Live M&S is also used by the PM to prove out principles that were developed in previous M&S efforts. During this phase, enough prototypes or pilot systems are available for unit-sized elements to run the systems in a field environment. This first live, large scale usage allows PMs and Mat/Devs the opportunity to validate results from small unit virtual and constructive simulations. (Beck, 1992, p. 35)

As in the previous phase, M&S is also used for logistics and pre-production planning. Some of these data were generated in Dem/Val but now the PM and the contractor will use the final designs to generate final cost estimates, unit price through life-cycle. At this stage, also, M&S is used to provide final plans for production facilities support plans.

5. Production and Deployment

At the production and deployment phase, M&S usage has tailed off considerably. PMs use M&S at this point primarily

for training of crews and preliminary testing of any new system modifications. It is also at this point that the PM must consider funding the support of M&S tools that will be required in the future.

During this stage virtual M&S tools are also being fielded to support the operations and training on the new system. While these M&S tools are not specifically used in the acquisition process, they do represent an important part of modern programs. Many programs now will actually define their operations and support costs for a system based on the cost savings provided by troop usage of these virtual simulators and models in lieu of live simulation.

While the PM continues to use M&S at this stage of a program, he normally does not foresee M&S requirements past fielding a system. This shortsightedness is the primary reason that M&S is not used more widely in the next phase. M&S tools require PM funding to be maintained, but normally this is the first part of program funding that is cut to save money. (Beck, 1994)

6. Operations and Support

M&S in the operations and support phase is probably the most under-used tool at the PM's disposal. It is at this phase that M&S use is lowest but also the point where all

three types of M&S can have a significant positive impact. PMs have used M&S to troubleshoot problems in the field and test proposed modifications to systems. (TARDEC, 1994)

The major hindrance to the full realization of M&S capabilities at this point is funding. A properly maintained and updated M&S tool for a specific system can be extremely valuable. Funding for this maintenance, however, is of low priority until the tool is needed. At that point, the PM must provide more money to update the tool in order to get valid data than if he had funded maintenance previously. (TARDEC, 1994)

C. BARRIERS TO CHANGE

As can be seen from the previous section, the Army uses M&S extensively in its acquisition cycle. Although M&S use is extensive, it is not as well integrated as it could be. In this case, an integrated system would be one that allows for rapid communication of information across boundaries. These boundaries are primarily functional and phase driven.

As an example, if the Comanche PM uses M&S tools to lock in a design for the cockpit in the demonstration and validation phase, he will be able to provide an initial design for his engineers. In a fully integrated M&S system, the

design could be automatically transmitted to the manufacturer for its impact on producibility. System integrators would be able to review its functionality within the total system and comment on it as changes occur. Cost analysts would be able to see the impact the design might have on existing estimates. All this would occur near-instantaneously instead of being delayed because of transcription or transportation. Similar results could be achieved across phases as well.

The Army essentially has the facilities and expertise to provide the PMs with this type of integrated M&S system. There are a number of barriers to exploiting the full potential of the Army's M&S expertise. These barriers come in many forms. They are regulatory, cultural, economic, and technical. (US AMC TF - Draft, 1994)

1. Regulatory

Recent studies have characterized the regulatory barrier as a kind of vacuum. This vacuum exists because the Army has an overall lack of guidance regarding the proponency, coordinated planning, and funding of M&S. The Army also lacks regulations on how M&S should be integrated across various functional environments and, in the case of acquisition, phases. (US AMC TF - Final, 1994, p. 42)

The Army has recently recognized this vacuum and is

taking steps to fill it. The Army has created a Simulation Strategic Planning Office (SSPO) to coordinate the M&S efforts across the Army. This office will merge the M&S requirements of the operational, training, and acquisition domains of the Army and eliminate any redundancies in efforts and capabilities. (Glashow, October 1995, p. 32)

The SSPO sprang from a concept of General Gordon R. Sullivan, at the time Chief of Staff of the Army, to have one office that plans the development and management of all Army M&S tools in order to maximize available resources. This new office will also work with the other services to publish a Department of Defense master plan for M&S. This plan is another in an effort to provide clear guidance on M&S uses and goals.

2. Cultural

The move to fill the regulatory vacuum recognizes the potential of an integrated M&S system and is the first step in more fully exploiting these benefits. The creation of this office does not, however, do anything to change perceptions of how M&S should be used. This is the cultural paradigm that presents itself as one of the largest inhibitors to realizing the full potential of M&S.

Most PMs still see M&S as a means to conduct training or

try out concepts. They do not recognize that M&S could supplement, and in some cases replace, many of the tests that cost their programs large amounts of money.

