AEROSPACE SYSTEMS SURVIVABILITY HANDBOOK SERIES

Volume 5. Survivability Models and Simulations

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FOREWORD

This Aerospace Systems Survivability Handbook Series is designed to provide its users with insight into the key activities performed by survivability personnel in support of aerospace systems acquisition. The series is not a specification or standard but rather a “how-to” guide for all survivability managers, engineers, and analysts associated with survivability activities likely to be needed on any program, government or commercial.

Some of the material used in the handbook series has been adapted from various sections of the Department of Defense (DoD) Deskbook, Internet links, and survivability documents produced by the Joint Technical Coordinating Group on Aircraft Survivability (JTCG/AS), under the sponsorship of the Joint Aeronautical Commanders’ Group (JACG). The service laboratories and centers also produced source documents. This handbook series emphasizes the requirement for integrated teamwork of survivability management, engineering, test and evaluation, and systems analysis in order to accomplish a successful systems acquisition.

The handbook series (JTCG/AS Project A-8-01, Acquisition Deskbook Survivability Section Rewrite) was prepared for the JTCG/AS under the sponsorship of the Principal Members Steering Group (PMSG) and directed by LTC Charles R. Schwarz, Director, JTCG/AS. The handbooks were drafted by Hubert (Hugh) Drake, SRS Technologies, under contract to the Naval Air Warfare Center Weapons Division, China Lake, CA. As the Contract Technical Monitor, Dave Hall provided guidance and initial review. The following working group members provided oversight:

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ACRONYMS AND ABBREVIATIONS

1v1	One-on-One
1vN	One-on-Many
AAA	Antiaircraft Artillery
AAM	Air-to-Air Missile
ACTD	Advanced Concept Technology Demonstration
ADS	Advanced Distributed Simulation
AMSAA	Army Materiel Systems analysis Activity
AIRGuide	Accreditation Information Requirements Guide
AoA	Analysis of Alternatives
C3I	Command, Control, Communications, and Intelligence
C4I	Command, Control, Communications, Computers, and Intelligence
CINC	Commander in Chief
DAB	Defense Acquisition Board
DEW	Directed-Energy Weapon
DIS	Distributed Interactive Simulation
DoD	Department of Defense
DOT&E	Director of Operational Test and Evaluation
DPRB	Defense Planning and Resources Board
DT	Developmental Test
DT&E	Developmental Test and Evaluation
DTO	Defense Technology Objective
EO	Electro-optical
EW	Electronic Warfare
HITL	Human-in-the-Loop
HWIL	Hardware-in-the-Loop
HW/SWIL	Hardware/Software-in-the-Loop
IADS	Integrated Air Defense System
IPPD	Integrated Product and Process Development
IPT	Integrated Product Teams
IR	Infrared
JACG	Joint Aeronautical Commanders' Group
JASA	Joint Accreditation Support Committee
JROC	Joint Requirements Oversight Council
JTCG/AS	Joint Technical Coordinating Group on Aircraft Survivability
JTCG/ME	Joint Technical Coordinating Group on Munitions Effectiveness
LFT&E	Live Fire Test and Evaluation
M&S	Modeling and Simulation
MDA	Milestone Decision Authority

MNS	Mission Need Statement
MOE	Measure of Effectiveness
MOO	Measure of Outcome
MOP	Measure of Performance
MvN	Many-on-Many (also M on N)
OA	Operational Assessment
OT	Operational Test
OT&E	Operational Test and Evaluation
Pk/h	Probability of Kill Given a Hit
PM	Program Manager
PMSG	Principal Members Steering Group
RF	Radio Frequency
SAM	Surface-to-Air Missile
SURVIAC	Survivability/Vulnerability Information Analysis Center
STEP	Simulation Test and Evaluation Process
STOW	Synthetic Theater of War
SWIL	Software-in-the-Loop
T&E	Test and Evaluation
V&V	Verification and Validation
VV&A	Verification, Validation, and Accreditation

EXECUTIVE SUMMARY

This volume explores the types and uses of survivability models and simulations (M&S) in the acquisition process. Representations of proposed systems (virtual prototypes) are embedded in realistic, synthetic environments to support the various phases of the acquisition process, from requirements determination and initial concept exploration to manufacturing and testing of new systems and related training. M&S are used in support of survivability engineering, systems analysis, and test and evaluation (T&E) throughout acquisition in compliance with acquisition guidelines.

Models and simulations are tools that can be used to support the program manager (PM) in each phase of the acquisition process. M&S can aid in minimizing risks to cost, schedule, performance, and supportability; they are efficient and effective sources of valuable information to be used in the development and evaluation of new weapon systems. When used properly, in an accredited and integrated manner, they can reduce expenditure of resources, accelerate understanding through early insight, and shorten overall acquisition-cycle time. At the same time, M&S can improve the quality of the system under development. In the area of T&E, M&S have become an integral part of the “model-test-model” testing process. The use of M&S is seen as complementing traditional tests and providing an essential element of an integrated survivability T&E strategy.

M&S can substantially contribute to improving the pillars of military capability — readiness, modernization, force structure, sustainability, and survivability. M&S will enable cost-effective joint and combined training, mission planning, and mission rehearsals involving active and reserve forces, multiple echelons, and computer-generated simulations of large-scale forces (friendly, neutral, and hostile) on a synthetic battlefield.

Representations of proposed systems (virtual prototypes) will be used to support acquisition activities, significantly reducing the time and expense of concept exploration, engineering, analysis, manufacturing, and follow-on support activities (such as training or maintenance). Decision-makers can effectively and quickly simulate and then evaluate the consequences of alternative force structures with known or projected capabilities placed in various mission scenarios. High-fidelity models of logistics, personnel management, medical support, etc., will be integrated with combat models to allow a comprehensive analysis of operational effectiveness, survivability, and sustainability.

Accredited M&S are applied, as appropriate, throughout the system life cycle in support of the various survivability acquisition activities: requirements definition, project management, design and engineering, efficient test planning, and pre-test prediction; M&S are also used to supplement actual T&E, manufacturing, and logistics support. Survivability projects integrate the use of M&S within project-planning activities and integrate M&S across the survivability functional discipline.

The principal source of information on survivability models and simulations is the Survivability/Vulnerability Information Analysis Center (SURVIAC), located at Wright Patterson Air Force Base, Dayton, Ohio. SURVIAC is jointly sponsored by the Joint Technical Coordinating Group on Aircraft Survivability (JTCG/AS) and the JTCG on Munitions Effectiveness (JTCG/ME). The SURVIAC Website at http://bahdayton.com/surv1 has further information.

1.0 INTRODUCTION

Models and simulations comprise a major component of survivability in acquisition. According to the DoD Defense Acquisition Deskbook, M&S are used in acquisition as follows:

> Modeling and Simulation. The use of models, including emulator, prototypes, simulators and stimulators either statistically or over time, to develop data as a basis for making managerial or technical decisions. [M&S Educational Training Tool]

As the backbone of survivability engineering, analysis/assessment, and T&E, M&S are tools that can be used to support the program manager's decisions in each phase of the acquisition process. They are an efficient and effective source of valuable information in the development and evaluation of new defense systems. M&S can aid in minimizing risks to cost, schedule, performance, and supportability. When used properly, in an accredited and integrated manner, they can reduce the expenditure of resources, accelerate understanding through early insight, and shorten overall cycle time. At the same time, M&S can improve the quality of the system under development. Implementing state-of-the-art M&S for planning, design, analysis, management, and testing can significantly improve the effectiveness of the Integrated Product and Process Development (IPPD) management technique. It is through IPPD and the Integrated Product Teams (IPT) that the full potential of M&S to support acquisition can be realized.

Analysis of Alternatives (AoA) guidelines describe a model as "a representation of an actual or conceptual system that involves mathematics, logical expressions, or computer simulations." Models are used in AoA to estimate how a particular system would function. They could be applied, for example, to investigate questions such as "What would be the effect of an improved sensor on a submarine versus submarine engagement?" or "What would be the likely impact of additional aircraft hardening on aircraft performance in battlefield air interdiction?" The models can take a variety of forms, from simple "stubby-pencil" calculations to elegant mathematical formulations to large force-on-force computer simulations. Clearly, the type of model most useful for an analysis depends on the purpose being served. The following general guidelines apply when M&S are used to support AoA:

- Remember that like weapon systems, models are rarely entirely "good" or "bad." They are suitable or unsuitable for particular purposes.

- Exercise caution when you use models that include a "man-in-the-loop." Models should help eliminate personal bias and preference.

- Consider the models already available before you attempt to build new ones. Numerous models are available in almost every mission area.

- Keep the model simple. Often a simple mathematical equation can project the performance you are seeking to display.

- Be sure to test the model to see if it describes the base case well. Generally, more is known about the base case, the existing system, than about the alternatives. If the model does not "predict" what the existing system is known to do, it is not likely that the model's other predictions will be sound.

- Use several models. If different models yield similar results, confidence can grow that the estimates are reasonable.

- Run a "common-sense" test. Are the results plausible? Are they within reasonable bounds?

- Evaluate the quality of the environmental simulation and the environmental limitation evaluation. For systems using sensors with known vulnerability to adverse environmental conditions, for instance, does the model adequately incorporate the adverse effects of the environmental conditions during the simulation?

DoD has formed an extensive infrastructure for M&S; Appendix A delineates the major elements of that infrastructure. The principal source of information on survivability models and simulations is SURVIAC, which is located at Wright Patterson Air Force Base, Dayton, Ohio, and jointly sponsored by the Joint Technical Coordinating Group on Aircraft Survivability (JTCG/AS) and the JTCG on Munitions Effectiveness (JTCG/ME). The SURVIAC Website at http://bahdayton.com/surv1 has further information.

2.0 SURVIVABILITY AND THE SYSTEM LIFE CYCLE

Models and simulations, which are used to complement traditional tests, are viewed as essential elements of an integrated T&E strategy. The potential uses of M&S in support of survivability for system life-cycle activities — mission need, system acquisition, and operations and support — are discussed below. The system life-cycle process involves much overlap, with different analysts and engineers having to apply the same model(s) and analytical technique(s) across several of the life-cycle phases. Depending on requirements and system needs, the same models may be used by program office analysts, operational analysis, systems engineers, design engineers, support analysts, and independent analysts during one or more phases.

