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THESIS

THE ANALYSIS OF SIMULATION BASED ACQUISITION (SBA) ECONOMIC BREAKPOINTS IN THE LIFE CYCLE OF MAJOR PROGRAMS

by

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December 2002

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The research area of this thesis is Simulation Based Acquisition (SBA) and the methods in which it has been implemented into the Department of Defense (DoD). Application of SBA initiatives relies upon the use of modeling and simulation, among other methods, to effectively use scarce resources – funds, manpower, equipment – in the life cycle of major programs. The SBA initiative has been used in the Department of Defense for approximately six years. Accordingly, program managers have employed the techniques of SBA to achieve significant advances while reducing costs. Thus, those resources saved may be used elsewhere in the program. Typically, savings can be realized early in the program life in terms of downstream logistics. Users who have identified Operating and Sustainment (O&S) constraints during the preparation of the Mission Needs Statement should examine the inclusion of SBA during concept exploration and system development. The Department of Defense has provided guidance on the SBA initiative and the methods of SBA are being incorporated into programs. The attempt of this study will not only identify the key points within the program to use SBA, but also how to best employ those methods.

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LIST OF ACRONYMS

A

AAAV - Advanced Amphibious Assault Vehicle
ACAT - Acquisition Category
ACEIT - Automated Cost Estimating Integrated Tools
ACR - Advance Concepts and Requirements
ADPA - American Defense Preparedness Association
AMSO - Army Modeling and Simulation Office
AoA - Analysis of Alternative
AR - Army Regulation
ASA(AL&T) – Assistant Secretary of the Army (Acquisition, Logistics and Technology)
ASOAR - Achieving a System Operational Availability Requirement

C

CAD - Computer Aided Design
CAE - Computer Aided Engineering
CAIV - Cost As an Independent Variable
CAM - Computer Aided Modeling
CCTT - Close Combat Tactical Trainer
CE - Concept Exploration
CE - Collaborative Environment
COMPASS - Computerized Optimization Model for Predicting and Analyzing Support Structures

D

DIS - Distributed Interactive Simulation
DMSO - Defense Modeling and Simulation Office
DoD - Department of Defense
DA - Department of the Army's
DON - Department of the Navy
DoAF - Department of the Air Force
DoDI - Department Of Defense Instruction
DoDD - Department Of Defense Directive
DOT&E - Director, Operational Test and Evaluation
DSCOPS - Deputy Chief of Staff for Operations and Plans

E

ECPs - Engineering Change Proposals
EMD - Engineering and Manufacturing Development
EUD - Early User Demonstration
EXCIMS - Executive Council for Modeling and Simulations

F
FCS - Future Combat System
FLIR - Forward Looking Infrared
FSCS - Future Scout and Cavalry System

H
HW/SWIL - Hardware- or Software-in-the-Loop

I
ICE - Integrated Crusader Emulator
ICT - Integrated Concept Team
IDE - Integrated Digital Environment
IPPD - Integrated Product and Process Development
IPT - Integrated Product Team

J
JSB - Joint Synthetic Battlespace

L
LC - Life Cycle
LCET - Logistics Cost Estimating Tool
LOBL-I - Lock-On Before Launch Inhibit
LSCFT - Low-Speed Captive Flight Tests

M
M&S - Modeling and Simulation
MACS - Modular Ammunition Charge System
MAVs - Micro Unmanned Aerial Vehicles
MNS - Mission Needs Statement
MSRR - M&S Resource Repository
MSIAC - Modeling and Simulation Information Analysis Center

N
NAVMSMO - US Navy Modeling and Simulation Management Office

O
O&S - Operating and Sustainment

P
P&D - Production and Development
PDRR - Program Definition and Risk Reduction
PM - Program Manager

R
RAM - Reliability, Availability, and Maintainability

RD&A - Research, Development, and Acquisition
RDT&E - Research, Development, Test, and Evaluation
RSV - Resupply Vehicle

S
S&T - Science and Technology
SAF - Semi Automated Force(s)
SAMP - Single Acquisition Management Plan
SBA - Simulation Based Acquisition
SBCCOM - Soldier and Biological Chemical Command
SD&D - System Development and Demonstration
SECDEF - Secretary of Defense
SECNAV - Secretary of the Navy
SESAME - Selected Essential-Item Stock for Availability Method
SMART - Simulation and Modeling for Acquisition, Requirements, and Training
SPH - Self Propelled Howitzer SSP - Simulation Support Plan
STEP - Simulation, Test, and Evaluation Process

T
T&E - Test and Evaluation
TEMO - Training, Exercises and Military Operations
TEMP - Test and Evaluation Master Plan
TOC - Total Ownership Costs
TRACER - Tactical Reconnaissance Armoured Combat Equipment Requirement

U
USAF - US Air Force
USA - U.S. Army
UK - United Kingdom
USD (A&T) - Undersecretary of Defense Acquisition and Technology

V
VV&A - Validation, and Accreditation

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I. INTRODUCTION

A. ABSTRACT

The research area of this thesis is Simulation Based Acquisition (SBA) and the methods in which it has been implemented into the Department of Defense (DoD). The application of SBA initiatives relies upon the use of modeling and simulation, among other methods, to use effectively scarce resources – funds, manpower, equipment – in the life cycle of major programs. This concept has been defined as:

> Simulation Based Acquisition is an iterative, integrated product and process approach to acquisition, using modeling and simulation, that enables the warfighting, resource allocation, and acquisition communities to fulfill the warfighter's materiel needs, while maintaining Cost As an Independent Variable (CAIV) over the system's entire life cycle and within the DoD's system of systems (Johnson, et. al., 1997 – 1998).

SBA has been used in the Department of Defense for approximately six years. Program managers have employed the techniques of SBA to achieve significant advances while reducing costs. Thus, those resources saved may be used elsewhere in the program. Typically, savings can be realized early in the program life. The U.S. Army has recognized this point and is actively addressing it. In 1998, Ms. Ellen Purdy (with the office of the Secretary of the Army for Research, Development, and Logistics (since renamed Acquisition, Logistics and Technology (ASA(AL&T))) was quoted as saying:

> What costs the most is operation and support. There are many opportunities to impact the cost of operating and supporting a system at the beginning of the development cycle. By the time we hit Milestone I, we have locked in 70 percent of the cost of operating and sustaining a system' (AR Today, Nov/Dec 1998).

Clearly, the Army recognizes the impact that design has on the total ownership cost for the program. Any savings that can be attained during the development of the system translate into huge downstream funding opportunities. Users who have identified Operating and Sustainment (O&S) constraints during the preparation of the Mission Needs Statement should examine the inclusion of SBA during the concept exploration and system development.

The need for up-front involvement also affects the risk associated with performance as can be seen by the following passage.

> The SBA process offsets increased performance risk by enabling the user to become a member of the design team and to influence the design much earlier than the current process allows; and this provides rapid feedback to the design team by enabling them to perform “what if” analyses, or iterations, on hundreds of different designs (AR Today, Oct/Nov 2000).

Using modeling or simulation is a powerful tool for the program manager who seeks to reduce performance risk, incorporate concurrent design changes, or examine the possibility of using off the shelf commercial items. Each of these possibilities can be analyzed in the Modeling and Simulation (M&S) process and have an immediate determination as to its usefulness.

The Department of Defense has provided guidance on the SBA initiative and the methods of SBA are being incorporated into programs. However, it is not specifically clear to program personnel on how to best utilize these techniques. The attempt of this study will not only identify the key points within the program to use SBA, but also how to best employ those methods.

B. SCOPE OF THE THESIS

It is the intent of the thesis to concentrate on Simulation Based Acquisition (SBA) and its impact on military programs. The basic premise of SBA is to reduce initial costs through modeling and simulation. These cost savings can then be driven back into the program in some form. Oftentimes, these funds can be used for additional units in production, spares and repairs, or effective logistics management.

The thesis research will include a survey that will concentrate on Navy programs across all Acquisition Category (ACAT) programs. All data collected will be analyzed through the narrative response provided by the respondents. The thesis will attempt to identify the points in a program that effectively use different forms of SBA to achieve cost avoidance or technical advances. In doing so, the result would be a more effective use of funding for additional requirements within the same acquisition.

The principal question to be answered through the study can be stated as: *"Are there specific times within the life cycle of a major program when it is in the best economic interest of the Program Manager to use the methods of Simulation Based Acquisition?"* For example, can Program Managers or other key leaders identify SBA methods that can be employed at the onset of Concept Development, System Development and Demonstration, and Production and Development?

C. THESIS ORGANIZATION

In this thesis, the paper will attempt to identify economic breakpoints in a program where employing SBA techniques will easily provide funding benefits. One may assume that such breakpoints would occur at each Milestone decision. In attempting to answer this question, the thesis will identify and analyze several supporting sub-questions. These queries form the underlying essence of each chapter. Those same questions may be documented as the following:

1. What is the background and history of Simulation Based Acquisition?
2. How has the Department of Defense provided guidance on Simulation Based Acquisition?
3. Have there been SBA success stories in the Department of Defense?
4. What data can be reviewed to determine the ability of SBA to provide economic breakpoints? What are the results of the data analysis and how may these results be applied to SBA?
5. What conclusions may be drawn from the preceding information that might be applied to DoD programs?

D. METHODOLOGY

The thesis uses standard literary research for addressing the first three issues listed above. In addressing the hard data, the study will make use of a survey to derive information on the use of SBA in Navy Programs. The survey will be designed to identify the degree that Program Managers have used SBA in the past and how SBA is incorporated into the overall program.

E. BENEFITS OF THE STUDY

The thesis is timely in the sense that the Department of Defense has created an initiative to use SBA throughout programs. However, there is not clear direction on how to adequately implement SBA. This study is expected to benefit Program Managers of Major Weapons programs as well as provide guidance to Program Managers of smaller acquisition programs.

The Soldier and Biological Chemical Command (SBCCOM) Modeling and Simulation (M&S) Team has expressed interest in this study. The SBCCOM M&S Team provides simulations across Services for high fidelity representation of battlefield environments. These simulations are typically used in soldier and unit level training to improve efficiency on the battlefield. However, the SBCCOM M&S Team also can provide to its customers the ability to test, though modeling and simulation, of systems. Use of the data and conclusions from the thesis would be employed by the M&S Team to carry forward to all levels of Program Managers and headquarters. This information would then be disseminated to provide a better understanding of the essentials of SBA techniques and how SBA can improve the acquisition program.

II. BACKGROUND

A. SCOPE

The use of Simulation Based Acquisition (SBA) throughout the Department of Defense (DoD) is a tool that many Program Managers (PM) have employed in military programs. Succinctly stated, SBA is the use of simulation (M&S) techniques and tools to leverage resources in the program.

There has been significant work, by the Government and private sector, in bringing the elements of SBA to program managers. This research will use the published guidance and industry studies as a base from which to illustrate the tenets of SBA. Accordingly, a lesser intent of this thesis is to serve as a basis for future studies.

B. WHAT SBA IS

Simulation Based Acquisition can be a difficult concept to express in one concise statement. As such, SBA may be thought of as an amalgamation of various Modeling and Simulation (M&S) methods throughout the acquisition life cycle. For example, the use of Computer Aided Design (CAD) for developing a revised technical drawing is as much a part of SBA as is a training simulator used by soldiers in the field or a Distributed Interactive Simulation (DIS) used by numerous activities concurrently.

The concept of SBA is more of a mindset and philosophy than a tangible set of steps in place at specific points in the program's life. A definition has been set forth as "An acquisition process in which DoD and Industry are enabled by robust, collaborative use of simulation technology that is integrated across acquisition phases and programs (DMSO, 2000)." The point paper continued by identifying three goals of SBA. These goals are:

- Substantially reduce the time, resources, and risk associated with the entire acquisition process.

- Increase the quality, military worth, and supportability of fielded systems while reducing total ownership costs throughout the total life cycle.
- Enable Integrated Product and Process Development (IPPD) across the entire acquisition life cycle. (DMSO, 2000)

This definition conveys the crucial elements of SBA and its impact on the life cycle of the program. The elements are risk reduction, cost reduction, and ownership of the program. Through the use of modeling and simulations, program managers can leverage scarce resources while improving development and fielding.

Caution is made in the point paper of what SBA is not. SBA is not a waiver of common sense and required activities. Specifically, SBA should not be used as a substitute for proper planning, insightful engineering, allowing the modeling to dictate program direction, or abdicating the responsibility for the program (DMSO, 2000). Therefore, the PM must continue to remain as the program's most vigorous advocate while encouraging the program team to buy into total ownership costs.

Another DoD paper on SBA is more definitive in what SBA is not. The paper states that SBA should not be:

- A replacement for good systems engineering;
- Having simulations make the decisions;
- Giving all information to everyone and letting everyone see everything you do;
- The loss of security and proprietary advantage;
- The loss of responsibility, authority, and/or accountability; and,
- Just using M&S in an acquisition program (NARO, 2001)

Clearly, the implication here is that SBA is a tool to be effectively wielded by program managers in advancing their programs. PMs that rely upon SBA and ignore other factors (not a replacement for good systems engineering) may find that SBA, in such a case, might actually be a detriment to their program. This is analogous to using a periscope to look only forward and not use other detection and navigational aides in plotting future courses.

Indeed, SBA should almost be considered a sub-function of systems engineering with its ability to rapidly simulate different configurations of a system dependant upon intended system use or proposed doctrine. Ultimately, the program manager must be the final authority on program issues rather than a simulation generated decision.