Additionally, most decision-makers view M&S as a supplement to hardware development. In its ultimate form, an integrated M&S system could allow for hardware to supplement an M&S based development cycle. This type of systemic change would allow for rapid, virtual prototyping early in the acquisition cycle. Coupled with an integrated M&S system linked to the production process, early virtual prototyping could significantly reduce schedule and start-up costs. (US AMC TF - Draft, 1994)

3. Economic

Another barrier to full utilization of M&S is lack of adequate funding for M&S tools. This funding barrier takes many forms. It can take the form of under funding, inflexibility resulting from type of funding, and lack of focus. (US AMC TF - Final, 1994, p. 41)

As with all Army acquisitions, funds for M&S are extremely tight. Few programs are funded to their programmed amount. As an example, the Army is currently looking at plans to cut all M&S programs by ten percent in 1997 to find funds to maintain troop levels. (Glashow, et.al., September 1995, p.

4)

Not only can inadequate funding be a problem but the type of funding can be restrictive as well. In broad terms, funds are appropriated for one of three areas: development, production, or operations and support. M&S systems procured or funded by a specific type of fund may only be used for that function. Additionally, funds appropriated for development are further restricted for use in specific phases of the acquisition cycle.

The final shortfall of funding comes in focus. Most funding for M&S is appropriated via programs. While this enables PMs to dedicate funds to those areas where they need M&S help, it does not provide the research, development, and engineering centers (RDEC) with funds to maintain their systems. This is especially true with creating and maintaining models for the Army's legacy systems of the eighties. These systems were fielded prior to the wide use of M&S and therefore few models of these systems exist for input into M&S tools.

4. Technical

As noted above, the technical challenges inherent in using M&S to facilitate system acquisition are daunting. They encompass everything from attracting qualified, quality

personnel to making sure the computers in the system can communicate with each other. While the technical challenges may seem the most daunting, they are the easiest to overcome.

Currently, most of the Army's M&S tools are near state of the art. These tools call for an open type of architecture that allows for free exchange of information and data. The major failing of this technical state is the plethora of different M&S tools. Although these tools allow for communication, much time must be spent in defining how to transfer the data. Also, the PM must spend an inordinate amount of time searching for the best tool to use since there is no readily available catalog on all the available tools.

The M&S tools all work with different databases. Further, most M&S facilities have no databases on any systems produced prior to the late eighties, early nineties. This means that the systems that will require HTI items to remain effective in the near term have no digital database. These items include the M1 Tank system, the M2/M3 Bradley system, the M109 Howitzer family, and practically every system used in Desert Storm.

D. SUMMARY

As has been seen, the Army uses M&S extensively throughout each phase of the acquisition cycle. Currently, M&S tools provide a means for the PM to mitigate risk in specific functional areas. These areas could be in design, logistics, testing, threat analysis, etc. The best area for realizing additional benefits from M&S comes from better integrating these M&S uses. In order to realize these savings, the Army must first recognize that the potential benefits exist and then go about removing the barriers to reaping the benefits.

The Army has begun to remove some of the barriers already. They have created the SSPO to coordinate the Army's M&S efforts in acquisition, operations, and training. It will also provide guidance for how the Army should direct its M&S efforts. This initiative begins the breakdown of the regulatory barrier, but others remain.

The hardest of these to remove is the cultural barrier. The Army must convince current and future PMs that an integrated M&S system can be an enabling technology to true cost and time savings. Currently, most PMs see M&S as only a tool for specific uses, as opposed to a medium for rapid communication of information across functional and phase

boundaries.

The final two barriers are closely related and have impacts upon each other. These barriers are economic and technical. Currently, funding for M&S tools can be inadequate, unfocused, and inflexible. These economic problems have adverse effects for RDECs, which impact their ability to maintain the technical capabilities of their tools.

While M&S usage is widespread in Army acquisitions, it is not the only segment of society that uses M&S in its acquisitions. The next step in the analysis is to see how industry uses M&S in its large system acquisitions. One must also see what, if any, barriers must be overcome in applying M&S.

IV. COMMERCIAL USE OF M&S

A. INTRODUCTION

Before one can examine how M&S impacts the commercial acquisition process, one must first understand how the commercial sector conducts acquisitions and programs. In order to maintain a commonality for future comparisons, one must restrict observations to industries that compare to Army acquisitions. In this case, data have been restricted to commercial aviation, defense contractors, aerospace, and construction enterprises. These industries, like the Army, conduct acquisitions that run into millions of dollars, can be multi-year undertakings, and are complex.

After laying the foundation of commercial acquisition, one can begin to see the impact of M&S. The second part of this examination will explore how these enterprises use M&S in their large scale programs and acquisitions. It will also point out any barriers that may exist to full utilization of M&S.

B. OVERVIEW OF COMMERCIAL ACQUISITION

Commercial acquisition of products and systems can take a myriad of forms. Each company will have its own unique

process for acquiring items. All companies will make a decision to make an item itself or buy it from a supplier. Even if a company decides to make a system, it will more than likely have to purchase some parts from other companies. (Burt, et.al., p. 151)

Regardless of the specific acquisition system of each company, the following process will apply to most companies. In general, the acquisition process will consist of three phases. Although each phase has a specific goal, they are not mutually exclusive, i.e., parts of each phase may overlap. These three phases are recognition of need, test and development, and production and support. This section will define each of these phases in broad terms.