Survivability analyses and associated M&S play an essential role in the DoD life-cycle process. M&S are used extensively to support DoD decision-making bodies such as the Joint Requirements Oversight Council (JROC), the Defense Planning and Resources Board (DPRB), and the Defense Acquisition Board (DAB). In addition, M&S are important in the education and training of the military forces of all DoD components. The systems engineering process, so essential to the program office and the decision-making bodies, is intended to provide *disciplined engineering* during all system life-cycle phases. Throughout this process, analysis forms the foundation for survivability assessment and systems engineering. The keys to successful analyses are the tools used, specifically M&S. Figure 1 illustrates how M&S interface within the decision support process.

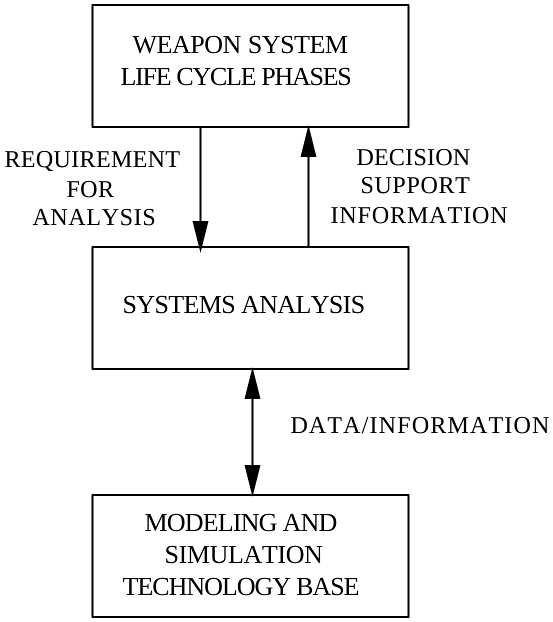

Figure 1. M&S and the Decision Support Process

Models and simulations are used to reduce the time, resources, and risks of the acquisition process and to increase the quality of the systems being acquired. Representations of proposed systems (virtual prototypes) are embedded in realistic synthetic environments to support the various phases of the acquisition process, from requirements determination and initial concept exploration through manufacturing and testing of new systems and related training.

When accredited M&S are used properly, their applications can often illuminate potential reductions in the expenditure of resources, accelerate understanding through early insight, and shorten the overall cycle time. Accordingly, M&S often have the potential of minimizing risk, reducing cost, and shortening schedules while at the same time improving the quality of the system under development.

Survivability M&S Verification, Validation, and Accreditation (VV&A)

Verification is the process of determining that a model implementation accurately represents the developer's conceptual description and specifications. *Validation* is the process of determining the manner and degree to which a model is an accurate representation of the real world from the perspective of the intended use of the model. Validation provides an indication of the confidence that should be placed on the model results. *Accreditation* is the official certification that a model or simulation is acceptable for use for a specific purpose. DoD Directive 5000.59 requires the DoD components to establish VV&A policies and procedures for the M&S applications the components manage.

Each DoD component accredits for its own forces and capabilities the M&S applications used to support major DoD decision-making organizations and processes (such as the Defense Planning and Resources Board; the Defense Acquisition Board; the Joint Requirements Oversight Council; and the DoD Planning, Programming, and Budgeting System).

The Joint Accreditation Support Activity (JASA), sponsored by the JTCG/AS, provides support to programs that are required by DoD directives to accredit their models and simulations. JASA has developed an Accreditation Information Requirements Guide (AIRGuide), which can be used to help assess the risks inherent in the application of models and simulations, and which guides the development of a verification and validation (V&V) plan to mitigate those risks. The AIRGuide process is based on assessing both the impact of a wrong decision made with incorrect model outputs and the probability of a wrong decision being made. Risk is defined as the product of impact and probability.

More information on JASA and on the AIRGuide may be found at JASA's Website, http://www.nawcwpns.navy.mil/~jasa.

3.0 USES OF SURVIVABILITY M&S IN ACQUISITION

Modeling and simulation are applied, as appropriate, throughout the system life cycle in support of survivability acquisition activities, including the following: (1) requirements definition, (2) project management, (3) design and engineering, (4) test and evaluation, (5) manufacturing, and (6) logistics support. Survivability-associated M&S are used as tools in all DoD technology areas to support conceptual analysis, technology development, acquisition, testing, fielding, sustainment, operational effectiveness, training, and planned product improvement. As a result, M&S are used in concert with most current DoD survivability technology developments. Guidance for the use of M&S in acquisition may be found in DoD Regulation 5000.2R, *T&E Overview*; Appendix B provides a summary of that guidance.

The following sections discuss how survivability M&S are applied in the various acquisition activities.

In Conjunction With Science and Technology Demonstrations

Models and simulations are demonstrated in concert with most current DoD technology developments, with these demonstrations oriented toward showing advances in the application of M&S as tools. Demonstrations are grouped according to the M&S Defense Technology Objectives (DTOs).

Development efforts supported within the M&S sub-area or coordinated in other technology areas include the following:

- High-level architecture
- Application support services
- Dynamic multicast grouping technologies
- Data structures, dictionaries, enumerations, and interchange formats
- Simulation system support tools
- Authoritative representations of the environment
- Simulation interfaces with command, control, communications, computers, and intelligence (C4I)
- Authoritative representations of human and group behavior
- Authoritative representations of systems
- Network communication services
- Protocols and standards
- Conceptual models of the mission space
- Complex data modeling techniques, tools, formats, and structures
- Simulation analyses and assessments
- Simulation interfaces with instrumented live systems
- Human-simulation interfaces (immersion technologies)

- Simulation interfaces with design and manufacturing
- Scenario generation

For modernization, M&S technology reduces the time, resources, and risks associated with the acquisition process while enhancing the performance of the acquired systems. Virtual prototypes are evaluated in realistic synthetic acquisition and operational environments, supporting the many phases of the acquisition process from requirements definition and initial concept exploration to the manufacturing and testing of new systems. Technology advances are needed to effectively link live, virtual, and constructive simulations. For example, the Synthetic Theater of War (STOW) Advanced Concept Technology Demonstration (ACTD) is intended to develop and demonstrate modeling and simulation technology for the next generation of training tools needed by the Combatant Command, Commander Joint Task Force, and Joint Task Force Component Commanders and their staffs.

Investments in synthetic environments and distributed simulations can be leveraged to develop tools for linking performance in joint exercises to estimates of joint training readiness. Performance and assessment data can then be linked to cost-effectiveness evaluations and tradeoff decisions to guide joint training policy and resources.

Simulation interconnections and interfaces provide the basis for logistics training and rehearsal simulation interoperability through a common modeling and simulation infrastructure and seamless interfaces. These capabilities will continue to be demonstrated in Commander-in-Chief (CINC)-level exercises with ACTDs embedded in joint warfighting exercises. The capabilities will also migrate into the emerging Global Combat Support System.

Added technological opportunities can result in a need to incorporate a new technology into a weapon system. “Technology in search of an application” studies are usually performed by the technology developer. Conversely, the analysis community requires technological support to advance existing M&S or create new ones. Engineering models are used to estimate the effectiveness and size/weight of potential applications. The outputs from these models feed studies comparing cost and effectiveness of new technologies and other alternatives that might accomplish the same functions. If a new weapon system is required to accomplish the function, an engagement model might be used to provide the alternative comparisons.

When a list of possible alternatives has been developed, the associated command may wish to prepare a mission need statement (MNS). The command may want to use engagement/mission models and theater/campaign models to support development of the need document.

Periodically a system’s survivability needs to be examined. Simulation models are best used to determine which parts might be damaged in an encounter with an enemy defense system. Components that contribute to a large number of mission failures are often identified using these techniques. This information can be used as justification for installing enhanced components or redundant systems to improve survivability. Concept and Technology Development and System Development and Demonstration survivability analysis activities may include significant participation by M&S in order to better define system operational requirements and clarify the characteristics of competing alternative approaches. Modeling, simulation, analysis, and T&E activities are keys to successful completion of phase activities.

In Conjunction With Systems Engineering

The survivability process, a subset of the systems engineering process, begins with the mission need statement and continues throughout the acquisition life cycle. Initially, mission need and top-level operational requirements are used to develop alternative survivability concepts for the system and to select or develop top-level digital models of the system. For a weapon system program, these top-level survivability models are typically evaluated in theater/campaign and/or mission/battle-level simulations.

Mission/battle-level models are used to evaluate the ability of a multiple-platform force package to perform a specific mission. During this level of analysis, the system models are varied to make tradeoffs of the weapon system survivability characteristics, and the simulations are used to predict the performance of the system, ideally under the conditions defined in the system's test scenarios. Evaluations during the systems engineering process provide a basis for assessing the relative merits of alternative concepts and for supporting the survivability conceptual design review. The results of these early simulations can also be used to aid in operational assessments (OAs) of the system's performance, survivability, and suitability.

Throughout the acquisition process, system and functional survivability requirements are refined. They are used for developing the system design and for increasing the maturity of the interdependent models of the system. Early in the acquisition process, engagement-level models are employed to predict the system's performance and to evaluate the system's effectiveness and survivability against appropriate threats.

Survivability mission and functional requirements continue to be refined as the system reaches the preliminary design stage. As the design detail increases, the system developer builds detailed engineering-level models for use as engineering development tools. At this point, many engineering-level models are based on phenomenology (science-based) models. Normally, live testing cannot be done up to this point because components, subsystems, and systems have not yet been built. However, throughout this entire process, survivability M&S tools can be employed to support an evaluation of the alternative designs for their adherence to system requirements.

The results of such an evaluation can support the decision-makers in better managing risk and in refining their requirements. The results of more detailed M&S activities should also be used to refine higher-level models, which can be used in turn for reevaluation of the system's military worth. This process results in a set of models that describes the system characteristics and performance at all levels.

In Conjunction With Design Development

From design development throughout the remainder of the development cycle, survivability M&S are used both as predictive tools and with testing in an iterative process to evaluate the system design. Both test processes and test facilities can be simulated to provide effective evaluation of survivability design changes.

Through this iterative process, the consequences of survivability design changes are evaluated to help translate the most promising design approach into a stable, interoperable, and cost-effective design; demonstrate the system's survivability capabilities; and support the preliminary design review.

In Conjunction With Test and Evaluation

The T&E process involves the deliberate and rational generation of data concerning the nature of the emerging system, as well as the creation of information useful to the technical and managerial personnel controlling the system's development. In a broad sense, T&E may be defined as all physical testing, modeling, simulation, experimentation, and related analyses performed during research, development, introduction, and employment of a weapon system or subsystem.

As real survivability-associated hardware and software representations/mock-ups of the system's components or subsystems (brass boards or breadboards) are built, these representations are tested in the laboratory environment (i.e., they replace their digital counterparts). During T&E the survivability process assumes an expanded and more integrated role. At this point, data from actual hardware exist to employ a survivability model-test-model approach.