C. DOD BACKGROUND

In 1995, the Director, Operational Test and Evaluation (DOT&E), released his annual report. Contained within the report was a discussion of Secretary (of Defense) Perry's theme's for the future. One theme was that modeling and simulation (M&S) needed to be used more effectively in acquisitions and program life cycles. It may be inferred from the annual report that M&S is not inexpensive, but that the initial cost is recouped by more robust designs, less hardware needed for testing, and effective training for personnel. The report also quoted the USD(A&T), Dr. Paul Kaminski, as saying, "This means our underlying approach will be to model first, simulate, then test, and then iterate the test results back into the model." The underlying requirement was, therefore, to have M&S be a part of each Test and Evaluation Master Plan (TEMP). With this emphasis, programs would have attributed more integration to modeling and simulation activities such that the program derives these robust designs (DOTE FY95 Annual Report).

In 1998, the Undersecretary of Defense Acquisition and Technology (USD(A&T)) spoke before the National Defense Industrial Association. In his remarks, Undersecretary Gansler stated that there are three significant challenges before the Department of Defense. These are to develop/deploy major new systems, to support those systems, and do this at a lower cost and reduced cycle time (Gansler, 1998). Part of the answer to this challenge is the implementation of SBA in the major (and minor) military programs. Simulation Based Acquisition easily meets these demands through the use of modeling/simulation, defining program requirements resulting from those simulations, and having the personnel be dedicated to the success of the program overall.

Indeed, Mr. Gansler went on to state that modeling and simulation must be a greater part in testing and evaluation (Gansler, 1998). Additionally, such use of M&S in testing must be validated, though, prior to implementation. Therefore, the resources that program managers must judiciously employ are applied effectively through validated M&S activities. The virtual testing does reduce the program risk while reducing program cost. It may be inferred that Mr. Gansler implored program managers to use SBA proactively to offset risk, while defining a robust and dynamic system design.

The DoD document, DoD 5000.1 states that,

> Program managers shall plan and budget for effective use of modeling and simulation to reduce time, resources, and risk associated with the entire acquisition process, increase the quality, military worth, and supportability of fielded systems; and reduce total ownership costs throughout the system life cycle. (DoDD 5000.1, The Defense Acquisition System, (Incorporating Change 1, January 4, 2001) 23 October 2000)

The DoDD 5000 series has been cancelled and replaced with interim guidance from Undersecretary of Defense Paul Wolfowitz. By memorandum dated 30 Oct 02, the guidance cancelled the 5000 series and provided two attachments. The first attachment provides the program manager with policies that are simple and flexible to encourage maximum autonomy for the PM. In the attachment, the guidelines discuss numerous aspects of program management including cost realism, cost sharing, and program affordability. More specifically, the guidelines instruct the program manager to define total ownership costs (and those drivers), identify cost risks before contract award, and that undue risks are not placed upon the contractors. (Wolfowitz, 02)

Therefore, to keep in compliance with this most basic requirement and to manage their systems in a smarter fashion, it is axiomatic for the PM to employ modeling and simulation, as a minimum, in their program.

The Army has embraced the concept of Simulation Based Acquisition through its propagation of Simulation and Modeling for Acquisition, Requirements, and Training (SMART) (Price, 2002). The intent of SMART is to improve higher readiness levels through reduction of life cycle costs.

The Navy, as early as 1994, sought to incorporate modeling and simulation into their policy. A Modeling and Simulation Program was established to oversee the development and use of models and simulations. The guidance went on to discuss interoperability issues, joint configuration concerns, and define how coordination of plans shall occur. (DONMSP) (Navy, 1994). In 1998, the Navy moved forward with further instruction regarding Simulation Based Acquisition. An Acquisition Reform Executive was established as the lead for SBA issues and initiatives. The intent was to meet the Defense System Affordability Council goals of…

> …fielding high quality defense systems quickly, and supporting them responsively, while lowering total ownership cost (Navy, 1998).

The Navy, like the other Services, was moving to incorporate the use of SBA into its programs.

D. INDUSTRY'S VIEWPOINT

In 1995, the American Defense Preparedness Association (ADPA) proposed a study of SBA and its role in the military and industrial environment. The study defined SBA as having three separate elements in its composition, environment, and use. The first element is a forum in which systems engineering techniques are proactively utilized through the implementation of advanced technology systems. The system engineering techniques are most often used in the capacity of design efficacy (better designs and less manpower to design) and life cycle tools.

The second element identified in the study is the use of better design data for implementation in the life cycle acquisition process. Such design improvements can be leveraged in acquisitions through more efficient design and fielding requirements. Furthermore, the Performance Specification, as it changes over the life of the program, will be more accurate based upon the knowledge and data gathered through the improved design process.

The final element ADPA found in SBA is the social norm of the personnel involved in the process. The participants in the program must be willing to accept the values imposed and be encouraged to be creative in their respective areas. Additionally, the participants are encouraged to think outside the box and use the data from SBA to leverage new concepts and ideas. (ADPA, 1996).

III. GUIDANCE

Should one desire to find a specific source or definition for Simulation Based Acquisition in Government documentation, one would undoubtedly encounter a surfeit of guidance, policy, and regulatory information. Before attempting to understand guidance that controlled Service implementation of SBA, one should appreciate the concepts of SBA. This chapter will set forth the definition of SBA as well as illustrating the policy of the Defense Department.

A. DEPARTMENT OF DEFENSE

In 1995, based upon the direction of the Clinton Administration, the Department of Defense identified ways in which the acquisition process could be streamlined. The prevailing environment of doing more with fewer resources mandated PMs to critically evaluate their programs. Accordingly, DoD moved assertively towards better use of resources in military programs. This same environment motivated higher headquarters staffs to clarify methods in which those same resources could be leveraged as a form of policy. The genesis of Simulation Based Acquisition was created from within this atmosphere.

1. Department Of Defense Directive (DoDD) 5000.59, DoD Modeling and Simulation (M&S) Management

This directive, issued 04 Jan 94, provided initial guidance in the management of modeling and simulation. The directive sets forth the requirements and stands up the Executive Council for Modeling and Simulations (EXCIMS). The document also stands up the Defense Modeling and Simulation Office (DMSO). Under DMSO, the Modeling and Simulation Information Analysis Center (MSIAC). Numerous policies are established in this document including the following:

- Setting an organizational structure for the management and administration for DoD M&S issues;
- Developing a Master Plan for M&S;

- Investing in the resources required for M&S including enhancements, common tools and databases, and establishing standards/protocols for data exchange;
- Implementing a M&S Information Analysis Center (MSIAC);
- Assigning common and general use applications to a specific Component for responsibility;
- Directing that the Services shall establish Verification, Validation, and Accreditation (VV&A) policies for the M&S applications managed by the Component;
- Requiring that all the applications in use by DoD decision makers must be accredited; and,
- Requiring that all applications must conform with DoDD 8320.1 "DoD Data Administration (DoDD 5000.59, 1994)

The directive also stated that the Undersecretary of Defense for Acquisition and Technology establish the EXCIMS. The mission of EXCIMS is to be the advocate for M&S in the Department of Defense. The Council will advise the USD(A&T) on the uses of M&S, oversee M&S development, improve communications, invest in M&S applications, and promote cooperative research within the Services.

The EXCIMS Charter mandates that this council advises and assists the Undersecretary of Defense for Acquisition and Technology (now USD (AL&T)) in the aspects of Modeling and Simulation throughout DoD. The Charter goes on to state eight functions which EXCIMS must undertake in order to achieve this assistance. These are:

- Oversees development of DoD M&S policies, plans, programs, publications, and procedures.
- Encourages improved communication and coordination among DoD M&S activities.
- Identifies investments in M&S that have high value return in fulfilling DoD requirements, or that fill gaps in M&S capabilities.
- Promotes joint and cooperative research, development, acquisition, and operation of M&S systems, technologies, and capabilities among DoD components.
- Recommends DoD M&S goals, objectives, and an investment strategy and plan to achieve them.
- Recommends DoD components for designation as DoD M&S Executive Agents for general use M&S applications, as needed.

- Acts as an Executive Steering Committee for DoD general use M&S applications for which Executive Agents have been appointed.
- Fosters programs to develop and, where applicable, implement DoD M&S interoperability standards and protocols.

Under these functions, the EXCIMS is the lead group for M&S across DoD. One of the most critical functions that EXCIMS is tasked with is the interoperability issue. As Defense programs become more advanced with technology, the ability for systems to communicate with each other diminishes. This holds true for modeling and simulation as well. It is critical that models and simulations be able to be used, simultaneously, across and within all Services. By doing so, then digital mock-ups of battlefield conditions can be used for training, software used for virtual training on missiles might be used for the platforms that would carry the missiles, and long term logistical concerns for one Service can be identified early in the program life.

2. Department Of Defense Instruction (DoDI) 5000.61, DoD Modeling and Simulation (M&S) Verification, Validation, and Accreditation (VV&A)

The intent of this instruction is to build off the aforementioned DoDD 5000.59 regarding modeling and simulation. A crucial element of developing a model or simulation is the determination that the simulation is appropriate, useful, and approved by the proper chain of command.

According to the VV&A Recommended Practices Guide Glossary, the following definitions should be used for these terms:

- Verification: The process of determining that a model or simulation faithfully represents the developer's conceptual description and specification. Verification evaluates the extent to which the model or simulation has been developed using sound and established software and system engineering techniques.
- Validation: The process of determining the degree to which a model and its associated data are an accurate representation of the real world from the perspective of the intended uses of the model.

- Accreditation: The official certification that a model, simulation, or federation of models and simulations and its associated data are acceptable for use for a specific purpose (VV&A Guide, 2001).

DoDI 5000.61 sets forth the guidance for the use and implementation of VV&A within the Department of Defense. In this Instruction, the following points are set forth:

- DoD Components shall establish VV&A policies and procedures for every M&S they develop and manage.
- M&S used to support the major DoD decisionmaking organizations and processes…shall be accredited for that use by the DoD Component sponsoring the application. Likewise, M&S used for joint training and joint exercises shall be accredited for that purpose by the application sponsor.
- Each DoD Component shall be the final authority for validating representations of its own forces and capabilities in joint-, general-, and common-use M&S applications and shall be responsive to the other DoD Components ensure they are appropriate represented (DoDI 5000.61).

The intent, therefore, is to have models and simulations that are accurate, highly representative, and re-usable. The Modeling and Simulation Information Analysis Center (MSIAC) states that SBA is…

> The aggressive, comprehensive application and sharing of mature advancements in information technology such as distributed networking, multi-user computer environments, database management systems, and particularly advanced modeling and simulation (M&S) tools, including commercial product development automation tools, (e.g. CAD, ERP), HLA-based distributed simulation, and interactive virtual reality (MSIAC, 00).

The MSIAC, which is sponsored by both the Defense Modeling and Simulation Office (DMSO) and the Defense Technical Information Center (DTIC), has offered an excellent working definition for SBA as follows:

> An acquisition process in which DoD and Industry are enabled by robust, collaborative use of simulation technology that is integrated across acquisition phases and programs (MSIAC, 00).

This guidance dovetails with that set forth in DoDI 5000.1 to use modeling and simulation to reduce costs (para 4.5.4) while increasing quality. This definition paper went on to state that a key aspect of SBA is the use and sharing of mature advancements in information technology. However, the technology also must be able to be used by numerous programs, sometimes at the same time (in the case of a distributed interactive simulation [DIS]).

3. Simulation, Test, and Evaluation Process (STEP)

The Department of Defense has established guidelines for the implementation of SBA into military programs. These guidelines, entitled Simulation, Test, and Evaluation Process (STEP), are designed to assist the program manager in the application of SBA into their programs. In the guide to implementing STEP, the Honorable Philip E. Coyle (Director of Operational Test and Evaluation) and Dr. Patricia A. Sanders (Director of Defense Research and Engineering, OSD) have stated the purpose of the process as follows:

> The Simulation Test and Evaluation Process (STEP) is one that integrates both simulation and test for the purpose of interactively evaluating and improving the design, performance, joint military worth, survivability, suitability, and effectiveness of systems to be acquired and improving how those systems will be used. (Coyle and Sanders, 1997)

The clarity of this statement to the Program Manager is critical. The PM, through the use of STEP, needs to actively incorporate simulation and test techniques in the program. By doing so, the whole program will be dynamic throughout its life cycle through operative improvements. The STEP Guidelines go on to state:

> The Department's vision is to have an acquisition process that is enabled by the robust, collaborative use of simulation technology that is integrated across acquisition phases and programs. The goals of Simulation Based Acquisition are to:

- Substantially reducing the time, resources, and risk associated with the acquisition process,
- Increasing the quality, military utility, and supportability of systems fielded, while reducing their total ownership costs, and
- Facilitating Integrated Product and Process Development (IPPD) across the full acquisition life cycle. (Coyle and Sanders, 1997)

Traditionally, the method in which program or system problems are addressed had been through a test-fix-test process. The STEP process has the program manager using a model-simulate-fix-test-iterate progression. In this approach, the system incorporates design improvements and problematic fixes through simulation. The process contains more than one model. As the system progresses through the acquisition cycle, models are built to represent the system at the current level of development. Therefore, as progress is made, models are developed for interfaces, environments, and future design potential. Coyle and Sanders went on to describe how STEP could be applied throughout the old acquisition cycle (CE – Production).