1. Recognition of Need

Recognition of need in commercial acquisitions will take place at one of two places in the commercial sector. In one case, the user of a product will recognize the need for a new product or system to meet a new market requirement. The second case involves a producer of a product recognizing a need for his product or system and marketing it to the eventual end-user of the system. For the purposes of this discussion, one must consider both cases as essentially the same.

In both cases, a company will conduct a number of studies at this point in the acquisition process. A producer or user will conduct trade-off analyses to determine the most cost effective means of meeting this new need. For an end-user, the decision is whether a change to operating and support procedures may satisfy the new market or a totally new system must be acquired. A producer will examine how much of a market exists for his new system and how many he must sell to break even on costs and begin to reap profits. Both users and producers will conduct cost analyses of procurement, operating, and support costs for a new system. A producer will also conduct producibility studies for the new system. (Burt, et.al., 1990, pp. 151-165)

The final event of the various trade-off, cost analyses, and producibility studies will be presentation to a corporate decision-maker for the approval to proceed. The level of the decision-maker will vary depending on the amount of risk the project's success or failure represents to the corporation's future survival. In the case of Boeing's 777 project, where the corporation had to expend large amounts of cash prior to the first sale, this decision was made by the board of directors. (Rich, 1995)

Assuming that the project receives approval for

production or procurement, the company proceeds to the next phase. Also as part of the approval process, the company will set schedule, cost, and performance parameters for the project, with schedule being preeminent. (Perkins, et.al., p. 71, 1989)

2. Test and Development

The test and development phase encompasses more test than development. Most commercial projects will encompass existing technology in their system rather than incorporating emerging technology. As a result of this approach, most companies will expend more time and money on testing their system than on developing new technology. Any new technology will have been explored and prototyped prior to exit from the first phase. Examples of this approach are 3M's entrepreneurial development centers and Bell Labs in New Jersey.

Despite the preponderance of low to medium risk technological approaches for the overall system, some development does occur in this phase. Normally, this development will take the form of developing and integrating new technologies for components of the system. These development goals will be identified at the start of the project. This approach keeps "requirements creep" within the project to a minimum.

Testing in this phase is extensive. It will encompass everything from component to full mock up testing. A key part of the testing is the locking in of the system specifications and design.

Another important element of this phase is integrating customer requirements into final design as results from tests return. This feedback loop between project and user allows the company to successfully field a system with a minimum number of customer required changes after production. Companies do not see this as requirements creep because the performance specifications do not change as much as the means to achieve the performance changes. (Rich, 1995)

The final part of this phase is development and testing of production facilities. Companies will ensure that facilities have adequate capacity and capability to produce the system in the quantities required. They will also test their production processes through various trials.

3. Production and Support

This is the final phase of commercial acquisition. This phase is only entered into once the system has met its performance requirements and the required market for it has been established. During this period, the systems are produced, operators are trained, and logistical support is

marketed or provided.

C. USE OF M&S

While M&S are not common in all parts of the commercial sector, they are very prevalent in those companies conducting large, complex projects and acquisitions. These companies have recognized the need to get items to market quicker and with shorter lead time in order to be commercial leaders in the next century. The highly successful companies have gone so far as to create M&S systems that connect all phases of acquisition together in one seamless tool. (Davis, 1995)

This tool provides the company a foundation to make changes to a system and almost simultaneously see the affect this change has on every aspect of cost, schedule, and performance of the system. This tool allows the project manager real savings by allowing him to determine how much performance he gets for his dollar and how much it will cost to get a given level of performance (Davis, 1995). This revolution in information is accompanied by new methods of managing and organizing projects.

Prior to this M&S ability, projects were stove-piped in their roles and responsibilities. Designers designed a system and passed it on to engineers to build. Engineers developed

the construction process and passed to the factory. The factory built the system and if any problems arose, they had to crawl back up the process chain to correct it. Currently, these elements, along with customers and suppliers, are linked together via M&S to provide continuous and real-time feedback. (Rich, 1995)

In order to fully understand the benefits of this structural use of M&S, one must understand how M&S is used in some of the key areas of the acquisition process. There are five specific areas where M&S have had a large positive impact. The positive impact has provided either a direct cost savings to firms or a schedule savings to projects.

1. Business Analysis

Although many firms use financial and cost models to estimate the cost of projects, very few have the capability to update these models rapidly as design changes occur. M&S tools such as the Simulation-Based Design (SBD) tool being designed by Lockheed-Martin provide cost updates automatically as design changes occur (Davis, 1995, Briefing). This represents a significant time savings over past methods of manual re-computing.