Planning for survivability tests includes M&S to support a more efficient use of resources. Simulated tests can be run on virtual ranges to predict system performance, assess the system's operational effectiveness and survivability, evaluate data-collection capabilities and test procedures, conduct rehearsals, and determine if test limitations (and their effects on the ability to demonstrate critical system design issues) have been resolved.

Uses for M&S during this phase include the following:

- Provide stimuli with as many survivability operational characteristics as possible.
- Provide a real-time baseline to evaluate the progress of the tests. Test results are evaluated and used for the refinement of the system's survivability requirements and design.
- Support the validation of existing M&S, which can then be employed with greater confidence to examine conditions not yet tested.

Survivability tools are used to provide data for determining the real component or subsystem's performance and interaction with other components (e.g., Hardware-In-the-Loop (HWIL) or

Software-In-the-Loop (SWIL) integration testing), including the operator of the system (e.g., Human-In-The-Loop (HITL)).

Live tests, such as open-air range tests, are conducted for both developmental tests (DT) and operational tests (OT). Developmental test includes range tests to demonstrate system and subsystem performance and survivability and to provide data for the total evaluation effort. These data can be used to support the VV&A process. Operational test is used to assess the operational effectiveness and suitability of a system under realistic operational conditions.

M&S are used during both DT and OT to increase the amount of data and supplement live test events needed to meet test objectives. Through the integrated use of these simulations, a more successful transition may be made from DT to OT. Consequently, DT and OT merge into an efficient, effective, and continuous process for evaluation of system performance and operational effectiveness and suitability.

The revised 5000.2R regulation spells out the responsibilities of the Director of Operational Test and Evaluation (DOT&E) as follows:

> The DOT&E shall assess the adequacy of OT&E and LFT&E [live fire test and evaluation], and evaluate the operational effectiveness, suitability, and survivability, as applicable, of systems under DOT&E oversight. … At the conclusion of LFT&E, the Director shall prepare an independent assessment report describing the results of the survivability or lethality LFT&E and state whether the LFT&E was adequate to provide information to decision-makers on potential user casualties and system vulnerability or lethality when the system is employed in combat; and to ensure that knowledge of user casualties and system vulnerabilities or lethality is based on realistic testing, considering the validated operational requirements of the system, the expected threat, and susceptibility to attack.

An important aspect of pursuing T&E and associated M&S for survivability involves identifying the elements that make up T&E and determining how those elements relate to potential customers, including those who create requirements, plans, guidance, and policy. One person's T&E might not equate to another person's T&E. According to DoD policy, "To assess and manage risk, PMs and other acquisition managers shall use a variety of techniques, including technology demonstrations, prototyping, and test and evaluation." This statement implies a continuum from technology through acquisition.

Because of the attention given T&E and M&S during acquisition reform, numerous processes are in existence. Each process identified at the time of this volume's preparation is discussed below. No attempt has been made to evaluate these processes for survivability application, although a great deal of commonality exists. A standard multi-service T&E process, blending the existing processes, would be useful, and the development of such a process should be considered.

In Conjunction With Recurring Assessments of Military Worth

With the system represented by high-level M&S, the current version of the system under development should be reexamined periodically during the acquisition process in a synthetic operational context to reassess its military worth. How often this examination needs to be done is program-dependent, but a general guideline would be to conduct such analysis after each significant design change in order to understand the impact of that change on overall theater or battlefield performance and not just on system performance. Understanding the answer to the "what difference does this change make" question as the system develops is a significant aspect of the STEP process.

4.0 HIERARCHY OF MODELS AND SIMULATIONS

Survivability-associated M&S support acquisition-program activities ranging from engineering design to test operational support. The assortment of survivability tasks requires a suite or hierarchy of M&S with differing levels of detail suited to their particular applications.

A model is a physical, mathematical or otherwise logical representation of a system, entity, phenomenon or process. The term "modeling and simulation" is often associated with huge digital computer simulations, but it also includes manual and man-in-the loop war games, test beds, hybrid laboratory simulators and prototypes. A mathematical model is an abstract representation of a system that provides a means of developing quantitative performance requirements from which candidate designs can be developed. Static models are those that depict conditions of state while dynamic models depict conditions that vary with time, such as the action of an autopilot in controlling an aircraft. Simple dynamic models can be solved analytically and the results represented graphically.

M&S can be classified as follows:

- **Constructive.** Wargames, models, and analytic tools.
- **Virtual.** Systems simulated both physically and by computer. Real people fight and train on synthetic battlefields, interacting with one another and with artifacts in the simulation. Examples include individual aircraft (weapon system) simulations and virtual prototypes.
- **Live.** Operations with live forces and real equipment in the air, on the ground, and on and below the sea. Also included are hardware prototypes on instrumented ranges.

Models and simulations support survivability acquisition program activities ranging from design to operational effectiveness assessments. This assortment of tasks requires a suite of models and simulations with differing levels of detail suited to their particular application. These models and simulations form what may be called an M&S hierarchy. The levels include:

- **Engineering** for survivability design, cost, manufacturing and supportability. Provides measures of performance (MOP).
- **Engagement** for evaluating system effectiveness against enemy systems in support of survivability assessment. Provides measures of effectiveness (MOE) at the system-on-system level.
- **Mission/Battle** for effectiveness and survivability of a force package, or multiple platforms performing a specific mission. Provides MOE at the force-on-force level.

- **Theater/Campaign** for the outcomes, including survivability, of joint/combined forces in a theater/campaign-level conflict. Provides measures of value added at the highest levels of conflict, sometimes called measures of outcome (MOO).

Special Types of M&S

Hybrid M&S. In many survivability applications, linkage among two or more M&S classes results in hybrid models and simulations. Such a hybrid might employ constructive analytical models to represent a threat, kinematics, or a weapon in conjunction with actual (live) system hardware and software. Examples of such hybrid applications include physical simulations, hardware/software-in the-loop (HW/SWIL) simulations, and ADS. In many instances, the actual signals representing the outside environment to a test article are not available. These signals might represent a radar return from a target, a signal from another weapon system, or a background noise in which a system must operate. In this situation, a simulation could be used to stimulate the test article just as if the outside signal were present. These stimulators can be hard-wired into the system or applied in the same manner as in the real environment. Stimulators may be used in acquisition to simulate threats or other phenomena either in a HW/SWIL simulation or a live simulation (test) of a weapon system.

The HW/SWIL simulations are often described as engineering-level simulations. They typically consist of multiple classes of simulations. The HW/SWIL simulation includes actual hardware and software, mathematical models, and external stimuli used together to demonstrate the capability of a system or subsystem to operate within an environment simulating actual conditions. An HW/SWIL simulation has proven to be an important tool in system development, test, and operational support. In development, HW/SWIL simulations can be used to demonstrate new technology; evaluate designs, concepts, and prototypes; and show hardware and software integration. In support of test programs, the HW/SWIL simulations allow for pre-test simulations to identify test conditions. As a risk-reduction measure, they are used for checkout of actual hardware and software. These simulations are also used to conduct post-test analysis and to fill in a test matrix for conditions that are not testable of for which no test assets are available. The HW/SWIL simulations allow early identification and correction of developmental problems, as well as identification of live tests (simulations) and focusing of these tests on critical issues.

Advanced Distributed Simulations. ADS is an emerging form of simulation that has demonstrated the ability to link different types of simulators at dispersed locations, permitting the simulators and their crews to conduct operations on the same simulated battlefield environment. Distributed refers to geographically separated simulations, each hosted on its own computer without a central computer. The ADS are interactive, indicating that simulations or simulators are linked so that they can act upon one another in a common environment (e.g. terrain, ocean, weather, etc.). The linked simulations may be any combination of constructive, virtual, and live; they are likely to include human-in-the-loop simulations. Distributed interactive simulation (DIS) is the infrastructure within which such distributed linkage takes place. DIS can be used to support test and evaluation planning, test operator training, scenario development, execution (e.g. with additional simulated forces), and post-test evaluation results.

5.0 SURVIVABILITY-ASSOCIATED MODELS

Support of weapon systems effectiveness and survivability assessments requires knowledge and understanding of the requirements that must be addressed as well as of how to formulate solutions and derive answers to questions on critical operational issues. Such knowledge is accomplished via analysis and assessment of elements that contribute to survivability or effectiveness. Many specific M&S tools have been developed to address areas or functions that can provide quantifiable results to the analyst.

These M&S have been developed by agencies or components with varying areas of interest or responsibility. As a result, considerable overlap exists in scope and capabilities among similar models. Therefore, several models are often needed during the course of a particular analysis to address the scope of the survivability assessment objective. It is imperative that the analysis team be well informed as to assumptions, limitations, and capabilities of any M&S applicable to the problem at hand.

Survivability M&S by Analysis Area

A number of the models used in survivability-related analyses and assessments are listed in Table 1 and described in the following paragraphs.

Table 1. Models and Simulations by Applicable Analysis Areas

M&S Area	Model or Simulation	Applicable Analysis Areas
Target Geometric Model	FASTGEN BRL-CAD	Geometric Model Development
Air-to-Air Missile	TRAP JAAM	Susceptibility Air Vehicle Performance Tactics Threat Vehicle Simulation
Flight Path	BLUEMAX	Tactics Mission Profiles
Laser	LTM LELAWS	Vulnerability to Directed-Energy Weapons (DEW) Susceptibility to DEW
RF DEW	DREAM	Vulnerability to DEW Susceptibility to DEW
Vulnerability	COVART HEVART HEIVAM MUVES	Vulnerability Vulnerability Indexes

M&S Area	Model or Simulation	Applicable Analysis Areas
Fuzing	GTD AOTD	Threat Missile Endgame Lethality Analysis Fuze/Warhead Design Terminal Geometry Analysis
Guns	RADGUNS	Susceptibility Air Vehicle Performance Tactics Electronic Warfare Detection/Acquisition/Tracking Threat Vehicle Simulation
Lethality, Vulnerability, & Endgame	AJEM	Missile Endgame
Endgame	JSEM SHAZAM	Threat Missile Endgame Lethality Analysis Fuze/Warhead Design Terminal Geometry Analysis
SAM	ESAMS IMARS DISAMS JMASS	Susceptibility Air Vehicle Performance Tactics Electronic Warfare Detection/Acquisition/Tracking Threat Vehicle Simulation Terminal Geometry Analysis
Detection & Tracking	AIRADE ALARM RADSIM	Susceptibility Signature Analysis Detection/Acquisition/Tracking Threat Vehicle Simulation
Countermeasures	ESAMS RADGUNS MOSAIC TEAM	Tactics Electronic Warfare Detection/Acquisition/Tracking Threat Vehicle Simulation
M on N Air-to-Air	AASPEM BRAWLER TRACES	Air Vehicle Performance Tactics Detection/Acquisition/Tracking Threat Vehicle Simulation Mission Effectiveness Analysis
M on N Surface-to-Air	DIME SUPPRESSOR SWEG EADSIM JIMM THUNDER	Tactics Mission Profiles Electronic Warfare Detection/Acquisition/Tracking Mission/Threat Analysis Tradeoff Analysis Mission Effectiveness Analysis
Signature Prediction	McPTD SPIRITS XPATCH	Signature Analysis Tradeoff Analysis

The M&S listed in Table 1 are used to assess weapon systems (both U.S. and hostile). For example, the M on N M&S (e.g., BRAWLER, AASPEM, DIME, SUPPRESSOR, THUNDER, etc.) use as input various T&E results and the output from other M&S of direct interest to survivability. A full understanding of the utility and associated sensitivities of survivability-related M&S requires more than a cursory knowledge of the M&S using their output.