Analysis of Mission Need: Models and simulations offer a way to quantify the shortfalls in numbers and type of systems for force structure analysis, to quantify the consequences for a wide variety of scenarios, and to identify thresholds of operational significance to the accomplishment of national military objectives.
Concept Exploration: During this phase, an Analysis of Alternatives (AOA) is developed to aid and document decisionmaking by providing insight into the relative advantages and disadvantages of the options being considered to meet a mission need.
Program Definition and Risk Reduction: During the Program Definition and Risk Reduction (PDRR) phase, STEP can provide: early insight into the reliability, availability, and maintainability (RAM) of the proposed system; information to support the assessment of risk; information from ergonomic models to support maintainability; information on physics of failure; and data on the human-machine interface. Predictions from *engineering-level* M&S are also used as a the basis for representing the system's performance in *engagement-level* M&S
Engineering and Manufacturing Development: During the Engineering and Manufacturing Development (EMD) phase, the most promising design approach is translated into a stable,

interoperable, producible, supportable, and cost-effective design. This is when models, simulations and tests are used to:

(1) verify the system's design;
(2) confirm that design risks have been controlled;
(3) certify readiness for operational testing; and
(4) evaluate the system's operational effectiveness, suitability, and survivability.

Feed back from the tests to simulations is not only required for verification, validation, and accreditation (VV&A), but also to allow progressive improvement in the M&S. In this manner M&S can support the tests with performance predictions for use in planning future tests and in risk assessment.

Production, Fielding/Deployment, and Operational Support: The process of updating models and data sets is critical in resolving design problems after fielding and in making modifications to the system throughout its life cycle. (Coyle and Sanders, 1997)

Figure 1 shows the relationship between the previous 5000 series acquisition cycle and the life cycle set forth in Attachment 2 to the 30 Oct 02 Deputy Secretary of Defense Paul Wolfowitz memorandum. Through the comparison below, the above uses for STEP can easily be transferred to the new cycle model (the upper scale).

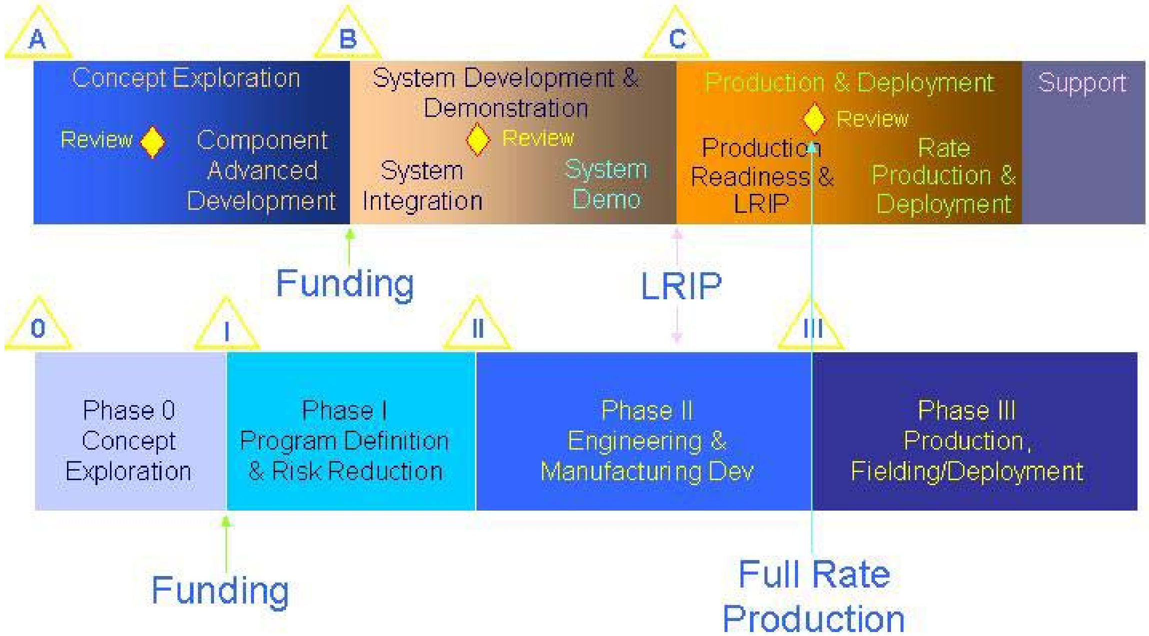


Figure 1

A Comparison Between the 5000 Series Timeline and the Revised Model

The use of M&S in system development is critical in order for both the system design as well as the model/simulation to mature appropriately. Figure 2, is a representation of how modeling and simulation flow upward to campaign specific goals. The STEP guidelines describe this flow, as did the PDRR reference above:

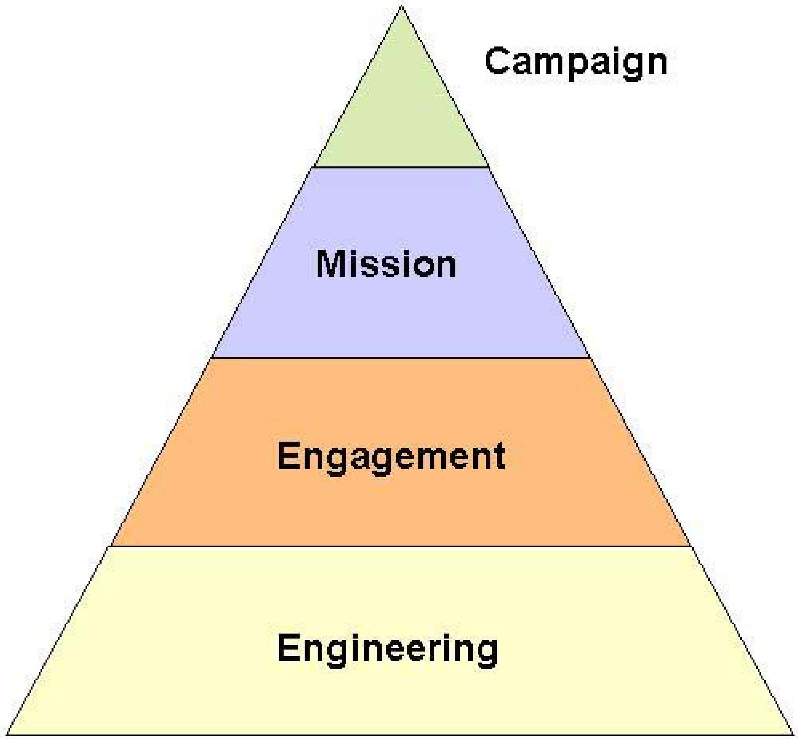


Figure 2
Hierarchy of Modeling and Simulation

Engineering-level models often involve the use of three-dimensional CAD/CAM/CAE, or computational fluid dynamics or other computational approaches to consider such effects as signatures, extreme environments, mobility, and fatigue.
Engagement-level models are used to explore such issues as end-game lethality, firepower, manufacturing, and producibility.
Mission/battle-level, system-on-system models support analyses of system performance, platform engagement, survivability, and mobility.
Theater/campaign-level, force-on-force models provide insights into a system's contribution to force effectiveness, as well as force structure and logistics requirements. (Coyle and Sanders, 1997)

So the incorporation of STEP into the programs should improve system design at all points in the acquisition life cycle. Additionally, STEP addresses the use of SBA, by way of M&S, from engineering design to campaign systems. As the Department of Defense promulgated the use of SBA in programs, each Component developed their own policies on SBA and Modeling and Simulation.

The following sections of this chapter address the Components' actions in providing direction on SBA.

B. DEPARTMENT OF THE ARMY

The US Army has established guidance on the management and administration of modeling and simulation. The Army Regulation (AR) directs the Deputy Chief of Staff for Operations and Plans (DCSOPS) to establish the Army Modeling and Simulation Office (AMSO). AR 5-11 goes on to state that:

> The Army's philosophy is that M&S, to include Simulators, are not an end unto themselves, but a critical set of closely related tools which contribute to the accomplishment of Army missions (AR 5-11, Jul 97).

The guidance further defines four elements of M&S management. These are: develop policy; establish standards; prioritize and integrate requirements and investments; and, direct research and technology.

The use of M&S in Army programs is divided into three distinct functional groups. These are:

- **Training, Exercises and Military Operations (TEMO)** – This area includes individual and collective training; joint and combined exercises; mission rehearsal; and, operations planning. This domain would use system and training simulators to accomplish these tasks.
- **Advance Concepts and Requirements (ACR)** – The domain includes force design; operational requirements; and, warfighting experiments. Reconfigurable simulators and constructive models are applied to these tasks.
- **Research, Development, and Acquisition (RD&A)** – Basic applied research; weapons system development; and, test and evaluation make up this domain. System prototypes and engineering/physics models are used to complete these tasks. (AR 5-11)

The US Army Modeling and Simulation Office is the lead for Simulation and Modeling for Acquisition, Requirements, and Training (SMART). This process has been described as a revolution…

- in process: replacing a traditional linear acquisition cycle with an integrated, iterative process in which simulation and virtual prototyping replaces hardware prototyping in early cycles.

- in collaboration technology: seamless data exchange will support the joining of a distributed IPT into a common data framework.
- in simulation technology: extending the precepts of simulation across all phases of the acquisition process, across all functional domains, and across all levels of fidelity.
- in culture: providing the Acquisition Manager with the analytic and evaluation tools to fully direct program goals and efforts from Day 1. (Olson, 1999)

To further exemplify these concepts, SMART has been defined as an initiative that promotes the robust use of M&S integrated across acquisition programs and phases to reduce Total Ownership Cost (TOC), provide quicker delivery of products to the field, while simultaneously increasing military utility and worth (SMART 2001).

The Planning Guidelines for SMART state that a simulation support plan (SSP) is needed to support the use of M&S in programs. The SSP is designed to provide a clear direction how the application of M&S tools support the development of the system. The Guidelines further state that the SSP defines the timing of M&S tools during concept exploration and system development (Ellis, Kern, and Hollis, 2000).

The Guidelines also address the issue of developing Modeling and Simulations through SMART. More specifically, the Guidelines define how M&S can be used conceptually, through the application of SMART, to aid in the functions of combat development, design and engineering, logistics and support, test and evaluation, and training. (Ellis, Kern, and Hollis, 2000) Two of these will be described below:

Combat Development. The Guidelines state that an Integrated Concept Team (ICT) should develop the SSP. To effectively develop the SSP, the ICT should use M&S in the following ways:

- The ICT can look at the feasibility of reuse of M&S throughout the life cycle.
- The ICT should examine other current Army, OSD, and sister Services' programs.
- Upgrade existing M&S while verifying and validating the M&S for its new use.

- Developing new M&S. (Ellis, Kern, and Hollis, 2000)

Design and Engineering. The intent of SMART and M&S in the design or engineering process is to reduce costs by using one centralized database. More specifically, the guidelines state:

> M&S used as part of the collaborative environment (CE) by ICTs or IPTs should be able to support detailed design and reduce design risk by allowing all functional disciplines to work from the same design database. A reduced number of engineering change proposals (ECPs) is an important result of this CE. Employment of hardware- or software-in-the-loop (HW/SWIL) M&S is also part of this CE and results in significant risk reduction in test and evaluation through planning, hardware checkout, and mission rehearsal. Finally, this concept of a SMART CE allows transition to production to take place with reduced risk by the electronic transfer of digital design data directly to the manufacturing floor. (Ellis, Kern, Hollis, 2000).

With the previous two functional areas, it has been demonstrated that SMART, through M&S, provides the tools to reduce or affect life cycle costs. Price identifies five Army models that provide that type of life cycle cost management. These models work through improving logistics while meeting SMART readiness goals. These systems are: ASOAR, SESAME, COMPASS, ACEIT, and LCET. A table is provided below that defines whether or not these models can be used to address either readiness or cost issues.

Acronym	Model Name	Type
ASOAR	Achieving a System Operational Availability Requirement	Readiness
SESAME	Selected Essential-Item Stock for Availability Method	Readiness
COMPASS	Computerized Optimization Model for Predicting and Analyzing Support Structures	Readiness and Cost
ACEIT	Automated Cost Estimating Integrated Tools	Cost
LCET	Logistics Cost Estimating Tool	Cost

(From Price, 2002)

Table 1.
Linked / Integrated Army Models

C. DEPARTMENT OF THE NAVY

The US Navy Modeling and Simulation Management Office (NAVMSMO) is the lead agency for Modeling and Simulation for the Navy. As such, the office is charged with managing modeling and simulation issues including maintaining and disseminating documentation. An Instruction from the Secretary of the Navy, which is the defining document for Modeling and Simulation, can be found at the NAVMSMO website. This document establishes the Navy's definition of modeling and simulation as follows:

> Models include any physical, mathematical, or otherwise logical, representation of a system, entity, phenomenon or process. Simulations include a method of implementing a model over time. (SECNAV 5200.38A)

The definition that the Navy applies to these terms is comprehensive in nature. Furthermore, the definition lends itself to SBA, which was earlier established as an iterative, integrated process that incorporates modeling and simulation to achieve life cycle cost savings and reduction of risk.

The Navy has established objectives for modeling and simulation in order that M&S is treated uniformly throughout the Service. These objectives are:

- Modeling and simulation and associated information technology will be applied consistently across each of the four pillars of naval M&S. These pillars are: operations and experimentation; training; acquisition; and analysis and assessment.
- Modeling and simulation technology shall be readily available to the naval warfighter.
- Modeling and simulation, and its underlying data, will be consistently applied across the Navy-Marine Corps team afloat or ashore, at home or deployed.
- Investment in modeling and simulation technology will be cost effective, have measurable benefits, and build on the Department of Defense (DoD) and commercial capabilities and standards.
- The DON Science and Technology (S&T) efforts will ensure the development of technologies to meet the modeling and simulation needs of the Sailor, the Marine, and the DON. (SECNAV 5200.38A)

The Instruction goes on to state that M&S applications shall be interoperable throughout all levels. To support the intent of interoperability as well as the objectives listed above, the Navy developed a Modeling and Simulation Master Plan.