Boeing has been able to reap even more extensive benefits with their Computer-Aided Three Dimensional Interactive

Application (CATIA) based modeling system. By linking parts suppliers, engineers, designers, and customers together, Boeing can update their cost estimates on a regular basis. This linkage allows suppliers to directly input prices for design changes to components. Customers are able to see potential cost benefits or debits resulting from their requests. This system provides Boeing with a better cost estimating and marketing tool since they can provide customers with fact-based price updates on various models of the 777. (Rich, 1995)

2. Design

CAD/CAM use is now widespread in the commercial sector. The leading edge of CAD/CAM in design is paperless design. Boeing was able to design the 777 entirely on its CATIA system without any drafting on paper.

The future of design will encompass not only CATIA-like systems but also the design-build team approach of Boeing. Under this system more than twenty-three different major parts suppliers, all customers, and Boeing designers were linked in real time, allowing early input from all the stakeholders in the 777 project. This early input allowed for design changes early in the procurement process when costs are relatively low. (O'Lone, 1991, p. 35)

3. Test

Boeing's approach with the 777 is one of the leaders in the use of M&S for testing. Prior to any plane being built, Boeing ran simulations of the 777 and its subsystems on computers. These tests provided earlier feedback than Boeing had been able to achieve under previous methods of building a mock up and then breaking the mock up to discover faults.

This also provided an exponential cost and schedule savings. Additionally, the fidelity of these tests was such that Boeing was able to persuade the Federal Aviation Administration to waive some of their preliminary flight tests. This allowed Boeing to stay on schedule and apply the time saved from actual flight tests to resolving problems with one of their engine suppliers. (Dornheim, 1991, pp. 50-51)

Many other companies are also finding that integrated M&S tools can assist in testing. Lockheed-Martin has used SBD to test design changes in virtual environments. This has been used to identify stress points in new designs. They have also demonstrated the ability to conduct virtual tests of items that provide results in days as compared to months using previous methods. (Davis, 1995, Briefing)

4. Build

There are numerous examples of M&S use in the building of systems. The major impact it has had in this aspect of the acquisition process has been in the area of the virtual factory. Using an integrated M&S system, industry has been able to conduct full production runs of systems before a factory has even been provisioned. (Garcia, et.al., 1993, p. 140)

These virtual factory runs allow the factory managers to determine the most efficient set up before the first manufacturing machine is installed. The virtual factory also allows program managers insight into areas where the rework and scrap rate could be decreased.

Another aspect of building the system where M&S tools can make an impact is identifying assembly conflicts. High fidelity tools linked with designers allow assembly workers to point out space conflicts before parts reach the factory for assembly. This is especially important in projects where a large number of subassemblies are being made at sites away from the final assembly point. This ensures that everything will fit the first time. As an example, the first 777 was assembled to within an eighth of an inch of its designed specifications. This for an airplane composed of 130,000

parts. (Rich, 1995)

5. Support

M&S provide two key roles in supporting systems once they are completed. The primary role of M&S is training of operators. The secondary role is designing in maintainability.

By using high fidelity and integrated M&S tools, training can occur much earlier than previously. Linking operator training tools to engineering and design tools ensures that operators of systems will have access to the most accurate trainer available. As design and engineering changes occur to the project, the M&S systems will automatically update the training tools.

The second role is maintainability. Integrated M&S allow designers and engineers to ensure that humans can adequately access maintenance areas. This is an important consideration for many users of systems. If a system does not allow easy access for maintenance, then the downtime for the system will increase. This downtime translates into both lost revenues and increased labor costs.

D. BARRIERS

It is obvious that a fully integrated suite of M&S

provides commercial enterprises an added benefit. The question then becomes, why have more businesses not adopted this approach in their acquisition process. The two primary reasons are financial and cultural.

1. Financial

Most companies that have adopted the integrated M&S approach have had to invest a large amount of capital to purchase the computing power to run these systems. While actual costs are proprietary, one can imagine that the cost to Boeing of buying and installing more than two thousand terminals for CATIA input and eight of IBM's largest mainframes was relatively high (Dornheim, 1991, p. 50). In some cases, e.g., Northrop-Grumman and Lockheed-Martin, industry benefits from Government funding to modernize.

In the future, as the practice of integrated M&S systems in commercial acquisition becomes more widespread, the cost will come down. This barrier will decrease much more rapidly than the second barrier.

2. Cultural

The cultural barrier against full integration of M&S in acquisition is extremely difficult to overcome. Many upper-level corporate leaders see M&S not as technology to leverage change but as individual tools to solve problems quickly and

cheaply. The largest threat is that to fully realize the benefits of this architecture, corporations must change the way they manage projects. One of the largest hurdles Boeing faced in the 777 project was the use of design/build teams. The fear was that some of the company's proprietary information and processes would leak out through the close working environment fostered by this system. The Boeing teams contained not just Boeing employees but suppliers to competitors and, in some cases, competitors themselves.