Survivability M&S by Level of Application

Another taxonomy used to classify survivability M&S is based on their level of application, i.e., campaign/theater level, mission level, engagement level, or engineering level. As applications become more aggregated from the engineering to the campaign level, the fidelity of their treatment of elements that contribute to survivability naturally decreases. It is important for the analyst to realize that this decrease will occur and to understand the limits of proper application of the particular model or simulation.

Campaign/Theater Models simulate war activities within the entire area of the conflict. A common application addresses multiple air strikes and attacks by ground forces over a period of days, weeks, or months. Inputs for these models are largely derived from results predicted by mission-level models. Logistics models also play an important role in analysis at this level and may be used to provide inputs or be integrated with the campaign models. THUNDER, TAC RAM, and RECALL are examples of this type of model.

Mission-Level Models simulate coordinated strike operations, tactics, and most important, command, control, communications, and intelligence (C3I). These models are highly aggregated and synthesize the results from tactical models using stochastic variables to produce distributions of mission outcomes. They use detailed scenario inputs that include integrated air defense system (IADS) and command chain structures, force dispositions, suppression tactics, missions and objectives of opposing forces, and rules of engagement.

A salient feature of mission models is that their use must be coordinated with military planners because strategy, tactics, and employment of forces must be adaptive and altered throughout the mission whenever the relative combat capability of opposing forces is altered. These programs are useful to identify major capability deficiencies relative to a particular strategy and to evaluate the likely impacts of major force structure changes. The models can be difficult to use because of the complexity of various scenario input layers and the models' dependence on other models for inputs. Modeling at this level is too coarse to be used for determining marginal value or the impact of small force changes. Three popular models of this type, EADSIM, SUPPRESSOR, and SWEG, are in competition for acceptance and wide use across DoD.

Engagement Models simulate combat between a small number of participants and are further defined as one-on-one (1v1), one-on-many (1vN), or many-on-many (MvN), depending on the numbers of opposing elements simulated. The 1v1 models usually address the physics of aerodynamics, surface-to-air missile (SAM) or antiaircraft artillery (AAA) tracking radars, AAA guns, and air-to-air missiles (AAM). The utility of this type of model is in evaluating engineering or performance tradeoffs. These models are used for investigating susceptibility reduction factors such as signatures, tactics, performance, and countermeasures; or lethality enhancement factors such as improved seekers, guidance, warheads, and counter-countermeasures.

One-on-One Engagement Models are most often used for such evaluations. The AAM, SAM, and AAA models are the most frequently used because they can provide answers quickly. Initial assessments are performed without using terrain or sea states that would introduce clutter and multipath effects into the radio frequency (RF) tracking problem. Simulated flights by the representative threat system are usually linear at varying altitudes, airspeeds, and ranges. In some cases, more realistic flight paths are generated and used as inputs, and terrain or ground cover types (and sea states) are specified to stress detection and tracking performance.

ALARM, ESAMS, RADGUNS, and TRAP are currently the most popular simulations of 1v1 engagements; these models are distributed by SURVIAC. BRAWLER (formerly TAC BRAWLER) simulates 1v1 air-to-air engagements, but can also handle engagements among as many as 22 aircraft. AASPEM and BRAWLER are the air combat models distributed by SURVIAC for JTCG. LTM and LELAWS are also engagement models that address laser directed-energy weapon (DEW) threats, but their use has not become common outside of the Army, where concern for protection of helicopter aircrews is paramount. The Army has also developed the DREAM model for evaluating the effects of directed RF-energy threat systems.

Few-on-Few Engagement Models are used to evaluate effects of cooperative tactics or missions among combat sections or divisions via simulation of C3I processes in conjunction with electro-optical (EO), infrared (IR), and RF sensors and countermeasures. AASPEM and BRAWLER are often used for air-to-air work, but no comparable models for surface to air are available from the JTCG, except DIME, which provides an environment for sequential analysis of engagements of single aircraft against multiple threats using ALARM, ESAMS, RADGUNS, AASPEM, and most recently, the MSIC JMASS SAM simulations.

HELIPAC, a model developed by the Army specifically for analysis of helicopter engagements, was enhanced by addition of the BRAWLER pilot-decision-logic model and released under the name HAVDEM. Subsequent additions of terrain and a three-dimensional graphical scene playback have been completed and a new version, called TRACES, was released by the Army Materiel Systems Analysis Activity (AMSAA). TRACES is the most complete and comprehensive model available for analysis of helicopter-specific air-to-air tactics.

Additional model descriptions are contained in Appendix C.

Selection of Applicable Models and Simulations

One of the major problems facing a study team is the selection of a set of M&S to support the analysis. With the study plan completed and the methodology developed, the next step in the process is to select the appropriate M&S. For the team, the question that must be answered is “Does this model support the study?” Team analysts must consider whether the particular model candidate portrays the proper level of resolution, encompasses performance objectives, yields values for the study’s measures of effectiveness, and has been accredited for use in this study. The models ultimately selected, based on these features, are submitted to the working group for approval. These models must also meet the study requirements and still allow time for the analyst to complete contingency, parametric, and sensitivity analyses.

A candidate group of models is depicted in Figure 2, grouped in their respective application categories. A time-tested approach uses these models in a hierarchical, building-block fashion, with each level feeding into the next. Many of these simulations are DoD- and/or JTCG-approved standards and are resident in SURVIAC.

If the existing suite of models described above does not satisfy the study requirements, alternate approaches should be pursued. If another model that performs the necessary functions is available, attempt to obtain it. Otherwise, the team of engineers, analysts, and computer scientists needs to either modify an existing model or construct a new one, if time and resources permit. In either case, select the best model, recognize its limitations, and document them in the final report.

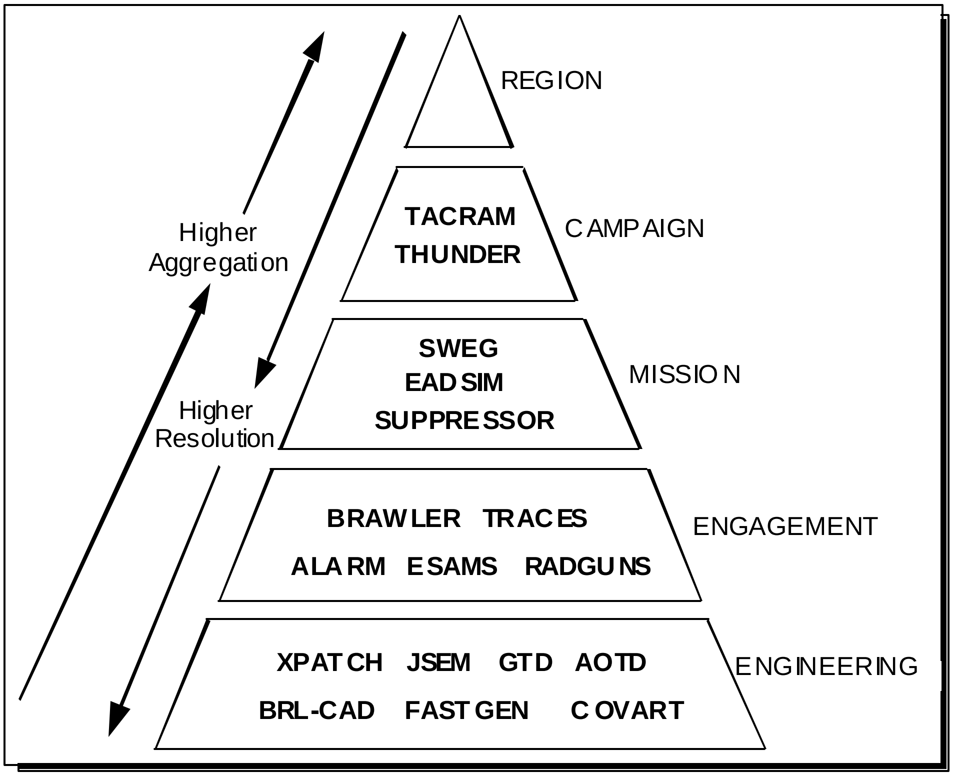

Figure 2. AOA Model Hierarchy

SURVIAC is the DoD focal point for non-nuclear survivability/vulnerability data, information, methodologies, models and analysis relating to U.S. and foreign aeronautical and surface systems. SURVIAC's scope covers the survivability of allied and other nonadversary systems to threat weapons as well as the effectiveness of U.S. weapons against foreign systems. Non-nuclear weapons include conventional missiles and guns, directed-energy weapons, and chemical/biological weapons. Data holdings in the weapons area include, as applicable, acquisition, detection, tracking, launch, fly-out, and fuzing characteristics; countermeasures and counter-countermeasures employed; and terminal effects.

Weapon systems include fixed and rotary-winged aircraft (both manned and unmanned), missiles, tanks, trucks, armored personnel carriers, artillery, radar vans, etc. Data holdings for systems include physical and functional characteristics; design, performance, and operational information; acoustic, infrared, optical, electro-optical and radar signatures; combat damage and repair; and system, subsystem, and component probability of kill given a hit (Pk/h) functions.