The Modeling and Simulation Master Plan describes the Navy's intent to implement M&S throughout its programs. The plan emphasizes three general areas that affect each program. These are Assessment, Training, and Analysis. The Navy's objectives, as stated in the guide are to use M&S to simulate before significant action is taken, integrate models of all types to support training, and allow collaborative mission planning while combined with M&S, to support planning and operations. (NAVMSMO, 1997)

Assessment is defined as making better and more informed decisions. Training includes those efforts that will improve warfighter skills and capacity. Acquisition is focused on reduced cycle time, reduced cost, and optimized systems. (NAVMSMO, 1997)

To support these general areas, the Navy has identified building blocks as Model Standards, Data Standards, and Communications (NAVMSMO, 1997). Figure 3 depicts this relationship. It should be noted that the general areas of Assessment, Training, and Acquisition are mutually coexistent and not meant as a flow upward into the next level.

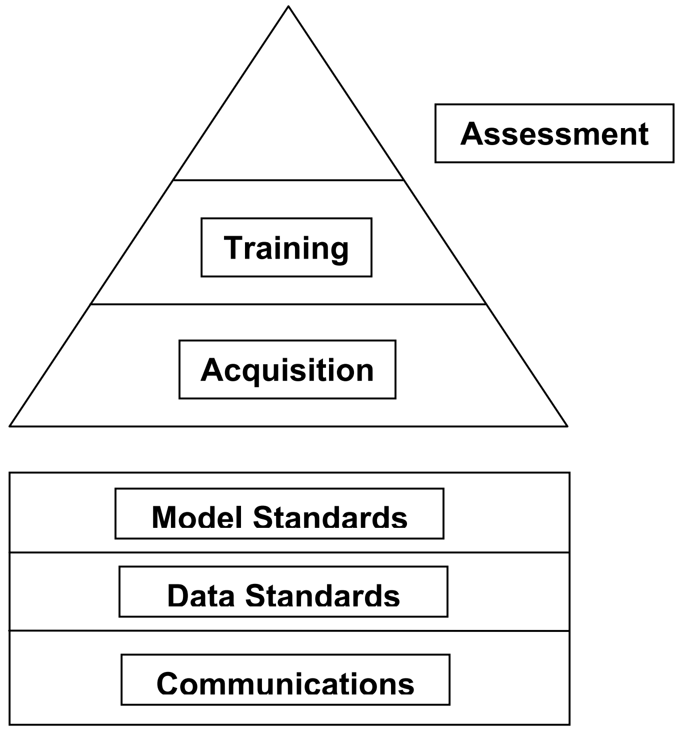


Figure 3.
M&S Building Blocks Supporting the Areas of Assessment, Training, and Acquisition

The Modeling and Simulation Master Plan uses the above representation to reflect the utilization of the Synthetic Battlespace. The concept of this battlespace is:

> …the collection of models and simulations and associated databases; the networks, including the supporting connectivity, interfaces, associated hardware, and underlying software and protocols and the real world operators, ranges, platforms, systems, and hardware (NAVMSMO, 1997).

The plan goes on to state that the intent is to use these elements on an as needed basis rather than simultaneously. These elements would be used to represent operations, activities, or processes, at a level acceptable to the user (NAVMSMO, 1997). So the user, in the Navy, may approach program issues with a variety of resources. Such resources can be used to model oceanic conditions, three-dimensional design capabilities, or future training requirements.

As the system matures, the M&S uses are refined and updated in the battlespace. The need for interoperability must be maintained and addressed in each model or simulation developed.

The building blocks of the synthetic battlespace were defined as Modeling Standards, Data Standards, and Communications. These elements are more explicit as described below:

- The Modeling Standards building block encompasses the development and promulgation of standards, the process to ensure models realistically represent valid Naval doctrine and behavior, the establishment of a M&S Resource Repository (MSRR), the "standardized" models themselves, and the designation of executive agents for specific areas and proponents for configuration management of specific models or programs.
- The Data Standards building block encompasses the process to ensure comprehensive, consistent and authoritative data are available to support the synthetic battlespace, the development and enforcement of data standards, the actual filling of the databases, and access to the data by the users through DMSO's MSRR.
- The Communications building block encompasses the development of evolving communication standards, formats, and protocols necessary for connectivity and data exchange over a network; the long-range plan for building the physical communication nodes and acquiring the hardware; the protocols enabling federations of models to interact; and multi-level security hardware and standards necessary for classified operations. (NAVMSMO, 1997)

The ideals of M&S, found in the Naval policies and Master Plan, can also be found in the Air Force policies and plans.

D. DEPARTMENT OF THE AIR FORCE

The US Air Force (USAF) also has provided direction to its Service regarding the use of M&S in its programs. USAF Policy Directive 16-10, modeling and Simulation (M&S) Management, clarifies USAF policies as:

- Provide M&S management policies and procedures which identify opportunities and implement practical programs to reduce costs; eliminate duplication; promote exportability of models and simulations; promulgate standards; streamline model development; and create seamless, interoperable, live, virtual, and constructive distributed simulations responsive to the users' needs.

- Where appropriate, promote M&S investments which incorporate enhancements of Department of Defense (DoD) M&S technologies in support of operational needs and the acquisition process.
- Promote the use of common tools, methodologies, and databases to the maximum extent possible.
- Establish standards and protocols when needed or implement existing standards and protocols when available that promote the internetting, data exchange, open system architecture, and software reusability of M&S applications.
- Publish a M&S Master Plan and a M&S Investment Plan. (USAF, 16-10)

The goals of the Air Force, with respect to Modeling and Simulation, are similar to those of the Navy and Army. All Services encourage reusability, use across systems and functions, and implementation of DoD overarching policy. The Air Force policy addresses the logistics area as defined in the Charter for the Air Force Logistics Modeling and Simulation IPT. In this charter, the Air Force's vision is:

> To develop Air Force Logistics Modeling & Simulation (M&S) in support of Air Force and Joint exercises, wargames, experimentation, studies, analyses, and acquisitions. This support will span the three M&S functional areas: Training, Analysis, and Acquisition. (AF IPT, 2001)

The master plan developed for the Air Force regarding Modeling and Simulation sets forth the intentions and policies regarding the use of M&S in Air Force programs. The Executive Summary states that the goal of M&S is to develop a capability using interoperable M&S systems to provide warfighters and decision-makers the tools to ensure readiness across the full spectrum of conflict (HQ USAF, 1995). The plan goes on to define the vision of M&S to develop a Joint Synthetic Battlespace supporting better decisions and warfighting skills to build the world's most respected air and space force for the Joint Force Commander (HQ USAF, 1995). It is the intent of the Air Force to have a battlespace representation for all elements in the acquisition cycle regardless of position within the acquisition cycle. To achieve this vision, the Air Force has defined the Joint Synthetic Battlespace as a vehicle for development of future forces, concepts, systems, and doctrine in a simulated environment where Air Force roles and missions will be appropriately and accurately represented (HQ USAF, 1995).

The Air Force intends to use modeling and simulation to accomplish and meet three functions within the Service. The first function is to provide improved quality management for the systems or programs throughout the Air Force. Second, M&S will be used to improve the level of training used by Air Force personnel. Finally, the Air Force will improve the structure of programs, including upgrading existing standards and protocols. (HQ USAF, 1995)

The Air Force also has identified two separate processes in which M&S will be applied throughout the Service. These processes are Analysis and Training. These two elements are also a part of the DON structure discussed previously. Analysis is aimed at making better decisions, while training is targeted at developing better skills (HQ USAF, 1995). To this end, the Air Force has also developed a pyramid similar to that of the Army's in which functions flow upward into more advanced or general uses. At the same time, the Analysis and Training elements are considered the building blocks for this pyramid. While DON uses Analysis and Training (and Acquisition) as functional groups, the Air Force has identified these as supporting the upward flowing elements. This can be seen in Figure 4 below.

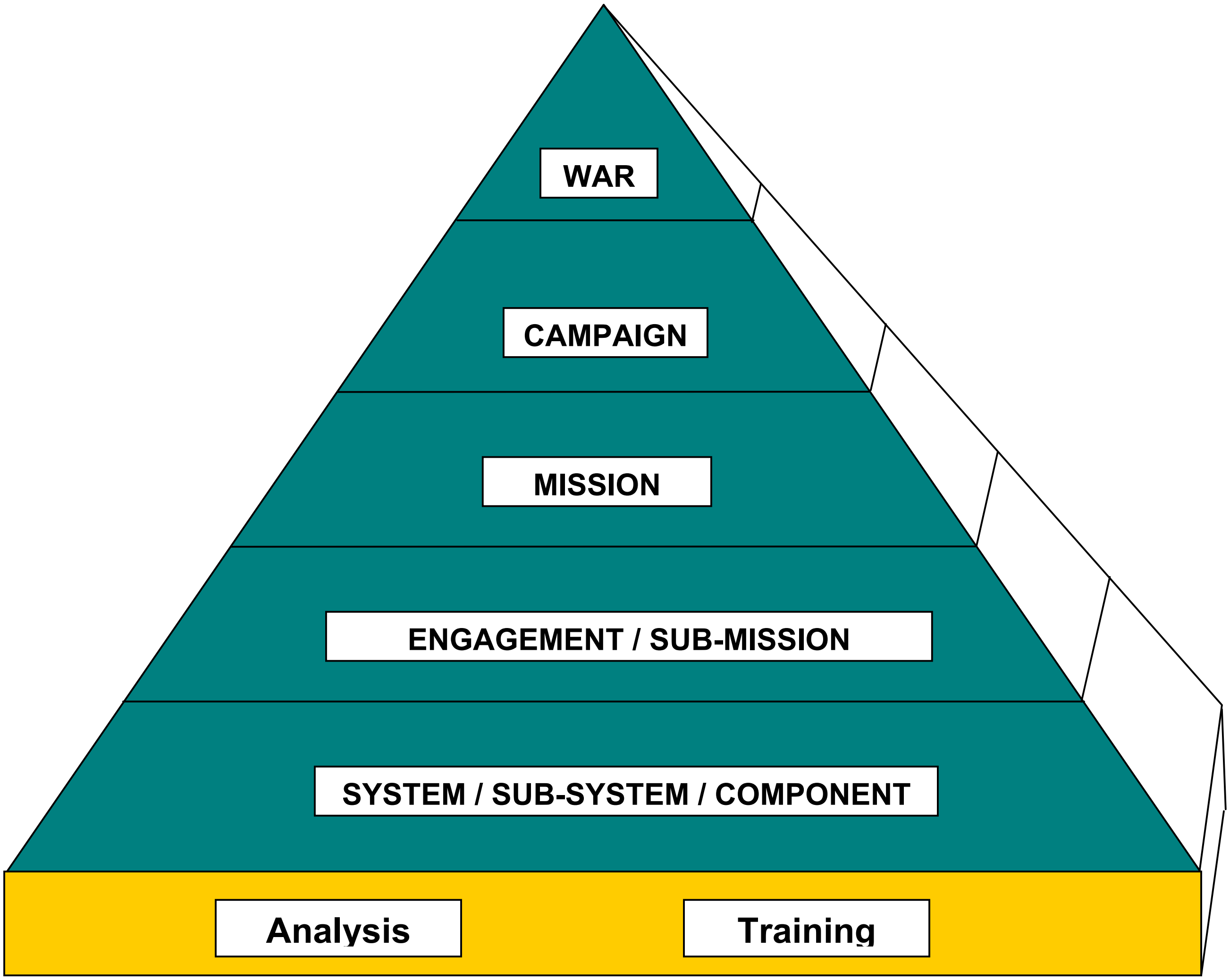


Figure 4.
Modeling and Simulation Hierarchy

The Modeling and Simulation Master Plan further develops the intent of this hierarchal pyramid as follows:

- **System/Sub-system/Component (Engineering)** – Design, cost, manufacturing, and supportability. Provides measure of performance.
- **Engagement/Sub-mission** – Evaluation of system effectiveness against enemy systems. Provides measures of effectiveness at the system level.
- **Mission (Battle)** – Effectiveness of a force package or multiple platforms performing specific mission.
- **Campaign (Theater)** – Outcomes of joint/combined forces in campaign/theater level conflict. Provides measures of outcome and other high level measures of merit. (HQ USAF, 1995)

In review of this chapter, the paper has covered the basic guidance from DoD and its Components as follows

- **DoD:** DoDD 5000.59, DoDI 5000.61, formation of EXCIMS, and STEP guidelines.
- **Army:** AR 5-11 and SMART.
- **Navy:** SECNAV 5200.38A and Navy Modeling and Simulation Master Plan.
- **Air Force:** Air Force Policy Directive 16-10 and US Air Force Modeling and Simulation Master Plan.

Throughout these documents, the intent of providing guidance on modeling and simulation has remained constant. Each of the Services has identified how Modeling and Simulation will be treated within the Service. Typically, this means creating a database of models, simulations, representations, and environments that accurately reflect the Service's mission. The plans go on to state how the use of M&S will flow through the programs and systems to achieve the end vision of theater involvement. Ultimately, it is up to the program manager to follow these guidelines in order to leverage the existing models/simulations against the development of the program.