Another aspect of culture that must be overcome is the Tayloristic method of management still prevalent in many companies. In many organizations, the company is structured so that engineers do not communicate with designers, who do not talk to assembly workers, who do not talk to marketers, etc. This lack of open crosstalk prevents full realization of the benefits of M&S. Successful users of integrated M&S eliminate these walls to communication. (O'Lone, 1991, p. 34)

E. SUMMARY

Commercial acquisition of large systems and management of large projects is a complex process. Each company will have its own specific approach to managing these efforts but one can construct a model for most commercial enterprises. This

model has three basic elements. The first element is requirements generation. The second element is test and development of the system. The third element is production and support of the system.

While many companies use M&S tools, those companies with very large projects are implementing integrated M&S systems. They recognize that an integrated M&S system can help get systems to market in a timely cost-effective manner. These systems provide rapid business analysis tools throughout the acquisition cycle. They help to lower design, test, and building costs. Finally, they also assist in enabling early and accurate training on systems as well as ensuring ease of maintenance.

In order to fully implement these M&S systems and realize their benefits, some barriers must be overcome. The first barrier is financial. Most companies must make a large investment in the hardware and training to use an integrated M&S system. This barrier will become less significant as integrated M&S systems become more widespread.

The cultural barrier will fall more slowly. Many corporations will have to convince their senior leaders of the value of these systems. They must also overcome entrenched corporate management and communication systems that prevent

full realization of the benefits of integrated M&S systems.

The successes and growing use of integrated M&S systems, coupled with flexible management and acquisition processes, are evidence that M&S provides commercial enterprises benefits beyond their costs, financial and cultural. The key point to recognize is that those businesses which have successfully employed this technology, have used it to leverage an overall change to the way they accomplish acquisitions. The final question, then, is how can this technology and process be applied to the Army's acquisition process.

V. COMPARISON OF ARMY AND COMMERCIAL M&S PRACTICES

A. INTRODUCTION

Up to this point, this thesis has concentrated on answering the subsidiary question put forth in the first chapter. It has indicated how the Army currently uses M&S and the problems associated with its use. It has examined the planned reforms of the Army with regards to M&S usage and the regulatory, statutory, and policy directives regarding M&S usage. Finally, it has reviewed the best commercial practices of M&S usage. All this has been done in order to lay a foundation for determining how commercial and Army use of M&S compare. From this comparison and understanding of M&S use in these two systems, one will be able to conclude how the Army can take better advantage of M&S to streamline its acquisition process.

B. EVOLUTIONARY FORCES OF ACQUISITION

The first step to comparing commercial and Army M&S use is to understand the evolutionary forces of the two acquisition systems. The Army undertakes an acquisition program to meet and defeat a newly perceived threat. In comparison, commercial enterprises undertake acquisitions to

increase or maintain their profitability.

While the need for continued profitability and the need to defeat a threat appear different, in their most basic form, they are quite similar. The Army must defeat a new threat in order to maintain its viability on the battlefield. A company must maintain its profitability to maintain its viability in the marketplace. Failure by either entity to remain viable in its environment would spell its doom. Thus, while profitability and military capability appear quite different, they both concern continued survival and success in their fields.

Additionally, business, like the Army, is hesitant to conduct new procurements. Both entities will look for other means to accomplish their goals before expending the large amount of capital necessary for large programs. In the case of a business, it will pursue other means such as cutting back on costs, retrofitting existing equipment, refocusing management efforts, etc, to maintain and increase profitability. The Army makes a similar effort, but accomplishes it via a formal report and approval process. It requires that all non-materiel solutions be considered and ruled out prior to authorization being given for a program start.

Thus, the evolutionary force of acquisition for a commercial entity and the Army is essentially the same. The reason for each entity to pursue a material acquisition is its continued survival in its respective field. Each entity also pursues an acquisition as a last resort to fostering this continued survival.

C. ACQUISITION SYSTEMS

While the driving forces behind commercial and Army acquisitions are essentially the same, the systems used by each entity to conduct these operations are very different. The Army's system is very formalized and requires approval from higher authority to exit and enter each phase. The commercial sector, on the other hand, is more flexible and normally only needs approval at the start of a program to proceed to the production and fielding of a new piece of equipment.

As shown previously, the Army's system for acquisition encompasses six distinct phases. Throughout this entire process, the program is subject to cancellation or restructuring. The commercial system on the other hand, is made up of only three phases. Although it is also subject to cancellation, normally, once a project is approved, it will

continue until completion.

This difference in program composition leads to differences in their agility. Agility in this case means a program's ability to continue in spite of external and internal interference. This agility difference manifests itself in the level of importance each system places upon the parameters of cost, schedule, and performance.

The Army system is primarily dependent on achieving a certain level of performance for a given amount of funds. This means that a program must be agile enough to react to technological barriers or funding changes during a program's life. Additionally, the Army must be able to react to the demands of a political system. Thus, the Army has a system that can react to external changes in funding and political pressure as well as the internal pressures of overcoming technological challenges associated with cutting edge technology.