Technical-area tasks for SURVIAC originate from user requests for specialized expertise or quick reaction analyses beyond the scope of normal inquiry response. These tasks are important because they are sources of new information and methodologies for DoD and the survivability and lethality communities. The general criteria for acceptance of technical-area tasks ensure that the tasks are within the center's primary technical interests, scope, and objectives; enhance the center's technical capabilities; and acknowledge SURVIAC sponsorship and control over project quality and products. The technical areas relevant to SURVIAC's mission include the following:

- Survivable Conventional Force Requirements
- Survivability Technologies
- Survivability and Lethality Optimization
- Live-Fire Testing
- Methodology Advancement
- Support of Combat Operations

The SURVIAC Information Resource consists of technical libraries, numerical databases, and major data collections. Databases maintained by SURVIAC include the following:

- Desert Storm Combat Database
- Joint Live Fire/Live Fire Test Information System
- JUST CAUSE-Panama Database
- ACFTDAB-Southeast Asia Fixed-Wing Aircraft Database
- HELODAB-Southeast Asia Rotary-Wing Aircraft Database
- GNDVEHSEADB-Southeast Asia Ground Vehicle Database
- YOM KIPPUR-1973 Arab-Israeli Ground Vehicle Database
- Laser Reference Library
- General Survivability/Vulnerability Reference Library
- Vehicle Signatures Reference Library

SURVIAC serves the analysis needs of the survivability and lethality communities by maintaining selected survivability and lethality models. The objective of SURVIAC's modeling resource is to provide a single focal point for distribution and expert advice on these models. SURVIAC maintains and disseminates the code and documentation, provides technical advice regarding their use, conducts workshops on their applications and operations, and is the clearinghouse for changes and updates for these models. A list of the current model inventory includes the following:

- AASPEM
- AJEM
- AIRADE
- ALARM
- BLUEMAX
- BRL-CAD
- COVART
- ESAMS
- FASTGEN
- TRACES
- IMARS
- JSEM
- LELAWS
- McPTD
- RADGUNS
- SCAN
- TRAP
- BRAWLER
- DIME

A Model Guide that describes each of these models in greater detail is available from SURVIAC. In addition, SURVIAC is familiar with, and provides advice and recommendations on, many other models that might be appropriate for solving specific problems.

Address and contact information is as follows:

Survivability Vulnerability Information Analysis Center
Booz, Allen & Hamilton Inc.
AFRL/VACS/SURVIAC, Bldg. 45
2130 Eighth St., Suite 1
Wright-Patterson AFB, OH 45433-7542
E-mail: surviacmodels@bah.com
URL: http://bahdayton.com/surv1/

Point of Contact:
Mr. Kevin Crosthwaite, SURVIAC Director
DSN: 785-4840
Phone: (937) 255-4840
Fax: (937) 255-9673
E-mail: crosthwaite_kevin@bah.com

Technical Monitor:
46 OG/OGM/OL-AC

Attn: Mr. Martin L. Lentz
2700 D Street
Bdg. 22B, Suite C-201
Wright Patterson AFB, OH 45433-7605
DSN: 785-6302, ext. 241
Phone: (937) 255-6302, ext. 241
Fax: (937) 255-2237
E-mail: Martin.Lentz@wpafb.af.mil

For help with verification, validation and accreditation of survivability models and simulations, contact the Joint Accreditation Support Activity (JASA):

Address:
Naval Air Warfare Center, Weapons Division
Survivability Division (Code 418000D)
1 Administration Circle
China Lake, CA 93555-6001

Point of Contact:
Ms. Kathy Russell
(760) 939-4908
FAX: (760) 939-2062
Email: ernstka@navair.navy.mil
URL: http://www.nawcwpns.navy.mil/~jasa

Appendix A.

DoD M&S Infrastructure

Modeling & Simulation Infrastructure Elements:

Executive Council on Modeling and Simulation, DoD (EXCIMS)
M&S Executive Agents (MSEA)
Defense Modeling & Simulation Office (DMSO)
  DoD Modeling and Simulation Master Plan (MSMP)
  DMSO M&S Community Services:
    Defense Modeling, Simulation, and Tactical Technology Information Analysis Center (DMSTTIAC)
    Modeling & Simulation Operational Support Activity (MSOSA)
    Modeling & Simulation (M&S) Repository Systems
    Modeling & Simulation Resource Repository (MSRR)
    Modeling & Simulation Information System (MSIS)
  Joint Warfare System (JWARS)
Special Interest areas:
  Simulation Based Acquisition
  STEP
  MASTER

Charter Of The DoD Executive Council For Modeling And Simulation (EXCIMS)

- **MISSION.** The mission of the DoD Executive Council for Modeling and Simulation (EXCIMS) is to advise and assist the Under Secretary of Defense for Acquisition and Technology (USD(A&T)) in strengthening the uses of modeling and simulation (M&S) in the Department of Defense.

B. FUNCTIONS

The EXCIMS:

1. Oversees development of DoD M&S policies, plans, programs, publications, and procedures.

2. Encourages improved communication and coordination among DoD M&S activities.

3. Identifies investments in M&S that have high value return in fulfilling DoD requirements, or that fill gaps in M&S capabilities.

4. Promotes joint and cooperative research, development, acquisition, and operation of M&S systems, technologies, and capabilities among DoD components.

5. Recommends DoD M&S goals, objectives, and an investment strategy and plan to achieve them.

6. Recommends DoD components for designation as DoD M&S Executive Agents for general use M&S applications, as needed.

7. Acts as an Executive Steering Committee for DoD general use M&S applications for which Executive Agents have been appointed.

8. Fosters programs to develop and, where applicable, implement DoD M&S interoperability standards and protocols.

C. ADMINISTRATION. The EXCIMS organization includes the Executive Council, a Secretary and administrative Secretariat, and the M&S Working Group (MSWG) with its associated Sub-Working Groups (SWGs) and Task Forces (TFs). (See Figure 1.)

1. **Executive Council.** The Executive Council advises and assists the USD(A&T) in strengthening the uses of M&S in the Department of Defense. EXCIMS members are Generals, Flag Officers, and civilians of equivalent rank and precedence. The Director, Defense Research and Engineering (DDR&E) chairs the EXCIMS meetings. The USD(A&T) may change EXCIMS membership as needed to fulfill his or her M&S responsibilities; however, the following organizations shall be represented on the EXCIMS:

a. Deputy Director, Defense Research and Engineering (DDDR&E)
b. Assistant Secretary of Defense for Command, Control, Communication and Intelligence (ASD(C3I))
c. Assistant Secretary of Defense for Force Management and Personnel (ASD(FM&P))
d. Assistant Secretary of Defense for Program Analysis and Evaluation (ASD(PA&E))
e. Assistant Secretary of Defense for Production and Logistics (ASD(P&L))
f. The Joint Staff
g. Army
h. Navy
i. Air Force
j. Marine Corps

2. **EXCIMS Secretary and Secretariat.** The Director, Defense Modeling and Simulation Office (DMSO), is the Secretary to the EXCIMS but is not a voting member of the Executive Council. The DMSO functions as the EXCIMS Secretariat and provides administrative support for the EXCIMS.

3. **M&S Working Group (MSWG).** The MSWG supports the activities of the EXCIMS and responds to guidance and direction from the USD(A&T) and EXCIMS. The Director, DMSO, chairs the MSWG. The membership of the MSWG will normally be O-6 military officers or GM-15 grade civilians. The MSWG promotes coordination and cooperation of DoD M&S at the working level. Members will repre- sent their organization, serve as the DMSO point of contact for M&S issues, and prepare their principals for EXCIMS meetings. MSWG membership shall mirror the organizational makeup of the EXCIMS; however, other organizations may be added by majority vote of the group, as required.

4. **Sub-Working Groups (SWGs) and Task Forces (TFs).** The USD(A), DDR&E, EXCIMS, or Director, DMSO, may establish SWGs and TFs to perform tasks as needed. SWGs and TFs are action officer level expert bodies. They focus expertise on specific issues rather than the broader issues addressed by the EXCIMS or MSWG. The USD(A&T), DDR&E, EXCIMS, or Director, DMSO, as appropriate, will conduct an annual review of existing SWGs and/or TFs.

DMSO Mission and Purpose

1. MISSION. On June 21, 1991 the Undersecretary of Defense for Acquisition, Mr. Don Yockey, established the Defense Modeling and Simulation Office (DMSO) to serve as the executive secretariat for the Executive Council on Modeling and Simulation (EXCIMS) and to provide a full-time focal point for information concerning DoD modeling and simulation (M&S) activities. Currently the DMSO promulgates M&S policy, initiatives, and guidance to promote cooperation among DoD components to maximize efficiency and effectiveness. DMSO is a staff activity reporting to the Director, Defense Research and Engineering, office of the Undersecretary of Defense for Acquisition and Technology (USD(A&T)).

The DMSO is leading a DoD-wide effort to establish an M&S common technical framework (CTF) to facilitate the interoperability of all types of models and simulations among themselves and with Command, Control, Communications, Computers and Intelligence (C4I) systems, as well as to facilitate the reuse of M&S components. The cornerstone of that effort is the High Level Architecture (HLA), the highest priority effort within the DoD M&S community. The HLA is proposed for acceptance by the North Atlantic Treaty Organization (NATO) as the standard for simulations used within the NATO Alliance, and has been nominated for consideration as an IEEE standard. The other elements of the CTF are the Conceptual Models of the Mission Space (CMMS) and Data Standards.

Current DoD policy and capabilities concerning M&S are contained in the DoD M&S Master Plan, DoD 5000.59-P. This plan is the DoD's vehicle to direct, organize, and concentrate its M&S capabilities and efforts on resolving commonly shared problems. DoD 5000.59-P is available with additional information on DMSO activities at http://www.dmso.mil/.

DoD Integrated Product and Process Development Handbook; August 1998

Modeling and simulation (M&S) supports the IPPD approach, the integration of complex systems, and is a key tool used by IPTs. The members of an IPT, including the Survivability

IPT, share test and simulation data and identify needed information from the tests and simulations. Furthermore, technical and operational challenges, which can be identified early in system development through simulation, can be targeted for further testing. Virtual prototypes embedded in realistic synthetic environments can aid in developing a shared vision of the proposed system and provide a means for understanding the complex interactions among the configuration items in the system design. Design, manufacturing, and test engineers can work together in IPTs to build a prototype that can be more efficiently manufactured and tested.

Accredited modeling and simulation shall be applied, as appropriate, throughout the system life-cycle in support of the various acquisition activities: requirements definition; program management; design and engineering; efficient test planning; result prediction; and to supplement actual test and evaluation; manufacturing; and logistics support. PMs shall integrate the use of modeling and simulation within program planning activities, plan for life-cycle application, support, and reuse models and simulations, and integrate modeling and simulation across the functional disciplines

In addition to increasing the effectiveness of the design, test, and manufacturing functional specialists, modeling and simulation will benefit the product support members of the team (e.g., the logisticians and maintainers), as well as the training and warfighting communities.