IV. DATA GATHERING AND RESULTS

Field Data is invaluable in terms of addressing the transitioning of the SBA concept to real time events. This study undertook a survey to gather data that described the uses of SBA in real programs. The question then was to identify which programs and what Service would be appropriate in terms of gathering data to study. Once the potential target sample had been established, a survey could be sent to the appropriate personnel for completion and return.

A. SURVEY STRUCTURE

In designing any survey, one must determine the fundamental question and any underlying sub-questions that need to be answered. Done well, a survey will obtain critical data from which meaningful conclusions and insights may be drawn.

In order to determine if there are economic breakpoints in programs, the survey established the fundamental question of the survey as "What is the degree of use of SBA in military programs, given the pre-existing direction promulgated by DoD?" There is a significant amount of information on SBA that has been disseminated from the highest levels. Each Service has established its component lead for Modeling and Simulation. Finally, the amount of information available on the Internet is staggering in quantity and quality. Given the amount of information on SBA and its concepts, one would expect that well-informed PMs will incorporate these concepts into their programs.

Therefore, the real question likely should be "How has one Service derived benefits from SBA in their programs?" However, one might also inquire, as an underlying question, as to the ways in which SBA is utilized in the program. This is conceptually different than the fundamental question set forth above. In the fundamental question, one is trying to determine how the *use* of SBA in programs has been put forth (e.g., phases and magnitude). In the second question, one would search for the *ways* in which SBA is present in the programs.

A second underlying question might be stated as to why the funding for SBA is typically done in the initial phases. One would assume that early funding of SBA in programs would provide more meaningful results than incorporation later in the life of the program. The intent of the survey is to assess the validity of this assertion.

The final underlying question addresses the kinds of benefits derived from the use of SBA. A program manager must believe that there is an inherent recompense for using SBA in their program. If not, then there would be little reason to pursue the use of SBA aside from meeting higher headquarters' requirements. The survey addressed the question of what types of benefits exist and how rewarding will those benefits were for the program overall.

B. WHO TO SURVEY

The need for a meaningful sample of a population is crucial to an effective survey. Typically, a survey will result in a return rate of approximately one to two percent. A higher rate of completion can be achieved through the notation of vested interest. In other words, should the individual receiving the survey believe that the survey is meaningful in some way, that individual would be more inclined to complete and return the survey.

In this study, the Department of the Navy (DoN) was identified as a potential source for data points. The reasoning for this selection is that DoN has a wide variety of military programs, these programs represent all levels of Acquisition Categories (ACAT), and a listing of these programs was readily accessible.

C. ISSUES OF THE SURVEY

It can be safely stated that most surveys are not without their weak points. The survey used in this study was intended to derive initial feedback as to the use of SBA in military programs. It was not, however, designed to be comprehensive.

One weak area in the survey was its inability to confine the respondents into a uniform response. Of the surveys received, six (6) could not be placed in the quantifiable set as the responses were narrative rather than measurable. This was not entirely without benefit as the study was able to use the narrative information.

A second area of concern was that the respondents did not have the information that was required by the survey. This might be a function of the program being compartmentalized or a respondent being out of the information loop. Another aspect of this concern is that the program manager might be disinclined to release information that is considered sensitive. Additionally, the respondent sometimes stated that he did not know or the response indicated that the respondent did not understand the question.

A third concern is that the survey did not make allowances for the ranges given in the responses. For example, the survey asked for the phase in which M&S funding was used. Responses oftentimes indicated more than one phase in which M&S funding had been used.

Finally, the survey did not allow for the size differential between programs. The survey accessed all ACAT levels. However, the impact that a multi-billion dollar program would have on the survey is greatly different than a much smaller million-dollar program.

D. OUTPUT FROM THE SURVEY

1. Responses

There were 471 total programs listed on the DoN ACAT Matrix that were under the cognizance of 132 separate program managers. Of these 471 programs, 416 surveys were emailed to the cognizant PM (107 total). There were several programs that did not list an email address or the survey was returned as undeliverable. The total number of surveys sent out represents 88.32% of the total number of programs possible. Of the surveys sent out, there were 50 responses that were completed and 4 responses that did not offer financial data, but did offer informative perspectives on the use of SBA in their program. Fifty-four responses provided a 12.98% response rate (of the 416 surveys sent), significantly higher than typical survey response rates.

2. Assumptions and Generalizations

In assessing the responses to the survey, it was necessary to make assumptions and generalizations. One such assumption occurred when a response was provided that had a range (e.g., Program phase was partly in EMD and partly in Production). In these cases, the range was averaged and recorded. However, if a program indicated that it would use M&S in more than one phase, the more recent phase was recorded. The reasoning was that programs would most likely have M&S be more significant in the EMD phase rather than PDRR. These were the two most frequent choices albeit only a small number of surveys required this manipulation. Additionally, in terms of either Life Cycle Cost (LCC) avoidance or factored in LCC avoidance, a recorded response of zero means that that either there were no preplanned LCC avoidances or that no quantifiable amount could be discerned from the response. Another convention is that some responses indicated that the program was in Post Production. In these cases, the recorded phase was Production. The program amount listed on the survey was another area in which a convention needed to be derived. If a program's value was more than $5 billion dollars, the survey needed to have all financial information completed in order to be recorded. Otherwise, the survey would contain significant outliers in the compilation of the data. This also implies, correctly, that some surveys were recorded that were incomplete. In doing so, the data would provide the most basic of information, rather than a purely empirical study. Finally, the survey did not baseline the funding dollars to a specific fiscal year.

3. Preliminary Data

The surveys returned diverse information and data from all levels of acquisition categories. Of significance is that eighteen respondents funded SBA, but slightly more than half of those did not recognize cost avoidance in their programs. Of the seven that did achieve cost avoidance, five of them received more in savings than expended on SBA. One may conclude that respondents were not able to accurately judge the downstream effects of the investment or that the program had not progressed enough to establish actual savings.

The other significant observation is that the ACAT Level III programs (who responded) are providing the most percentage in terms of SBA funding. It may be concluded that the reasoning for this is the acquisition cost of a ACAT Level III program is significantly less than that for ACAT Level I. Therefore, although an ACAT Level I program might spend more on SBA, the overall percentage is significantly less than lesser programs.

ACAT Level	SBA as % of Acquisition Cost	Cost Avoidance as % of Acquisition Cost
1	0.70	2.60
2	0.20	0.00
2	2.60	1.70
3	1.00	1.50
3	1.10	0.00
3	1.40	0.00
3	2.00	2.60
3	2.90	0.00
3	2.90	0.00
3	4.40	0.00
3	8.10	0.00
3	11.30	0.00
3	11.30	0.00
3	19.80	0.00
4	0.10	0.20
4	1.00	1.90
4	1.10	0.00
4	4.60	0.90

Tab le 2
Comparison of Projected SBA Cost to Anticipated Cost Avoidance

4. Initial Insights

There were numerous insights that were derived from the surveys returned. The first view was that there was little or no M&S sharing among programs. There were numerous examples provided that stated the program used M&S to simulate platforms or testing. It could be inferred that the most programs needed to develop program specific simulations rather than using a generic software device for most programs. A second observation is that most of the M&S funding has already occurred and this is consistent with the point that most programs are in the Production Phase. A correlated observation is made that 87.8% of SBA funding is typically made with RDT&E funds. Those responding to questions regarding cost avoidance were able to identify a life cycle savings. The $3.8 million dollars in life cycle cost avoidance identified were not pre-planned. In fact, in only one case were costs of $50 million dollars planned to be avoided through the use of SBA.

5. Significant Comments from Respondents

A significant number of respondents provided extremely useful and intuitive comments when completing the survey. These comments are provided below:

a. Computer Modeling

In one program, Computer Modeling has been used to analyze, in high resolution, structural composition. The intent of the analysis was specifically to reduce ground and flight testing. An interior simulation was used to design controls within the system. The program went on to study vulnerability issues and modeling through the use of extensive computer tools. The program incorporated SBA through the use of vulnerability analyses, susceptibility studies, structural analysis, and design functions. The benefit derived from the uses of SBA were cost avoidance by eliminating developmental testing and design as a function of simulations.

b. CAD/CAM

Another program, currently in EMD phase, estimates that between 1% - 2% of their total budget line will be spent on M&S throughout the life of the program. This is consistent with the earlier observation of the same nature in the Preliminary Data section. The program plans on using such tools as Computer Aided Design (CAD), Computer Aided Manufacturing (CAM), finite element analysis, and survivability studies. A result of these tools and actions in the past is the cost avoidance realized in the program. The computer models were found in existence already, rather than having modeling software exclusively made for the program. Furthermore, the program personnel proactively worked with the prime contractor to find M&S tools already in use in other military programs. Such an emphasis was placed on SBA during PDRR, that the program specified a lead team member to coordinate M&S functions. Finally, the program recognized the leadership direction of DoD and DMSO in providing commonality to military programs.

c. Virtual Prototyping

A different program has utilized virtual prototyping in the initial phase of the program. In addition, the program plans on using M&S to derive a reduction in engineering changes and product rework. In using M&S, the team believes that training and T&E will experience efficiencies, thereby reducing cost. Finally, this team developed a database that allowed an easy access to information by both the Government team and the prime contractor. The respondent also stated that use of SBA was a significant resource for the design teams. The database offered information for use in risk management, product model development, and requirements.

d. Production Data

One program plans on using SBA funding to update and maintain the production phase of the program. This program implemented high fidelity simulations to model the hardware in use. By doing so, the program eliminated the cost of multiple testing and functioning of the item. The program went on to say that SBA is a way of life in this type of program. Once the high fidelity modeling software has been developed, it is used throughout development, production, and product improvement.

e. Cost Savings

Modeling and Simulation have been mandated in another program to achieve cost savings. These savings are a result of design/concept trade-offs, lifecycle tests, system integration, and transitioning the program from development to deployment. By the mandated use of SBA, the program has been able to field the most effective and affordable weapon.

E. INFERENCES DRAWN FROM THE DATA

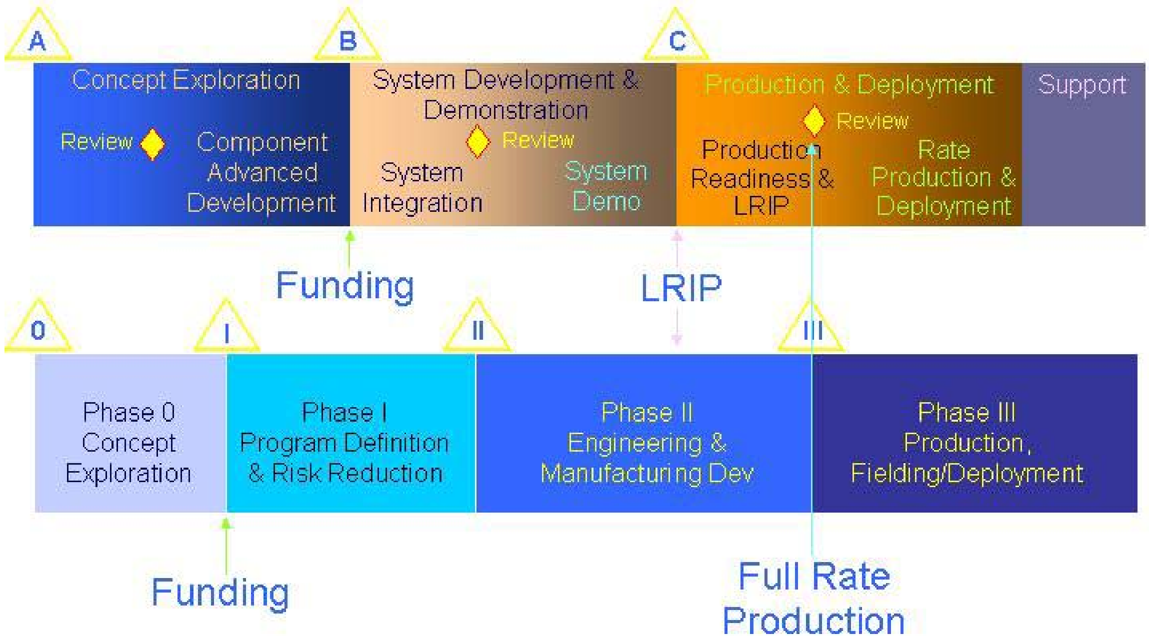
Earlier, this chapter established the question of "What is the degree of use of SBA in military programs, given the pre-existing direction promulgated by DoD?" In attempting to answer the question, this study surveyed a comprehensive listing of Navy programs. Limited conclusions from the data are:

- Cost avoidance exists for those programs willing to seek it. However, in this study, only one program sought to incorporate specific savings.
- Sharing of cost avoidance methods was not present in a majority of those programs responding to the survey.
- SBA was found to be generally disseminated through training, although some programs had yet to learn of SBA and its concepts. Many programs already are doing M&S and not realizing that this meets the criteria of SBA.
- Appropriately, when SBA is incorporated into the program, the funding is early in the program. However, only 1% of the average Program Acquisition Cost is spent on SBA methods.
- The benefits derived from the use of SBA were found to be directly related to the program in the form of requirements development, platform qualification, and product testing.
- The benefits of current and future design changes, risk reduction, and M&S interoperability were found to be derived almost entirely in the PDRR and EMD Phases of the program. This is consistent with the earlier observation that most funding is of RDT&E in nature.

F. DISCUSSION OF PRIMARY THESIS QUESTION

The intent of this study was to determine if there are specific times in the acquisition life cycle in which the program manager can use SBA to provide effectively cost avoidance in the system. The comparison of the old series DoD 5000 acquisition life cycle and the revised life cycle is shown below. The upper scale represents the new acquisition life cycle as set forth in a memorandum from the Honorable Paul Wolfowitz (Undersecretary of Defense) dated 30 Oct 02.