The commercial sector has different drivers and must deal with different pressures. The primary driver, in the program management triumvirate of cost, schedule, and performance, is schedule. Most businesses pursue materiel solutions to survivability to exploit a perceived opportunity. This window of opportunity is relatively short. As a result of the time-

sensitivity of this window, commercial programs emphasize maintaining their planned schedule. The commercial sector does not have to worry about politics. They do concern themselves with funding, but normally this is an internal concern.

Thus, while both systems are similar in their reasons for their inception, the way in which they operate and the outside factors that influence them are quite different. The Army system is very formalized and driven by the need to produce a product with a given performance. This performance may be achieved at the expense of cost or schedule.

Commercial systems, by comparison, are less formal. Their primary driver is schedule. They must get a product to market by a given date, even if it means some increased cost and less performance. The final difference between the systems is the external and internal forces that impact on each system. Political and funding forces act externally on Army programs, while there are limited external forces in commercial programs. Internally, cost has the largest impact in the commercial sector while technology has the largest on Army programs.

D. M&S COMPARISON

Within this framework of understanding of the Army and commercial acquisition systems one can compare M&S practices. This knowledge of the entire acquisition system is instrumental in comparing and understanding the varying roles M&S plays in each system. This comparison will look at the mission of M&S within each system, the extent that M&S is applied in each system, and the manner in which each system has adapted to take advantage of M&S technology.

1. Mission of M&S

The Army views M&S as a tool for a variety of missions, but its ultimate role is to mitigate risk, primarily technological risk. Commercial best practices also view M&S in a variety of roles, but its primary role there is as a tool to save cost and remain on schedule. These different missions cause each system to apply M&S differently.

Within the Army's acquisition system, M&S tools are used for specific results. The Army will use a tool to define specifications at various phases of the program, as in defining the Comanche cockpit configuration. It will use a different tool to determine cost estimates for the program. Another tool will be used to overcome technological hurdles through modeling and simulating a variety of different

solutions. The key factor here is that for each of these roles, a different and distinct tool will be used. For the most part, any sharing of information among these tools will have to be done manually.

By comparison, the commercial sector sees M&S tools in a different role. They see M&S tools as time and cost savers. They use M&S to accomplish the same finite missions as the Army but with a difference. This difference is the ability to link these finite tools together to communicate with each other. This linkage allows results from an engineering change to be applied to a cost model for a near instantaneous new cost estimate. This engineering change may have resulted from a simulation of the product performing in a new role requested by the customer.

The commercial sector has recognized the capability of a linked M&S system to provide time savings as changes occur or designs become more finite. They have also recognized the ability of a linked M&S system to provide real-time data exchanges between different parts of the acquisition team at widely dispersed sites. Companies are realizing that the time savings resulting from this linkage translates into cost savings. These savings, however, comes over the life of a program instead of in the near term.

These differing missions all emanate from the foci of each acquisition system. The Army's acquisition system is performance driven; therefore, its M&S usage tends to support resolving technological problems. While the Army's M&S tools save both time and money by their use, these savings are ancillary to the primary driver of supporting the system's performance. By comparison, commercial systems are schedule driven. The M&S tools assist in saving total program cost, instead of performance costs. They do this by rapidly communicating information gathered from M&S tools and showing how these impact price and schedule.

2. Extent of M&S Application

Not only are the missions of M&S within each system different but the extent to which M&S is applied is different as well. The leading users of M&S in the commercial sector use M&S extensively internal and external to their organizations. The Army, while using M&S tools more frequently, does not apply M&S technology with as much depth or breadth as the commercial sector.

Commercial leaders such as Boeing and Lockheed-Martin, apply M&S tools widely across functional areas. Systems such as Boeing's CATIA system are used by designers, engineers, marketers, and managers simultaneously. Each functional area

has a terminal or interface device that allows access to the central system. Within this system, there are numerous tools that are all linked.

In addition to the cross-functional linkage, there also exist external linkages. This access to the M&S system includes vendors, suppliers, and customers. Through these terminals, vendors can provide updates to the PMs on the availability of parts and price changes. Suppliers of components can instantaneously update PMs on the status of their products. This in turn allows PMs to update the whole spectrum of decision-making parameters. The linkage to customers allows them to play an active role in a project's progress and see the impact that their requested modifications may have on the program.

The Army, by comparison, does not presently use a centrally linked M&S system. The Army's M&S tools are functionally specific. The Army does have some externally linked tools, such as the distributed interactive simulation (DIS) system, that provides external linkage to customers. But, these tools are not widely used. Recent Army studies have also shown that there is a shortage of M&S tools available to assist with decision making. (DDRE TF, 1994, p. J-21)

Thus, the depth and breadth of M&S availability are quite different between commercial and Army systems. The commercial sector is using tools that work within a framework that crosses functional boundaries. The Army uses M&S tools within functional areas but does not have a widespread system that networks these functional tools together. Commercial M&S users also link their tools to sources outside their organization. The Army also has some links with entities outside the Army but they are not as widespread as those in the commercial sector. Numerous studies have shown that Army PMs feel that there is a shortage of M&S tools for decision making. The commercial sector does not have a commensurate shortfall because its broad linking of M&S tools was designed as a decision making tool.