Program offices need to support and use modeling and simulation more than ever before and must plan for the funding of program and legacy M&S. Modeling and simulation capability has matured to the point where it can facilitate several activities:

(1) development;

(2) communication between government and contractor;

(3) requirements exploration in the context of CAIV;

(4) demonstrating the significance of features found in component and subcomponent tests;

(5) test planning and analysis;

(6) communication between engineering, manufacturer, tester and user;

(7) logistics management; and

(8) training and human factors evaluation during the life-cycle of a system. M&S used well in the IPTs can be a key contributor to the implementation and success of IPPD.

M&S is increasingly being employed by the DoD to provide better insight into weapon system performance, reduce testing and training costs, and develop force mixes of weapon quantities and types. These uses ultimately support the twin goals of reducing DoD weapon acquisition costs and dramatically shortening the time to weapon system fielding. Accomplishment of these goals are supported by:

- **Simulation-Based Acquisition**

The DoD is seeking to streamline ways in which it acquires weapons systems. Evolving modeling and simulation tools have the potential to reduce the time, resources, and risk associated with the process, while improving the quality of the systems produced through a strategy called Simulation Based Acquisition (SBA).

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 SBA are to --

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

Increase the quality, military utility, and supportability of fielded systems while reducing total ownership costs

Enable IPPD across the full acquisition life cycle

SBA is an integrator of simulation tools and technology across acquisition functions and program phases and across programs. It is a concept in which M&S as a resource is more efficiently managed in the acquisition process. In a defense environment of decreased funding, SBA addresses both the decreasing availability of resources for system development and the increasing power of M&S tools.

Through reliance on the collaborative use of simulation technology in an IPPD environment, models and simulations are integrated between program phases to reduce the time, processes, and risks associated with the acquisition process.

– **The Simulation, Test and Evaluation Process**

The Simulation, Test and Evaluation Process (STEP) is a major DoD initiative designed to improve the acquisition process by integrating M&S with T&E. STEP is consistent with the regulations that govern systems acquisition and does not require their modification.

STEP moves beyond the "test, fix, test" approach to a "model-simulate-fix-test-iterate" approach. Problems are fixed as they are discovered. This approach (model first; simulate; test; fix after each step and then iterate the test results back into the model) is reiterated throughout system development. Iterative loops can occur in this process. For example, one can model, simulate, fix, simulate, fix, simulate, fix, test, and then feed the results into the model. When a need to fix is discovered, the time for each fix can be much shorter when the fix can be verified in the model in hours or days as opposed to a field test which can take weeks or months to verify a fix.

The latest information on STEP can be found at

- **Modeling and Simulation Test and Evaluation Reform (MASTER)**

Master is a management approach to M&S in support of DoD's policy of simulation Based Acquisition (SBA) and Acquisition Reform. It will ultimately provide critical mass funding to DoD's M&S efforts, add discipline to the development of M&S, ensure that funds are expended to further the state-of-the-M&S-art, including its VV&A.

In addition, it would add consistency to efficient connectivity across various model vectors currently being developed, free up the PM’s time and concerns about realistic M&S support, and assure that realistic models and simulations are exercised in designing, testing. Evaluating, training, fielding, and employing our defense systems in combat.

MASTER is designed to help in achieving the goals of both SBA and Simulation Test and Evaluation Process (STEP) initiatives. MASTER's first action is to identify the characteristics, "M&S vectors", of the M&S support historically needed to meet the needs of the acquisition community. Each vector being a specific category of technical modeling expertise in:

- Terrain Modeling
- Weather Modeling
- Geometric Solid Modeling
- Aerodynamic Flow/Flight Modeling
- Target Signature Modeling
- Sensor/Fuzing Modeling
- Smoke/Obscuration Modeling
- C3I Modeling
- Electronic Warfare Modeling
- Ballistic Modeling
- 1-1 Combat modeling
- M on N Combat Modeling
- Vulnerability/Lethality Modeling
- Logistics Modeling
- Others

In-house government R&D centers would be identified to lead each M&S expertise vector. These centers would be responsible for assuring that the models in the technical vector for which they are responsible are verified and validated. In each center would reside state-of-the art knowledge of assigned vectors, along with lead M&S responsibility for that same vector throughout DoD.

To provide needed M&S support to PMs in their respective vector disciplines, each center would also have the authority and responsibility to decide where model funding would be best allocated. In turn, these lead centers would be responsible for providing PMs timely support in the Model vector for which they are responsible.

A Consortium made up of personnel drawn, primarily from the civilian sector of DoD, would have the following responsibilities:

- Implement policy regarding established M&S architectures and codes.
- Assure that code under their oversight are verified and validated as well as accompanied by documentation explaining both the capabilities and limitations of each code to avoid misapplication.
- Maintain a repository of codes for access and application on behalf of other PMs, assuring that codes are not reinvented with each successive PM, but rather are upgrades, expansions, or modifications of those that already exist.

The Defense Modeling and Simulation Office (DMSO) would establish the set of rules within which the entire consortium membership would be managed, and all play would be executed. They would serve as the DoD's "Windows" protocol establishers, architecture writers, and the qualifiers and disqualifers when member organizations or individual members don't play by the rules.

DMSO would not any code but would oversee development and provisioning of key infrastructure enabling software that is developed commercially or through other development members of the Consortium until such time as a viable commercial marketplace for the applications could be fostered and sustained.

The Director, Defense Research and Engineering (DDR&E) is expected to play a vital role in MASTER's success.

It has been stated that the ideas set forth in MASTER might sound somewhat radical, but they do incentivize and fund the STEP and SBA concepts, which have become Pentagon policy in recent months and years

Summary of DoDD 5000.59

DoDD 5000.59 establishes the DoD policy, assigns responsibilities and prescribes procedures for the management of M&S within DoD. In particular:

It established the DoD Executive Council for Modeling and Simulation, and the Defense Modeling and Simulation Office (DMSO).

It directed the establishment of the Defense Modeling, Simulation, and Tactical Technology Information Analysis Center (DMSTTIAC), the development of a DoD Modeling and Simulation Master Plan (MSMP)(DoD 5000.59-P), and the designation of DoD M&S Executive

Agents to be responsible for common- and general-use M&S applications (such as terrain and environmental representations).

It directs that M&S applications used to support the major DoD decision making organizations and processes (such as the Joint Requirements Oversight Council and the Defense Acquisition Board) should be accredited for that use.

Summary of DoD 5000.59-P

DoD 5000.59-P establishes a DoD M&S vision and is the plan that coordinates and directs efforts to resolve commonly shared M&S problems.

(1) The DoD vision for M&S is:

"Defense modeling and simulation will provide readily available, operationally valid environments for use by the DoD Components:

To train jointly, develop doctrine and tactics, formulate operational plans, and assess warfighting situations.

To support technology assessment, system upgrade, prototype and full-scale development, and force structuring.

Furthermore, common use of these environments will promote a closer interaction between the operations and acquisition communities in carrying out their respective responsibilities. To allow maximum utility and flexibility, these modeling and simulation environments will be constructed from affordable, reusable components interoperating through an open systems architecture." (DoD 5000.59-P, Chapter 2, Para A.2)

(2) A key objective in achieving the DoD vision is the implementation of a Common Technical Framework for M&S. The three elements of the Common Technical Framework are establishment of a High Level Architecture (HLA), development of a Conceptual Model of the Mission Space (CMMS), and the establishment of Data Standards (DS) to support common representations of data in models and simulations.

(3) In addition, there exists an objective to provide a M&S infrastructure to meet developer's and end-user's needs. This infrastructure includes the development of methodologies, standards and procedures for the VV&A of models and simulations and the verification, validation and certification (VV&C) of data, establishment of a M&S Resource Repository (MSRR) system, and the establishment of a M&S Operational Support Activity (MSOSA) to facilitate the effective, efficient and responsive application of existing M&S capabilities.

Summary of DoDI 5000.61

Verification, validation and accreditation (VV&A) activities are essential to establish the credibility of models and simulations with regard to their ability to accurately depict the developer's specifications, their representation of the real world, and their applicability to a specific purpose. DoD Instruction 5000.61 was signed by USD (A&T) on 29 April 1996 after a two-year period of coordination. The instruction implements policy, assigns specific responsibilities, and prescribes procedures for the VV&A of models and simulations used and developed within DoD. Particular emphasis is placed on the performance of VV&A in Joint applications.

Appendix B.

M&S in 5000.2R

5000.2R contains the following information regarding Modeling and Simulation (M&S) in systems acquisition. This should NOT be a substitute for the directive itself. For the specific wording, the readers must refer to the specific paragraphs of the revised 5000.2R. Survivability related M&S are utilized in concert with applicable survivability engineering, analysis and test and evaluation acquisition activities.

- **Planning for Modeling and Simulation**

    - The PM shall use M&S during program planning, system design, and system T&E. M&S shall support all life-cycle activities of the system. M&S shall supplement actual T&E, manufacturing, and operational support. In collaboration with industry, PMs shall integrate M&S into program planning activities; shall plan for life-cycle application, support, and reuse of models and simulations; and shall integrate M&S across the functional disciplines. PMs shall plan for M&S and make necessary investments early in the acquisition life cycle. The PM shall use verified, valid, and accredited models and simulations, and ensure credible applicability for each proposed use. The PM shall use data from system testing during development to validate the use of M&S.

    - The Acquisition Strategy (AS) shall describe the integration and interoperability of M&S efforts throughout requirements definition; program management; engineering, manufacturing, and design trade studies; and operational and live fire testing applications.

- **Test and Evaluation (T&E)**

    - **Relationship of M&S and Testing.** The PM shall use both testing and M&S to evaluate the performance and maturity of the system under development. In addition, the PM shall use M&S to predict the results of operational and live fire testing events prior to the conduct of those tests. The PM shall focus the testing program on those tests with the highest expected payback in information gained. After completing the tests, the Defense Simulation and Modeling Office shall use test results to validate and mature the M&S tools and databases.

- **Overview.** T&E reveals information about the program and measures performance of the system against established requirements. The PM shall structure developmental test and evaluation (DT&E), operational test and evaluation (OT&E), live fire test and evaluation (LFT&E), and modeling and simulation (M&S) activities, into an efficient continuum, closely integrated with requirements definition and systems design and development. The T&E strategy shall provide information about risk and risk mitigation, provide empirical data to validate models and simulations, evaluate technical performance and system maturity, and determine whether systems are operationally effective, suitable, and survivable against the threat detailed in the System Threat Assessment.