The lower scale represents the traditional timeline for the acquisition life cycle set forth in DoD series 5000.



The survey has shown that there are times in which the use of Simulation Based Acquisition is appropriate. It should be noted, however, that different applications of SBA occur at different time in the program.

For programs entering Concept Exploration, SBA methods should be fully built into the system as it develops. For example, the use of virtual prototyping, CAD/CAM, and shared databases are extremely effective in this phase. The program manager has the opportunity to significantly affect downstream issues and control costs for the future.

When the program enters System Development and Demonstration, other SBA methods would complement those from the first phase. The program manager would want to add computer modeling for form, fit, and function, reconfigurable prototypes to mirror design changes in real time, and consider logistical issues.

In Production and Development, the system design has already been solidified. Therefore, the program manager will want to apply, in addition to those SBA actions already taken, reusable simulations for training and live fire exercises, interoperability models for follow on efforts or other Service programs, and application of the system in force or mission level distributive interactive simulations (DIS). This final action relates to the hierarchy of M&S that was discussed under the chapter on Guidance.

Therefore, it can be seen that at each stage in the acquisition life cycle, it is economically practical to employ SBA in almost every program type and ACAT level. Those responding to the survey indicated that savings were achieved in each phase. Finally, it should be noted that the more that SBA is funded in the initial stages of the program, the more effective it is as the program progresses. Aside from monetary savings, risk reduction was a significant issue as reported by survey returns.

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V. CASE STUDIES

Simulation Based Acquisition has been used or is being used in military programs since implementation of the guidance. In a statement to the Senate Committee on Armed Services, Dr. Kenneth Oscar stated:

> Through Simulation Based Acquisition (SBA), the Army is using modeling and simulation (M&S) to reduced acquisition costs, total ownership costs, and time to initial operating capability, while increasing the military utility and quality of a fielded system throughout its lifecycle (Oscar, 1998).

Additionally, the US Army believes and supports the implementation of SBA…

> …across acquisition programs and phases to reduce total ownership costs, provide quicker delivery of products to the field, while simultaneously increasing military utility and worth (Truelove, 1999).

In concert with his pronouncements, above, Truelove stated that the Army had identified four flagship programs in which Simulation Based Acquisition is being used. These were the Future Scout and Cavalry System (FSCS), the Crusader, the AH – 64 Apache Longbow Helicopter, and the UH – 60 Blackhawk helicopter. The use of SBA in these programs provides excellent insight into the application techniques as well as the benefits derived.

A. FUTURE SCOUT CAVALRY SYSTEM (FSCS)

(FAS, FSCS)

In late CY 1996, the Army identified a need to field a cavalry vehicle that provides the soldier with advanced capability to look forward for scouting. As a result, the US Army partnered with the United Kingdom (UK) to develop the Future Scout Cavalry System (FSCS). The intent was to have both parties benefit from advanced design work while supplying specific subsystems. Although the Army Transformation effort has now identified the Future Combat System as the platform to meet the requirements and FCS has replaced the FSCS concept, the initial integration of SBA into FSCS is worth reviewing as it exemplifies positive methods in which to employ models and simulations.

The FSCS is operated by a three-man crew, has Micro Unmanned Aerial Vehicles (MAVs), unmanned ground operated vehicles noted as robots. The United Kingdom is responsible for the Tactical Reconnaissance Armoured Combat Equipment Requirement (TRACER). Both the robots as well as the MAVs are designed to be operated as forward looking devices to seek out enemy positions. The FSCS also contains a mast that can rise to a height of 5 meters (FAS – FSCS, 2002).

Advancement of the FSCS design was facilitated by a simulation called Close Combat Tactical Trainer (CCTT). The use of this simulation was crucial in providing the user with a working model from which to make further decisions regarding design or doctrine. CCTT provides personnel with different interests and perspectives – the soldier, the commander, and the tester, for example – with the capability to derive diverse, but related, information from the item being simulated. For example, in terms of a FSCS, the soldier would have a system that replicates the fidelity of the combat vehicle's operation in order to understand better how it will respond to different scenarios. The commander can observe the implementation and effectiveness of different battle tactics. The tester can gather data related to the strengths and weaknesses of the overall systems.

The FSCS was identified as one of the SBA Flagship programs at the right point in its life cycle to use CCTT. Since the FSCS program was new, the use of CCTT seemed ideal. According to Truelove, by building a design and description that are digitized, the user can identify flaws as the development progresses. Additionally, the program will use the SBA concepts repetitively and end up with embedded training. Finally, the program can use virtual prototypes that will identify total ownership issues (Truelove, 1999).

CCTT is a Distributed Interactive Simulation (DIS) meaning that users can interact with the simulation from different workstations (even geographically separated) at the same time. Dr. Stuart W. Olson published a paper describing a hypothetical application of SBA to the FSCS program. In this paper, he addresses how SBA can be implemented across program phases using the simulation tool of CCTT. Personnel are trained in the CCTT using both a full crew simulator as well as a command post. The simulators offer such reality that trainees can fully perform their normal tasks to achieve mission success. Also inserted into the simulation are the Semi Automated Force(s) (SAF) that operate within the scenario without significant human intervention. (Olson, 1998)

Olson goes on to define how in each stage the information derived from the simulation can be utilized. By way of example, Olson suggests that in the concept phase, CCTT can be used to observe

> …combat effectiveness, information flow, tactics, techniques, and procedures, command and control, and soldier constraints of the concept (Olson, 1998).

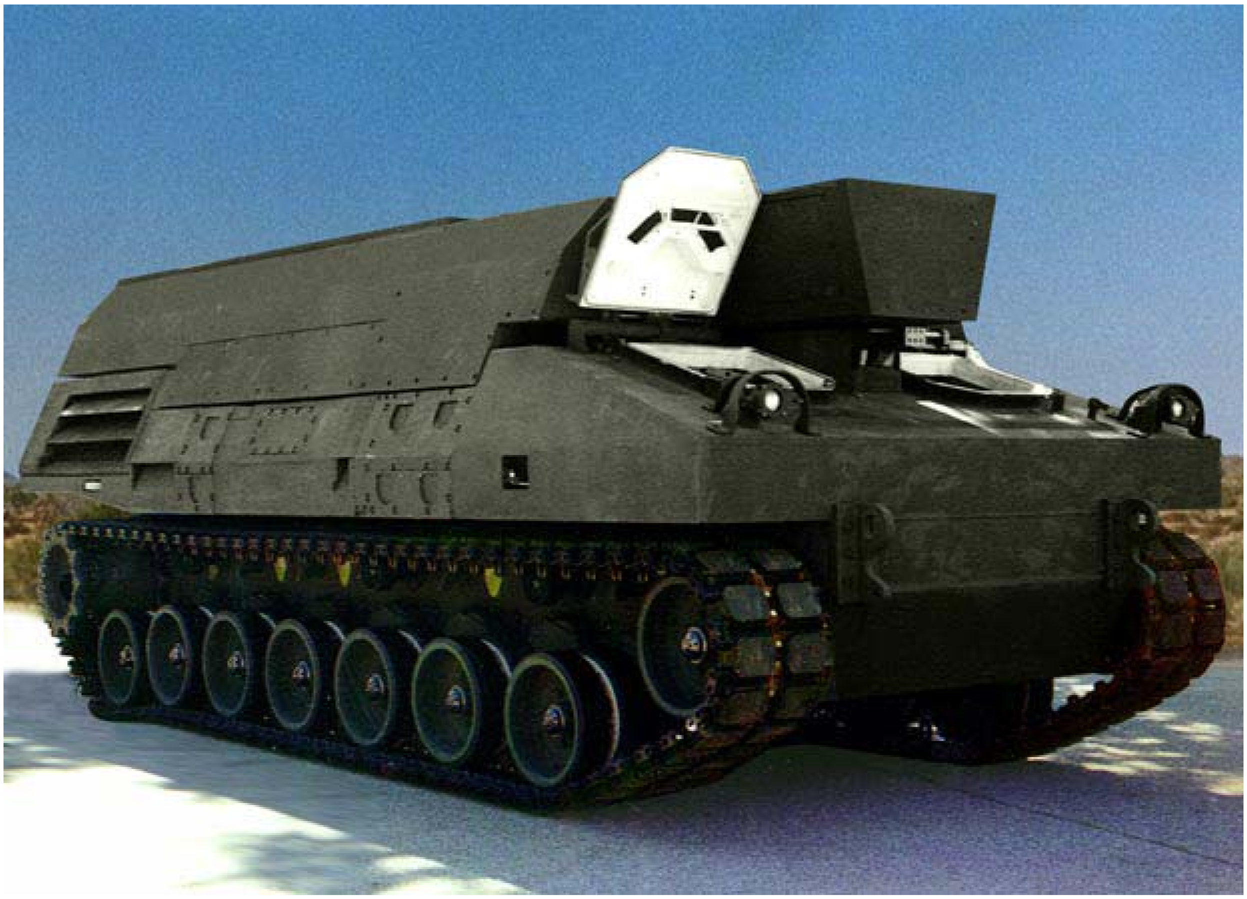
In the engineering phase, the design models can be tested with CCTT and improvements made accordingly. Olson goes on to state that in the test and evaluation phase that the amount of live testing can be reduced through the simulations. Finally, in the deployment phase of this concept, the advantages realized in the early phases are immediately seen in this stage of the program. (Olson, 1998)

B. CRUSADER

Forward Vehicle: Self – Propelled Howitzer (SPH)

(Army Technology, 13 Nov 02)

Rear Vehicle: Resupply Vehicle (RSV)



(Army Technology, 13 Nov 02)

The Crusader program was cancelled (in May 2002) because the concept did not fit the Army Transformation requirement. The concept of the two vehicles for the Crusader was noble, but the practicality of the overall system did not meet the requirement for strategic mobility. Although major revisions were initiated, the total system was simply too large to be transported anywhere in the world in support of our rapid deployment forces.

The Crusader program entered Program Definition and Risk Reduction mid-year 1997. This system was comprised of two vehicles that interlocked on the field. The forward vehicle was the actual platform consisting of a self-propelled 155mm howitzer, Modular Ammunition Charge System (MACS) propellant, the system for automatic gun positioning, and an automated ammunition handling system. The forward vehicle was designed to have fire support digital communications as well as navigational aids to support the crew in field mobility. The rear vehicle was capable of maneuvering to the forward vehicle on the field and interlocking with it. Once coupling had been achieved, automated transferring of projectiles and propellants would take place (Cartwright and Wallestad, 1998).

The US Army mandated use of SBA in the Crusader program as one of the Flagship programs. The rationale for this decision was that the program could identify and demonstrate verification, validation, and accreditation (VV&A) of modeling and simulation. Additionally, the implementation of collaborative efforts was exploited in the program. For example, there was collaborative prototyping, a collaborative environment (also known as Integrated Digital Environment), and training on virtual prototypes (Truelove, 1999).

The application of SBA in the Crusader through modeling and simulation, was applied throughout its development. Use of modeling and simulation proved to be effective in each application as shown in the selected examples that follow.

1. Engineering Design

The use of M&S in the Crusader engineering design was a consistent element throughout this process. According to Cartwright and Wallestad, M&S applied in the early stages of design identifies errors in logic as well as gray areas in the requirements. Identifying these issues prior to solidifying the design lessens design costs as well as reduces time through the program development. The authors further state that using modeling to mirror design steps offers efficiencies not otherwise available. Eventually, the design becomes a “life-cycle model” that evolves as the program advances (Cartwright and Wallestad, 1998).

2. Modeling and Simulation for Test and Evaluation (T&E)

The use of modeling and simulation in Test and Evaluation is crucial to effective management of a program. The application in the Crusader program proved to be no different. Although use or planned use was to occur in all phases, the use of M&S in PDRR was to be more extensive than in either Engineering and Manufacturing Development (EMD) or Low Rate Initial Production (LRIP). The authors identified four objectives for use of Modeling and Simulation support. These are:

- To facilitate the integration and test of Crusader hardware and software products at the subsystem, element, and segment, levels;
- To enable item checkout and debug activities at component and lower levels;
- To support item acceptance, software test, and hardware test effort;
- To provide an infrastructure for integration and interoperability of external models and simulations used in system level testing and analysis (Cartwright and Wallestad, 1998).

Through the use of M&S, it was hoped the program would achieve greater efficiency in its testing and evaluation elements. Components, subsystems, and systems would be verified, while still at a point where design changes could easily be made.

3. M&S for Milestone II

The use of modeling and simulation in this program to support Milestone II was significant. According to Cartwright and Wallestad, M&S had been used as

> …an aid in test design, and in many cases as a modeled or simulated test environment. In most cases…real–time simulations will be run in conjunction with the ICE (Integrated Crusader Emulator) at UDLP (United Defense, the contractor) to dry run the test in order to verify that the system, as configured for the test, is capable of attaining a firing state according to the test procedures *(parentheses added)*. (Cartwright and Wallestad, 1998)

Modeling and simulation, in this case, provided the means in which to test the simulation. The authors went on to state that actual test data would be measured against the model performance, thereby establishing the need, if any, for improvements or isolating unusual characteristics of the system. Additionally, modeling and simulation supported wide-ranging system parameters including range (gunfire dynamics), accuracy (Monte Carlo runs), mobility (vehicle dynamics), and crew size (Crew Module Demonstrator).