3. Adapting for Advantage

The third part of this comparison deals with the various ways in which each system has adapted to take advantage of M&S. The commercial sector has changed the way in which it manages programs to leverage the advantage that M&S offers. The Army, on the other hand, has not changed its acquisition system in response to M&S technological advances.

Commercial systems have a history of changing the manner in which they manage production and procurement as technology

advances. When the assembly line became the technology of mass production in the early 1900's, industry altered its management from one of craftsman/apprenticeship to one of Tayloristic oversight of the assembly line. A similar revolutionary change has occurred with the businesses that have adopted the use of an integrated M&S system.

These industries see M&S technology not merely as a tool but as a revolutionary technology that can positively change the way in which they do business. These industries view M&S as a communication facilitator. The ability of M&S to rapidly exchange information has been key to changing the project management. These businesses have changed from a vertically oriented management structure to a more horizontal structure.

This change in management styles has allowed corporations to take advantage of the speed at which M&S facilitates communication and information exchange. The networking of M&S tools means a company can be more responsive to customer and corporate demands. This networking also allows for better visibility of the impact of one function's actions on all the others. This visibility of interaction is new. It has driven the commercial sector to also create integrated product teams that can react to the new perspectives provided by M&S.

The Army does not have a networked M&S system comparable

to the commercial sector. As a result, it has not changed the way it manages programs. The Army currently uses M&S technology as tools for specific functions. It does not see this as a revolutionary technology that changes the way production occurs.

E. SUMMARY

From this comparison a number of conclusions can be drawn. The first step to comparing these two systems was determining how the roots of each system differ or compare. The next step was reviewing the differing forces that influence each acquisition system. Once this basic foundation of similarities and differences between the two acquisition systems was laid, a comparison of M&S within each system could be accomplished.

While each acquisition system appears to have different reasons for being (profit versus threat), in reality they both exist to facilitate the continued survival and flourishing of each entity within their environment. While it was found that their roots were comparable, their methods of achieving survival and the forces that act on them were quite different. The commercial acquisition process is fairly simple, with schedule being the primary driver of a program. The Army's

system can be characterized as formalized, with performance as its primary driver. The Army's system must respond to external political and financial forces, while the commercial system has limited external forces.

Within this framework of understanding, a comparison of M&S can take place. The missions that M&S fulfill within each system are different. M&S in the Army is used as a tool to mitigate technological risk. Commercial M&S is used to save costs and facilitate staying on schedule. Commercial enterprises apply a linked M&S network internally across functional divisions and externally to customers, suppliers and vendors. The Army uses a linked M&S system in limited numbers. The Army's lack of a more comprehensive and widespread linked system results in M&S being used as individual tools for specific functions. Finally, as a result of the widespread linked nature of M&S technology in the commercial sector, companies have revolutionized their program management techniques. They have adopted a flexible, horizontal management style. The Army has not adopted such a revolutionary change in management because it does not have the linked system to support it.

VI. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

While conducting this examination of how the Army can utilize M&S to create a more streamlined acquisition process, a number of other questions have been answered. It has been shown that anything short of actual combat is a form of M&S. M&S comes in one of three types: constructive, virtual, or live. It has been shown that the Army uses M&S primarily to mitigate risk to a program. This risk mitigation normally concentrates on the technical aspects of the program.

This focus on risk mitigation has influenced recommendations to reform M&S usage. The Army's agency responsible for materiel development, AMC, commissioned a task force to come up with recommendations on improvements for M&S use. These recommendations, while useful, can be characterized as focusing on tuning up current M&S practices as opposed to revolutionizing them.

This stands in contrast to industry best practices where it embraced M&S technology as an enabling technology to remain competitive. This change occurred in response to a highly competitive market environment, in which funding for large capital expenditures for procurements is tight. They coupled

M&S technology with a flexible, horizontal program management structure and an acquisition process that focuses on meeting a fielding schedule above cost and performance criteria. The synergy of these three elements allows the leading businesses in the use of M&S to gain a competitive edge over their competitors who have not adopted a similar strategy.

The Army is rapidly being faced with similar circumstances as the commercial sector. Funding for large programs is becoming tighter as the military downsizes and a recognizable threat becomes increasingly difficult to identify. This means that the Army's acquisition system will have to become even more efficient in its use of appropriations. It will also have to be able to rapidly develop and field new or modified equipment as threats become identified.

As it currently exists, the Army's use of M&S is extensive but it is not as extensive as commercial use. The Army views M&S technology as a tool for use by the PM on his program. This differs sharply from the commercial view of M&S technology as a key element to providing communication within its program management structure. The Army's adoption of the commercial sector's outlook on M&S would result in only partial improvement in the acquisition cycle. In order to

fully realize the total benefit that M&S technology could provide, the Army would also have to change the structure of its acquisition life cycle process.