- **T&E Strategy.** T&E planning shall begin during the Concept and Technology Development Phase. The PM shall form the T&E Working-Level Integrated Product Team (WIPT). Representatives from the DT&E (contractor and government), OT&E, LFT&E, and intelligence communities shall support the WIPT. If a project or program enters the acquisition process later than concept and technology development, the PM shall form the WIPT prior to entering the acquisition process. A T&E WIPT can be useful for a pre-system acquisition activity (e.g., an advanced concept technology demonstration, an advanced technology demonstration, or joint warfighting experimentation) that have a likelihood of becoming an acquisition program. A continuous T&E WIPT can help ensure a smooth transition, and can be used to prepare the initial TEMP. The early integration of T&E with program management ensures a test strategy consistent with and supportive of the acquisition strategy.

- **Evaluation Strategy**. Projects that undergo a Milestone A decision shall have an evaluation strategy. Immediately upon forming, the T&E WIPT shall craft an evaluation strategy to support pre-acquisition and early acquisition process activity. The evaluation strategy shall primarily address M&S, including identifying and managing the associated risk, and early T&E strategy to evaluate system concepts against mission requirements. Pre-Milestone A projects will not have an Operational Requirements Document (ORD) nor Critical Operational Issues (COIs), on which to base a detailed T&E plan. Therefore, the evaluation strategy shall rely on the Mission Needs Statement (MNS) as its basis.

- **Modeling and Simulation (M&S)** M&S shall be integrated with the T&E program. Test results will be used to revise both the test program and the test procedures as well as to develop and improve models and simulations. The T&E WIPT shall employ the Simulation, Test and Evaluation Process (STEP) to develop and document a robust, comprehensive, and detailed evaluation strategy for the TEMP, using both simulation and test resources. OTAs shall develop evaluation plans consistent with the evaluation strategy. The PM shall identify and fund required M&S resources early in the acquisition life cycle.

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- **Systems Engineering (SE)**

  - **Design Synthesis and Verification.** Design synthesis translates functional and performance requirements into design solutions that include alternative people, product, and process concepts and solutions, and internal and external interfaces. Design solutions shall be sufficiently detailed to verify that open system performance requirements have been met. Design verification shall include a cost-effective combination of design analysis, design modeling and simulation (M&S), and demonstration and testing. Verification shall address design tools, products, and processes.

  - **Modeling & Simulation (M&S).** The PM shall judiciously employ and reuse advanced M&S and related technologies. DoD and industry shall collaborate to produce integration and interoperability capabilities spanning all acquisition functions and phases. Expected results include improved acquisition program execution and superior acquired systems.

    PMs shall leverage M&S and related technologies as part of the M&S approach supporting the acquisition strategy and program design. They shall properly integrate M&S and related technologies throughout systems acquisition. They shall identify and employ knowledge representation and communication techniques and procedures associated with the design, development, and life cycle of both the program and its system early in and throughout the program, as appropriate.

- **Simulation Based Acquisition (SBA)**

  - Whenever and whenever possible throughout systems acquisition, the PM shall make use of an SBA approach to provide a robust analysis of system performance to compliment existing T&E. SBA shall be used to assess a system against design to threats and analyze to threats in those scenarios and areas of the mission space or performance envelope where testing cannot be performed, is not cost effective, or additional data is required. These analyses are performed using validated M&S, and are supported by validated test data.

- **M&S Standards**

  - M&S standards facilitate reuse, commonality, interoperability, and credibility. Properly applied, M&S standards reduce cost by providing approved solutions to common problems. As part of the M&S approach in the Acquisition Strategy (AS), the PM shall require contractors, where practicable, to use M&S standards where they exist.

Appendix C.

Survivability M&S Summaries

In the following paragraphs, survivability models are described and their application levels are identified. This description list is by no means exhaustive but does provide information on some of the pertinent survivability models.

Vulnerability Models

COVART determines *vulnerable areas and repair times* associated with specific levels of damage caused by single kinetic energy penetrators. Although used primarily for aerial targets, COVART can also determine vulnerable areas of ground targets. In the most recent version, the input file structure has been modified so the individual input sections (threat, JTYPE, multiple vulnerable, probability of kill (P_k) data, repair, etc.) are separated into stand-alone files. The JTYPE data input allows for the consideration of up to six kill categories. Additional penetration equations and updated fuel fire compilations have also been included.

The Computation of Vulnerable Area and Repair Time (COVART) computer program is a FORTRAN implementation of a method for determining the vulnerable areas and expected repair times of targets damaged by impacting single kinetic-energy (KE) penetrators, or high-explosive (HE) rounds. Although primary emphasis is given to aerial targets, both fixed and rotary wing, vulnerable areas of ground targets can also be determined, provided that their damage definitions and material properties are consistent with those acceptable to COVART 4.1.

The COVART 4.1 program has been written in the FORTRAN 77 top-down structured form. It contains a number of additions and changes not found in COVART 3.0. Notable among these are capabilities for handling small HE rounds and the FATEPEN 2 penetration equations for high-speed fragment impacts.

An essential part of the COVART 4.1 input data is information generated by tracing shotlines through a geometric description of the target. The COVART 4.1 program has been written to accept shotline information that has been generated by any one of the SHOTGEN, GIFT, FASTGEN, BRL-CAD or PGEN computer programs. The shotline information is independent of the source provided the input format restrictions are met. The shotlines for a given aspect of approach to the target are parallel lines, which simulate potential trajectories through the target for penetrators. In addition, burst point rays from the PGEN point burst ray generation program can be accommodated.

The COVART 4.1 vulnerable area calculations are based on, (a) test data from which empirical equations have been derived, (b) expert rules, and (c) user input data, which defines the target. Threat characterization reports and the JTCG Pk handbook are used as off line input data sources

Vulnerable areas and repair times are determined for single KE penetrators impacting on the target skin within a pre-selected weight and speed matrix. Each penetrator is evaluated along each shotline, and the contributions made along that trajectory to component and target vulnerable areas and to the repair time are determined. The aircraft target velocity is included when projectiles are to be evaluated. The weight and speed reduction of the penetrator are calculated and the probability that the component is defeated is computed using input conditional probability of kill (Pk) data. These data express the component kill probabilities as functions of threat impact (weight and speed, energy, hole size, etc.).

Among the features in COVART 4.1 are considerations of the effects of the loss of combinations of multiply vulnerable (redundant) components, JTCG armor-piercing incendiary (API) projectile penetration equations, JTCG fragment penetration equations, FATEPEN fragment penetration equations, depleted uranium (DU) projectile penetration equations, and output shotline Pk for a plot program.

The COVART 4.1 version includes the FATEPEN high-speed penetration equations for impact speeds up to 15,000 fps. The equations include fragment shatter and plate spall, and provide allowance for non-homogeneous (fluffy) fragments, rod threats, and arbitrary fragment shapes. Fragments can be steel, aluminum, tungsten, depleted uranium, tantalum, or titanium.

Penetration equations include graphite/epoxy composite. The equations include loss of velocity and weight in penetrating composite panels, and for API rounds, prediction of incendiary functioning as well as penetration.

Probability of kill functions include impulse, energy, momentum density, hole size, and aspect dependent Pk. The threats include HE/HEI warheads.

The component defeat probabilities are then combined, according to the various target damage definitions, in order to produce the target defeat probabilities.

COVART 4.1 includes the JSEM input format (for creating a VATB file), an ASCII output file with Pk for each shotline at all kill levels, impact speeds, threats, and shielded probability of kill table output for components.

Probabilities of component dysfunction given a hit are user inputs, and can be weapon dependent as well as kill mechanism dependent. They can be input for a given aspect, or averaged. The probability of component dysfunction given a hit is based on several engineering models for ullage explosion, dry bay fire, and hydrodynamic ram, as well as on combat damage data and experimental data including live fire tests. Airgap Pks are used in evaluating the effects of API functioning and fragment flash.

COVART 4.1 allows the user to compute vulnerable areas for up to six kill levels at a time. These can be independent of each other, so that inclusive (independent) kill methodology can be used for ground targets, while the exclusive kill methodology can be used for rotary wing targets.

COVART 4.1 can produce estimates of elapsed time or man-hours of effort required to repair combat damage, subject to the condition that the target survives to be repaired. Repair, in this context, is interpreted as repair in place, or remove and replace a damaged component.

COVART is a JTCG/ME and JTCG/AS approved methodology.

HEVART is a JTCG/ME developed model to compute vulnerable area and repair time associated with the damage caused by the detonation of small HEI projectiles. Defeat mechanisms such as projectile impact, jamming, blast, fragmentation, and combined lethal effects are modeled. HEVART functionality has been incorporated into COVART 4.1.

HEIVAM is a point burst methodology used to generate vulnerable areas for high explosive incendiary (HEI) warheads or projectiles. Modeled phenomena include: single fragment impacts, combined blast/fragment, lethal radius model, fuel tank fire, ullage explosion, and hydraulic ram. Uses the same target geometric models as COVART. PBLOC is a program within HEIVAM used to locate burst points on a target surface, inside a target, or in proximity to a target. PBLOC is used in conjunction with PGEN and HEIVAM in the analysis of target damage due to the effects of point-bursting munitions. PGEN is a model within HEIVAM that is used with FASTGEN or SHOTGEN target models to generate divergent rays from a Burst Point. These rays are traced through model components to produce vulnerability to bursting or spalling munitions. HEIVAM capabilities have been incorporated into the latest version of COVART.

MUVES is an acronym for *Modular UNIX-based Vulnerability Estimation Suite* and is a new software environment developed by the Ballistic Vulnerability/Lethality Division (BVLD) of the U.S. Army Research Laboratory (ARL). It is designed to evaluate the interaction of a threat and a target via ray-tracing a solid geometric target description (e.g., one developed with BRL-CAD). A programming environment designed to be modular and extensible as well as POSIX and ANSI C compliant, MUVES exploits the commonality shared by BVLD's models, such as those for armored combat systems, aircraft, and artillery. The compartment-level model, formerly known as the Vulnerability Analysis Methodology Program (VAMP) and a point-burst model called SQuASH (Stochastic Quantitative Analysis of System Hierarchies) are being implemented under the MUVES environment for analysis of armored combat systems. Design and implementation modifications to the MUVES development platform are being considered for emerging methods such as BLVD's Stochastic Analysis of Fragmentation Effects (SAFE) and Modular Aircraft Vulnerability Estimation Network (MAVEN). MUVES is available from AMSRL-SL-BV at the Aberdeen Proving Ground, MD.

QRV is a vulnerability estimation model designed for use with conceptual aircraft designs or foreign aircraft designs where little physical data is available. In these cases, it is not practical to expend a large effort developing geometric models which will require extensive revision as more data becomes available. This methodology was designed and implemented to provide relatively rapid development of vulnerability estimates without the requirement for a detailed geometric description of the target. The analysis can be tailored to the available data and a detailed FASTGEN model is not required. The outputs of this quick response methodology are target models and vulnerable area tables suitable for use in the JSEM endgame model.