C. AH – 64 APACHE LONGBOW

AH – 64 Apache Longbow

(*Army Technology, 14 Nov 02)*

The Apache helicopter is the Army's attack platform to be used in close combat and to penetrate behind lines to destroy and disrupt enemy forces. The system is equipped with Hellfire missiles for use against armored enemy forces, Hydra 70 (2.75") folding fin rockets for soft targets, and 30mm cannon rounds. Additionally, the system has an optical array consisting of Day TV, Forward Looking Infrared (FLIR) detection, and a color magnified imaging system (FAS – Apache, 2002). The Longbow variant (UH-64D) of the Apache utilizes a mast-mounted fire control radar for the missile (Hellfire) system. This system is deployable for use in all conditions regardless of time of day or visibility. The Longbow system utilizes digitization to acquire up to 128 targets and then prioritize 16 items as well as hand off targeting data to other attack platforms (US Army TACOM, 2002).

The program used modeling and simulation in terms of providing simulators to compare predicted results with live fire testing. In this case, the program used simulations of …

> …target acquisition and fly-out, Hardware-in-the-Loop (HWIL) testing of the guidance section, low-speed captive flight tests (LSCFT) of the missile seeker, and live firings at moving armored vehicles (DOT&E, 1998).

Therefore, in this utilization of M&S, the Apache Longbow program took action to measure actual results, compared to those derived in a simulation. Additionally, the simulation itself was tested to determine its reliability. The application of simulations attempted to forecast what to examine in testing, should results vary. As stated in the citation,

> …M&S was used to characterize the missile's performance in the LOBL-I (Lock-On Before Launch Inhibit)) mode in a far wider range of conditions than could be examined just using field test…The results from the LSCFT and the missile firings were then compared to the M&S predictions to help further validate the simulation models (DOT&E, 1998) (parentheses added).

M&S, in these Apache cases above, was used to both forward the program and reduce costs through simulated testing. Additionally, the application of data improved system performance. Further evidence of design considerations is presented in the next section on the UH – 60 Blackhawk Helicopter.

D. UH- 60 BLACKHAWK HELICOPTER

UH – 60 Blackhawk

Photo taken by: USAF

(Combat Aircraft, 15 Nov 02)

Another Helicopter platform widely used in the US military is the UH-60 Blackhawk helicopter. It is a utility aircraft designed to be operated by three crew members and carry a fully equipped combat squad of eleven. The platform is qualified to carry (sling load) a 105mm howitzer and 30 howitzer rounds. The helicopter can also serve in roles of medical (UH-60 MEDEVAC), firefighting (UH-60 Firehawk), electronics counter defense (EH-60A), and target acquisition (EH-60B) (FAS Blackhawk, 2002). Currently, the Blackhawk is in a program upgrade (UH-60M) status. The helicopter is undergoing redesign to achieve increased capabilities, including the amount of weight it may lift, operating range, and survivability (Edwards and Nikonchuk, 2001).

Modeling and simulation is being incorporated into this program as required by the US Army directive, Simulation and Acquisition for Acquisition, Requirements, and Training (SMART). According to the authors, the intent of SMART in the program is to prove out design effectiveness and reduce the cost of testing. In order to achieve the flexibility in the hardware design, a reconfigurable cockpit was developed to meet the design specifications. The program intended to upgrade the flight controls through a new design. In order to test the design, a virtual prototype was developed and tested in the reconfigurable cockpit. The cockpit design was handled through a Computer Aided Design (CAD) program, which allowed the personnel to view different designs in a direct comparison on screen. The CAD program permitted the form, fit, and function criteria to be considered and incorporated. Early User Demonstration (EUD) will comprise three events. These are:

> EUD1 will use CAD and computer-generated imagery to facilitate user and designer communication and analysis during risk reduction and prior to PDR. EUD1 allows pilots (users), designers, and PMO representatives to identify potential user issues and design solutions based on current configurations. EUD1 will also provide an opportunity to define the metrics necessary to measure situational awareness (SA) resulting from information presented to the pilot *(Event 1)*; establish measure of effectiveness/performance for future SA design and analysis activities *(Event 2)*; and facilitate initial human factors engineering of candidate instrument panel configurations *(Event 3)* (Edwards and Nikonchuck, 2001) (parenthesis added)

Again, SBA through modeling and simulation, is being utilized to effectively improve system performance. The ability to immediately reconfigure a helicopter cockpit based upon design comparison is a powerful tool for the program manager.

E. ARMY USE OF SURVEY DATA

The preceding four cases define the use of Simulation Based Acquisition methods through concrete examples. In all of the cases, the program managers, and the acquisition chain, recognized the potential for positive program impacts by employing these methods. Examples of Army use, that mirror survey data from Navy acquisitions, include simulation of hardware environments, prototype development, use of CAD/CAM, software verification, and platform qualification. It should be noted that the programs exemplified above reflect four very high profile programs and therefore the SBA methods employed are numerous. Accordingly, it is logical that the Army cases are significant in their replication of Navy uses.

Throughout this chapter, the paper has identified different ways in which program managers can utilize modeling and simulation to achieve program success, build prototypes, effectively conduct test, and validate simulations. Each of the programs benefited from these applications of modeling or simulations and the system designs became dynamic, oftentimes at a point in the program where such measures served the greatest good.

VI. CONCLUSIONS AND RECOMMENDATIONS

The intent of this thesis paper was to answer the Primary Thesis Question, *"Are there specific times within the life cycle of a major program when it is in the best economic interest of the Program Manager to use the methods of Simulation Based Acquisition?"*

In order to answer this question, the study reviewed guidance offered at the Department and Service levels within the Department of Defense. Case studies were presented that illustrated Simulation Based Acquisition (SBA) used in current or previous programs. Additionally, a survey was sent to Navy program managers for input on their SBA use and successes.

This concluding chapter will review the significant observations from earlier chapters, provide conclusions, and make recommendations for future research.

A. SIGNIFICANT OBSERVATIONS

1. Introduction

In the thesis introductory chapter, the paper presented a definition of Simulation Based Acquisition that identified the use by Government and industry, in a collaborative environment, and the simulation technologies currently available. The use should be across phases and programs. The intent is to reduce the consumption of resources, including time, and risk while increasing the quality of the program. The suggested manner in which to achieve this is through Integrated Product and Process Development (IPPD) in programs. SBA should not be considered to replace common sense and required activities. Essentially, the prudent program manager should incorporate SBA where it serves the interests of the Service and the taxpayer, through the available technologies, as a part of the program acquisition cycle.

Another point identified in the introductory chapter is the new paradigm of testing. The standard testing progression had been test-fix-test. Using SBA, the methodology shifts to model-simulate-test with the test results driven back into the model. This strategy should be explicit in every program's TEMP and followed zealously.

Additionally, the chapter presented information from the old DoDD 5000 series instructing program managers to utilize Modeling and Simulation within their programs. The purpose of this was to reduce time, resources, and risk. These are the elements that were present in the earlier definition of SBA. Clearly, the intent of the guidance and initial SBA documentation addressed the need to reduce program cost elements while increasing the quality of the systems. The interim guidance promulgated in November 2002 by the DEPSECDEF does not change the intent.

There are numerous methods of modeling and simulation that program managers can employ in their programs. Examples include three-dimensional design capabilities with input from all stakeholders in real time; distributed interactive simulations in which virtual forces are set in motion from wide (real life) geographical locations; virtual training for the soldier; and, using simulators to replicate live fire tests. Before simulations are accepted, actual testing or other verification means must be used to validate the simulation.

2. Background

SBA was defined to include three goals consisting of the following: to reduce time, risk, and resources; to increase the quality of programs; and, to enable the use of IPPDs in the life cycle. However, program managers are encouraged not to rely upon SBA as a replacement for common sense or quality systems engineering. The Department of Defense established in 1995 that programs need to use modeling and simulation more extensively. This would decrease the duration of testing and change the testing process into modeling, simulation, testing, and then incorporating the results into the model. In 1998, DoD stated that the military needed to develop new major systems, support them, and do it at a lower cost. Additional guidance came out of the Department of Defense in the form of DoDD 5000.1 and the USD memorandum. Both of these documents discuss the control of costs and resources to manage programs effectively. The Interim guidance that has replaced the 5000 series details the implementation of cost realism, sharing, and affordability in programs. Private industry encourages the use of SBA and suggests that systems engineering and better design data are the key elements in the SBA process.

3. Guidance

The Department of Defense and each of the Services have all put out guidance on modeling and simulation. Each Service has established a Modeling and Simulation plan as well as policy for M&S. Additionally, the Services have promulgated their information on the Internet in a variety of styles. However, the question is raised of how often the guidance and plans are updated. Additionally, the research proved that there is not a single specific Internet site for SBA throughout the Services.

4. Survey Data and Results

The thesis survey provided results that were quite divergent in nature. A significant feature of the survey was that programs across all ACAT levels from the Navy were requested to complete the questionnaire. A reasonable response was received and at least four significant uses of SBA were found in the DON programs. These were:

Computer Modeling – The respondents indicated that computer modeling was effective in reducing testing as well as making design changes in structural or form, fit, and function issues.

CAD/CAM – CAD and CAM were used as an aspect of SBA. Additionally, the engineers looked for existing M&S that could be applied to their program. One program established one manager for M&S PDRR (now Concept and Technology Development and System Development and Demonstration).

Virtual Prototyping – In this area, prototyping was used to provide database access to both Government and industry personnel. Prototyping was used to reduce the amount of rework in a system thereby saving man-hours. Although not discussed by survey respondents, prototyping can also be used for risk management. The USMC Advanced Amphibious Assault Vehicle (AAAV) uses database management for risk reduction.

Production Data – This data was used in the EMD phase (now primarily System Demonstration and Production Readiness and LRIP) to update the design through high fidelity representations.

4. Case Studies

Four programs were presented to exemplify how SBA can be applied to a program or system. The Future Scout Cavalry System (FSCS), although canceled, demonstrated the power of the Close Combat Tactical Trainer. This is a trainer that puts the user into a virtual environment. From such training, the soldier can get close to real life engagement of the system. The tester can review how the system behaves and reacts. The commander can observe the strengths and weaknesses of the system in battle and determine tactical maneuvers for use by forces. By inserting SBA into the Crusader early in its acquisition cycle, the program manager was able to change the design easily. Additionally, 70% of the downstream logistics cost is affected by design factors normally solidified early in the life cycle. By changing design for future logistics, the program manager can realize a significant savings for the fielded systems when operating and support budgets are typically limited.

The Crusader program, also cancelled, implemented SBA in its developmental efforts. Although modeling and simulation had been used or planned for use in many areas, there were three specific areas for the Crusader discussed in Chapter 4. These were Engineering Design, Test and Evaluation Support, and Milestone II support. Several examples of how M&S was expected to benefit Crusader include verification of the models (as compared to live fire testing); testing of the system and subsystems; and, providing a structure for demonstrating interoperability.

The Apache Longbow used M&S for test system performance in parameters that were not easily replicated in live fire testing, while the Blackhawk program used M&S in conjunction with a reconfigurable cockpit to expedite design changes.

The four cases provided in this study exemplify the wide spectrum of uses of SBA and, in some cases, modeling and simulation. Although these programs are highly visible (or were so in the cases of FSCS and Crusader), the use of SBA in lower level ACAT programs should not be overlooked.

B. CONCLUSIONS

Through a review of current guidance, an analysis of data derived from a survey, and an examination of case studies, this thesis has identified different uses of Simulation Based Acquisition. Significant conclusions may be defined as follows:

1. Guidance and Accessibility

The guidance has provided a roadmap, albeit patchwork in nature, of the use of SBA in programs. It should also be noted that guidance is dynamic and changes over time. Accordingly, it makes sense to have a central Department of Defense Internet site for SBA, its uses, Service guidance and policy, and lessons learned. As guidance is revised and issued, the Internet site would be updated to stay current. The hyperlinks on the central site would drive down to Service sites, which need to have links to the DoD site.

2. Funding and Return on Investment

One significant finding through the survey was that funding typically occurred during the PDRR or EMD phases in the acquisition life cycle. The uses include design efforts to reduce risk, cost, requirements development, platform qualification, and product testing. However, the program manager should plan for the cost savings that SBA will return throughout the entire program. Of all the survey respondents, when posed the question (of planned cost savings), only one answered in the affirmative that costs savings were *planned* through SBA use. This is significant in that slightly more than half of the respondents (who also stated that the program had planned investment in SBA) replied that they were able to identify cost avoidance though the use of SBA. Therefore, program managers should plan on using SBA methods at all points in the program to achieve some measure of return on investment.

3. Missing Uses

The survey provided information on how SBA was being used, but the responses also demonstrated issues that were omitted. For example, there were only two respondents that discussed the use of SBA in the first stage of the acquisition life cycle (Concept Exploration). Furthermore, there was no mention by respondents of design interfaces between developers, contractors, and users. Concept Exploration is the most significant area in which to employ SBA to achieve program savings downstream. Bringing the users, developers, and contractors together during CE is crucial for resolution of design issues. It was mentioned in Chapter I that by the time that the program hit Milestone I (under the traditionally acquisition life cycle timeline) that 70 percent of the eventual O&S costs had been locked in. By early involvement of these parties, the program can achieve significant savings and benefits in the future. Additionally, there was little discussion of use of SBA in place of live fire testing. The ability for SBA to replicate live fire testing while lowering costs is significant to the program and should be used as frequently as possible. Finally, narrative responses to the survey did not indicate to what degree future SBA efforts would be made. SBA is an initiative that is applicable to all phases of a program and should be used accordingly. It is most effective when used in the early stages, but SBA may still be utilized throughout Production as well.