B. RECOMMENDATIONS

Applying the following recommendations should enable the Army to realize improvement in the acquisition life cycle through better use of M&S technology. These recommendations, if fully implemented, would provide the Army a more responsive, cost-effective acquisition system than it currently has.

1. The Army needs to inform its senior leadership of the benefits that an M&S system provides.

The first, and most important, step to realizing the advantages of having a fully integrated M&S system is to convince the senior leaders of the Army of the benefits of a commercial-type M&S system. This program should include not only decision makers at the Department of the Army level, but continue down through the workers in the acquisition process. This program should not emphasize that current M&S usage is wrong but that it could be better.

2. Fund and name an executive agency to produce an integrated M&S system.

Although there are a number of initiatives to define and construct M&S systems, none of them specifically address producing an integrated M&S system like the commercial sector uses. An executive agent, perhaps AMC, should have the mission of creating this system and fielding it. Funding of this research and implementation could come from programs by adding a surcharge to their M&S requests. The major requirement is that the funding for this system needs to be stable. Stability is key to fielding a system quickly and efficiently.

3. As the M&S system comes on-line, the Army needs to change the focus from performance as the paramount concern to performance being balanced with schedule.

As shown earlier, the Army's primary focus is not on meeting a fielding schedule, but attaining a specified performance level. This level is the paramount concern of the acquisition system. Its series of phases and milestones provide stops along the acquisition pathway to ensure performance parameters are met. This focus needs to become more balanced to reflect the competing needs of cost and schedule. This recommendation does not mean that the Army should abandon its performance requirements, but it does mean that it must recognize that cutting edge technology may not be

required in the world of undefined threats.

4. The Army needs to adopt an acquisition process that includes only three phases.

While this recommendation is not new, the application of an integrated M&S system as the foundation for a shortened process is new. The new process would have three phases. The first would generate the materiel requirement. The second would encompass the research and development efforts leading to production. The third would encompass production, fielding and support. This new system would save time and allow the Army to rapidly develop and field new systems economically. This new process could not be initiated until a networked M&S system was in place. This networked system allows for the integration across functional lines that would obviate the need for multiple phases in the pre-production process.

C. AREAS FOR FURTHER RESEARCH

Further research is needed in the following areas relating to this thesis:

1. What is the current status of the AMC TF recommendations on change?

AMC's TF recommended seven ways to improve the use of M&S. At the time this thesis was completed, no action had

been taken on these recommendations. Research should be conducted to see how these recommendations were being implemented and what their impact has been.

2. Research should be conducted into the current beliefs of PMs with regard to M&S usage.

A survey-based analysis of PM feelings on M&S use and methods of improving it would be fruitful. Having this information would facilitate efforts to change or amplify PM conceptions of the benefits of M&S technology. This would be especially useful since the cultural bias of decision makers is one of the larger inhibitors to better M&S use.

3. Research into efforts to use M&S technology in conjunction with horizontal technological integration (HTI) would be useful.

As the Army fields fewer new systems, it will be conducting more HTI improvements on existing systems. Configurations of these improvements through the use of M&S techniques may result in considerable time and cost savings.

4. An in-depth case analysis of a current Army program would provide insight into the cost savings that M&S provides when compared to past programs.

This thesis did not try to address the quantitative benefits of M&S to a program. It would be useful to determine

how much time and money M&S saves programs. This information could then be used to compare results from a commercial program.

APPENDIX ACRONYMS

ACAT	Acquisition Category
AMC	Army Materiel Command
AMC PDA	AMC Principal Deputy for Acquisition
APB	Acquisition Program Baseline
AR	Army Regulation
ASA (RDA)	Assistant Secretary of the Army (Research, Development, and Acquisition)
ATD	Advanced Technology Demonstrations
CAD/CAM	Computer Aided Design/Manufacturing
COEA	Cost and Operational Effectiveness Analysis
DA PAM	Department of the Army Pamphlet
Dem-Val	Demonstration and Validation
DIS	Distributed Interactive Simulation
DOD	Department of Defense
DODI	Department of Defense Instruction
DSMC	Defense Systems Management College
DT	Development Testing
EMD	Engineering and Manufacturing Development
GDLS	General Dynamics Land Systems
M&S	Models and Simulations (or) Modeling and Simulation
MAA	Mission Area Analysis
Mat/Dev	Materiel Developer
MITL	Man-in-the-Loop
MNS	Mission Need Statement
MOE	Measures of Effectiveness
MOP	Measures of Performance
O&S	Operations and Support
OPTEC	Operational Test and Evaluation Command
ORD	Operational Requirements Document
PM	Program Manager
SSP	Simulation Support Plan

SSPO Simulation Strategic Planning Office
STRICOM Simulation, Training, and Instrumentation Command

T&E Test and Evaluation
TARDEC Tank-Automotive Research, Development,
and Engineering Center
TEMP Test and Evaluation Master Plan
TF Task Force
TLD Top Level Demonstrations
TRAC Training and Doctrine Command Analysis Center

VV&A Verify, Validate, and Accredit

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