4. Simulations

The Future Scout Cavalry System (FSCS) case study identified the use of simulations in the program by employing the Close Combat Tactical Trainer (CCTT). The program used the simulation to identify design flaws and to provide embedded training. Additionally, the CCTT virtual prototypes were described as being a tool that the program manager could use to recognize ownership issues for the future.

Program managers should employ the use of simulations within the bounds of technical feasibility, required time lines, and good economic judgment to achieve design fidelity, risk management, ownership costs, training opportunities, live fire replications, and prototyping. The implementation of this tool provides opportunities to the program manager for thinking laterally instead of resorting to rigid product development.

5. Prototyping

Although prototyping can easily occur digitally with reviews by users and engineers, there are higher levels of prototyping that may take place. In the Blackhawk program, design configuration is done normally through virtual prototyping. However, the program has also developed a physical cockpit that can be reconfigured as the virtual design is manipulated. The immediate benefit that can be realized is that the program can discern the impact of design changes upon the cockpit. But long-term benefits may be derived also. Direct costs are reduced through less labor and material used. Users can build in design features for future hardware, in process, but not yet available (next generation of communication equipment for example). Additionally, logisticians can use the current configurations to begin efforts for future considerations and adjust as the design changes. Ultimately, it makes sense for any program manager to use reconfigurable prototypes wherever possible to advance the program and achieve design and cost benefits.

6. Economic Breakpoints

The earlier discussion in points 2 through 5 above address the use of SBA in programs. The thesis, through use of the survey and research, was unable to determine a level of funding at which one could decide to employ SBA techniques. However, the guidance, data, and case studies were able to establish that SBA in multiple forms can be applied across program phases to benefit the program. The program manager should use SBA as early as possible, but that does not preclude use in later stages especially after the design is well fixed.

C. RECOMMENDATIONS FOR FUTURE RESEARCH

The intent of this thesis was to define specific breakpoints in military programs in which to employ SBA methods. Although breakpoints could not be identified, there were issues that could be pursued in future research. These include:

- A survey of ACAT level I programs across all Services that examine more thoroughly the funding aspects of SBA.
- A comparative examination of two specific programs in which one used SBA successfully in all phases and methods and the other underutilized SBA.
- A study of future SBA direction as set by DoD and the Services while working closely with the lead individuals in each area.

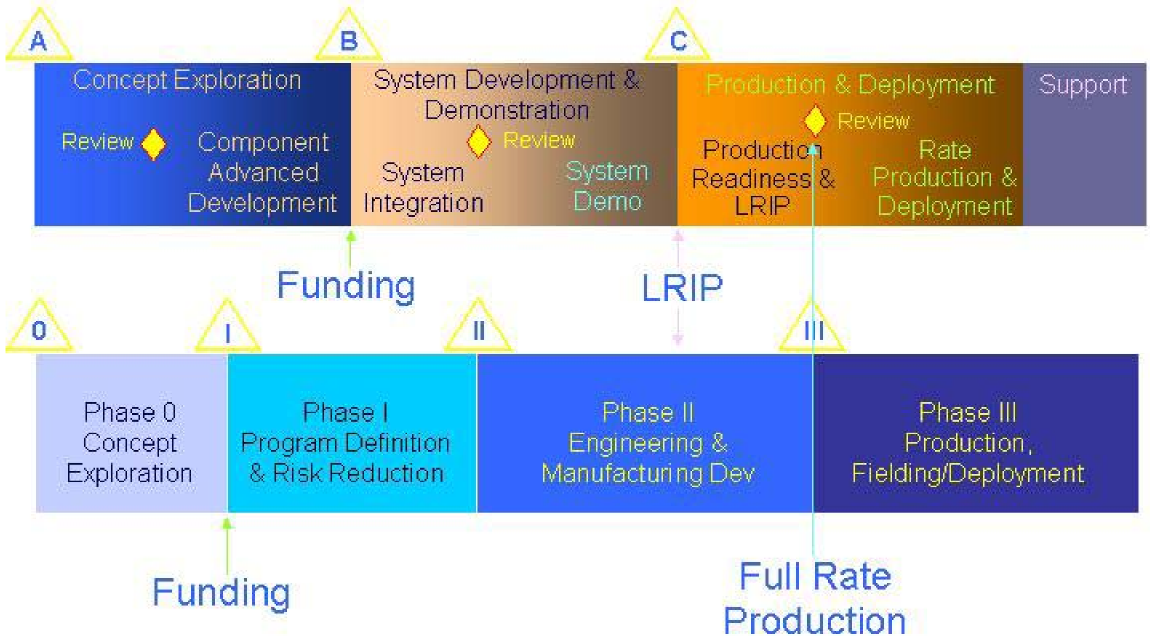
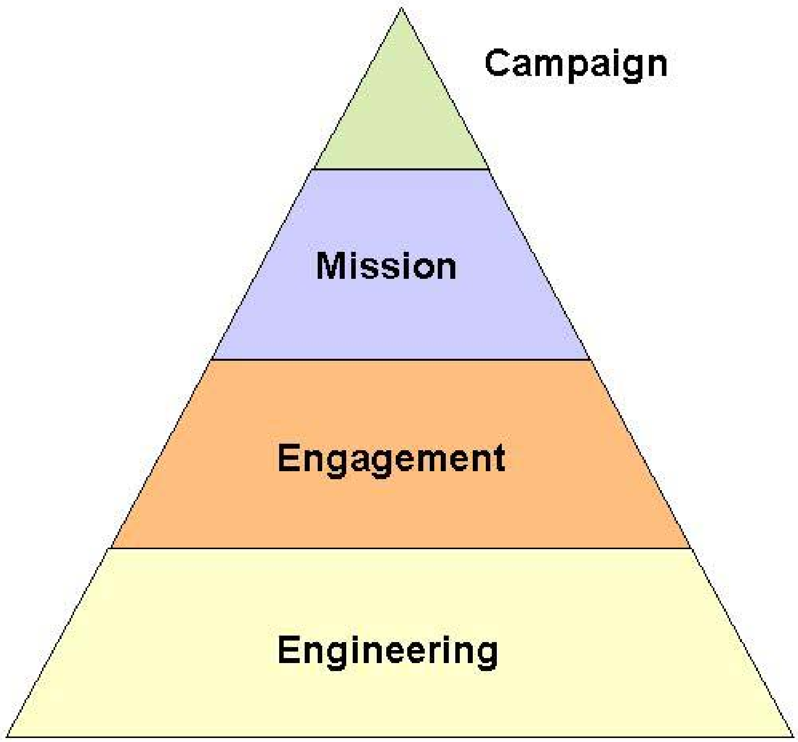


Figure 1. A Comparison Between the 5000 Series Timeline and the Revised Model



(STEP, 1997)

Figure 2. Hierarchy of Modeling and Simulation

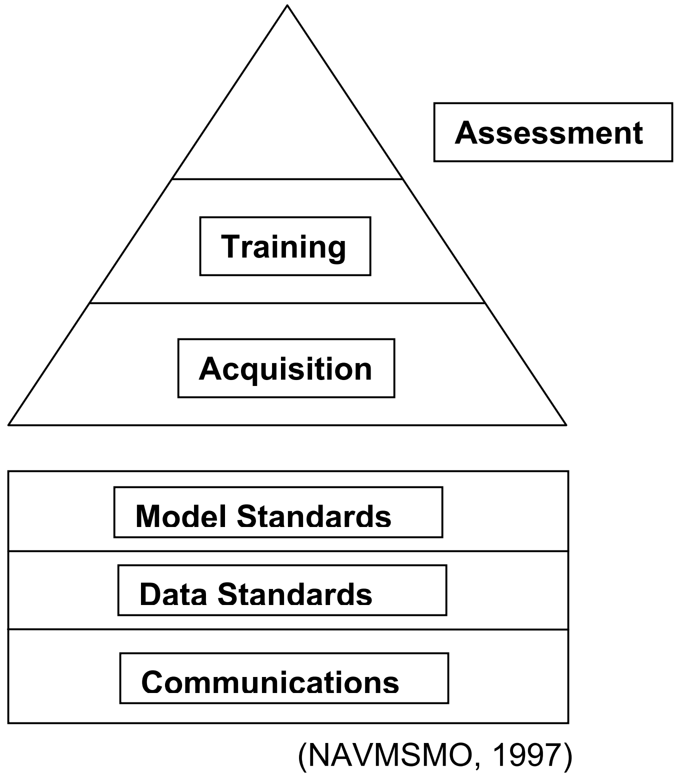
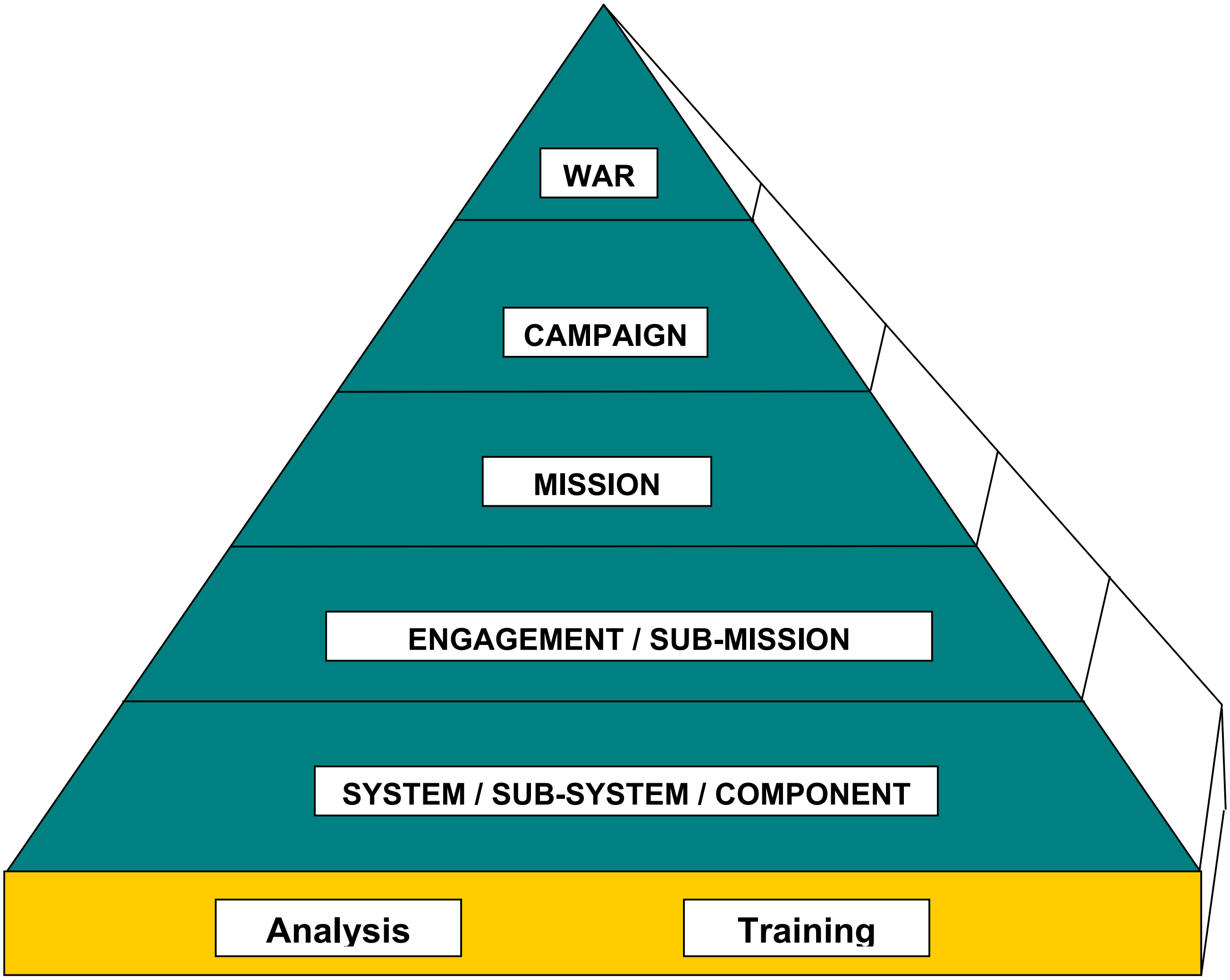


Figure 3. M&S Building Blocks Supporting the Areas of Assessment, Training, and Acquisition



(HQ USAF, 1995)

Figure 4. Modeling and Simulation Hierarchy

Acronym	Model Name	Type
ASOAR	Achieving a System Operational Availability Requirement	Readiness
SESAME	Selected Essential-Item Stock for Availability Method	Readiness
COMPASS	Computerized Optimization Model for Predicting and Analyzing Support Structures	Readiness and Cost
ACEIT	Automated Cost Estimating Integrated Tools	Cost
LCET	Logistics Cost Estimating Tool	Cost

(From Price, 2002)

Table 1. Linked / Integrated Army Models

ACAT Level	SBA as % of Acquisition Cost	Cost Avoidance as % of Acquisition Cost
1	0.70	2.60
2	0.20	0.00
2	2.60	1.70
3	1.00	1.50
3	1.10	0.00
3	1.40	0.00
3	2.00	2.60
3	2.90	0.00
3	2.90	0.00
3	4.40	0.00
3	8.10	0.00
3	11.30	0.00
3	11.30	0.00
3	19.80	0.00
4	0.10	0.20
4	1.00	1.90
4	1.10	0.00
4	4.60	0.90

Table 2. Comparison of Projected SBA Cost to Anticipated Cost Avoidance

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