QRV is a user-interactive menu-driven program and compliance with prompts will produce most of the input data needed for the JSEM endgame program. Additionally, QRV contains a library of vulnerability data for known components, which may be used as is, or modified as needed. QRV is equipped with its own menu-driven editing and file maintenance facilities to ease the task of synthesizing and storing libraries of vulnerability models. It produces vulnerable area tables for the target vulnerability to projectiles, fragments, or titanium rods. For each target component, its location on the target and shape (sphere or cylinder) are specified by the user. PKH curves for each component are provided from an internal data base or may be specified by the user. The presented area of each component from each view may be either computed by QRV or specified by the user. Shielding of each component is specified by the user as either a plate array or a percentage factor. A fault tree for critical systems is also entered by the user. The format for the fault tree is the same as for COVART or JSEM. Threat penetration methodology in QRV is the same as COVART for compact steel fragments and API projectiles. For titanium rods, the penetration equations are taken from Rod Recht's RODPEN model.

Geometric Model Development

BRL-CAD, The *Ballistic Research Laboratory Computer-Aided Design* Package is a powerful solid modeling system design to interactively create and analyze 3D geometric target descriptions. BRL-CAD includes an interactive geometry editor (MGED), a ray tracing library, two-ray-tracing based lighting models, a generic frame buffer library, a network-distributed image-processing and signal-processing capability, and a large collection of related tools and utilities. BRL-CAD supports a great variety of geometric representations, including an extensive set of traditional Constructive Solid Geometry (CSG) primitive solids such as blocks, cones and torii; solids made from closed collections of Uniform B-Spline Surfaces as well as Non-Uniform Rational B-Spline (NURBS) Surfaces; purely faceted geometry; and n-Manifold Geometry (NMG). Geometric objects may be combined using Boolean set-theory operations such as union, intersection, and subtraction. BRL-CAD also supports a rich object-oriented set of extensible interfaces through which geometry and attribute data are passed to other applications. The BRL-CAD solid-modeling package is currently used and maintained for numerous efforts. BRL-CAD, along with FASTGEN is the primary model used in conducting vulnerability analysis.

FASTGEN generates shotline data for vulnerability analysis using a method that assumes that penetrators have been fired far enough from the target that their trajectories are parallel rays. Input to FASTGEN is a file with geometric descriptions of all significant target components. The latest version of FASTGEN features improved target database development, error checking and correcting and enhanced compatibility with computer graphics and CAD/CAM packages.

CONVERT transforms data contained in a geometric target description into a format suitable for use with selected vulnerability or graphic programs, including SECTION, PIXPL, SHOTGEN, and FASTGEN. FASTGEN and CONVERT have been used in support of vulnerability analysis efforts applied to most tactical U.S. aircraft including the A-6E, AV-8B, F-14A, F-15C, F-16A, F/A-18C, C-130H, CH-46, and SH-60.

Susceptibility Models

Flight Path and Mission Profiles

BLUEMAX III is a flight path generator for aircraft. The current version contains several new features and enhancements over its well known and often used predecessor BLUEMAX II. An expanded interactive or automated command set, an interactive run-time display, and the capability to handle any DMA terrain data set are a few of the enhancements included. As with older versions, the model is primarily used to build realistic flight paths that can be used as inputs to most susceptibility (detection, acquisition, and tracking) models. BLUEMAX has been used extensively to support susceptibility, lethality and mission effectiveness analyses.

DIME FPG is a special version of BLUEMAX (FPG stands for flight path generator) that allows input to any of the models available under DIME (the *Digital Integrated Modeling Environment*). Inputs consist of waypoints and parameters associated with them that are produced via a graphical user interface (GUI) that facilitates placement of flight paths at desired ranges and aspects from ground-based threats on a color coded terrain elevation map display. This is how mission profiles are generated for analysis under DIME with ALARM, ESAMS, RADGUNS, and other susceptibility models.

Air-to-Air Missile (AAM) Models

TRAP, the *Trajectory Analysis Program* is a general-purpose trajectory analysis program used to determine the flight path of a missile. TRAP simulates up to three vehicles: a launch vehicle, a missile, and a target. It is built around a detailed missile fly-out model, with simplified launch vehicle and target models. It is usually used to generate a missile trajectory for a single shot, but can also produce launch acceptability regions (LARs) in either horizontal or vertical planes. It has also been used to estimate unknown missile attributes or capabilities given known data and observations as constraints. Missile flight can be simulated as a modified point mass or in 3, 5, or 6 degrees of freedom and the entire control system is modeled in detail.

TRAP is typically used to support the design and to evaluate the performance of threat air-launched weapons. It was designed specifically for modeling the performance of aerodynamic weapons, including AAMs, air-to-surface missiles (ASMs), and unmanned aerial vehicles (UAVs) against airborne or ground targets. The simulation and its intelligence-based threat model database reside at the National Air Intelligence Center (NAIC), Aerodynamic Weapons Design Branch, and is provided to many tri-Service users and their contractors. It is also distributed as part of the Survivability/Vulnerability Information Analysis Center (SURVIAC) aircraft survivability family of codes.

TRAP can simulate up to three vehicles: a launch aircraft, a missile, and a target aircraft. Although often referred to as an “engagement” model, TRAP does not strictly model an engagement. Only the launch aircraft carries a weapon and, although ground and airborne targets are modeled, this is only to the extent that they provide a target to which a missile can be guided. The modeling emphasis is on the missile fly-out portion of the engagement.

Four kinematic missile models are implemented: modified point-mass, 3-DOF, 5-DOF, and 6-DOF. The modified point-mass model uses information about the airframe, mass properties, and propulsion to calculate the instantaneous angle-of-attack (AOA) and angle-of-sideslip (AOS) needed to pull the required accelerations for intercept, subject to a maximum rate of change specified by the user that reflects missile agility. This allows synthetic body rates to be generated, which allows a detailed seeker model to be coupled to a point-mass airframe model.

The N-DOF models are built on the modified point-mass digital model. For these more detailed simulations, the missile guidance and control (G&C) system components are modeled in whatever detail is appropriate or possible, and output fin deflections are passed to the aerodynamics for the computation of the forces and moments on the missile body.

TRAP can be used to simulate single-shot launch scenarios, multiple stacked shots, or in an iterative mode to generate the maximum and minimum launch acceptability region (LAR) boundaries in both the horizontal and vertical planes. The simulation can also be used in a missile performance reconstruction capability, to estimate unknown missile attributes given a set of known data and observations. It does not model fuzing or warhead effects.

A digital model database in TRAP is maintained and distributed by NAIC, and consists of approximately 90 current aerodynamic weapon systems, comprehensively covering foreign air-to-air and air-to-surface threats. These digital models of threat weapon systems are used as an input to TRAP.

JAAM, *the Joint Anti-Air Model*, is a quick-look simulation of air-to-air 1v1 engagements developed by the JTCG/ME that includes P_k data for Blue missiles against many Red aircraft. It is a menu-driven program with a GUI that displays trajectories of both aircraft and missiles after the engagement and runs on a Macintosh PC. It also ties together multiple engagements to create effectiveness envelopes (LAR contours) and results are plotted on the screen for user inspection. Pull-down menus and dialog boxes allow users to select initial conditions and both preshot and postshot maneuvers. Placement of the launch aircraft on the ground to simulate a SAM system, but no aero, propulsion, or guidance data for such systems has been considered for inclusion. Like QRV, it is generally felt that this model has potential for use in rapid response requirements, but it is not currently available through SURVIAC. It is available through the JTCG/ME distribution system at Tinker AFB.

Surface-to-Air Missile Models

ESAMS simulates single or multiple encounters between an air vehicle target and a radar-guided surface-to-air (SAM) missile system. It provides a one-on-one framework in which to evaluate air vehicle survivability and optimization of tactics. The primary characteristics of a SAM engagement include sensor acquisition and tracking, missile flight dynamics, missile guidance and control, active and passive countermeasures, and missile endgame (warhead/fuzing). Though the primary model result is probability of target kill (P_k), the ESAMS user can examine details of other aspects such as the missile flight path, guidance characteristics, and the effect of ECM and terrain on an engagement. Developed and maintained by BDM, ESAMS has been used since it became available as TAC ZINGER more than 20 years ago. V&V activities were conducted for the SMART Project comparing model predictions to test data. The model manage at AFSAA/SAG has recently supported a standardization effort to coordinate threat and target coordinate frames a well as signature and vulnerability data formats among ALARM, ESAMS, and RADGUNS.

The ESAMS is a digital computer simulation designed to determine the outcome of an encounter between a single airborne target and a surface-to-air missile (SAM) system. It provides a one-on-one framework in which to evaluate air vehicle survivability and optimization of tactics. Most Soviet SAM systems are modeled in ESAMS, as well as the primary activities of engagement, including sensor acquisition and tracking, missile flight dynamics, missile guidance and control, offensive/defensive countermeasures, and endgame (warhead/fuzing). Although the primary model results are probability of target kill and missile miss distance, the ESAMS user can examine details of other aspects of an engagement such as the missile flight path and guidance, and the effects of electronic countermeasures (ECM) and terrain.

ESAMS has been used in the following major analytical areas:

a. attrition analysis
b. tactics development
c. survivability analysis
d. countermeasure effectiveness
e. support for force structure studies
f. research and development of new systems

ESAMS is written almost exclusively in standard FORTRAN (one GRACE-related subroutine is written in C) and consists of approximately 133,000 lines of code in 770 subroutines. ESAMS can be hosted on virtually any computer with a FORTRAN and C compilers and approximately 30 MB of memory (for source code, object code, executables, and data). UNIX scripts and VMS command procedures for compiling and linking the code are provided along with sample input data files on the ESAMS distribution tape.

NSAMS is the *NAVAL* portion of ESAMS that simulates the SA-N-1 through SA-N-9 and in the latest version, the CADS-1, Soviet naval surface-to-air missile systems. Developed by the Office of Naval Intelligence (ONI), NSAMS uses missile aerodynamic data, radar tracking data, and air vehicle flight path to produce missile trajectories and miss distances in near real time.

IMARS is a set of models that simulates one-on-one engagements between SAM systems and air vehicles. It consists of three components: a missile flyout module (MISSIM), a monopulse radar module (RADSIM), and a multipath module (MULTPTH). Together, these components form an integrated weapon system simulation that is able to produce realistic multipath and clutter effects, acquire and track a target, launch an interceptor so that the probability of intercept is maximized, and follow the engagement to its conclusion. IMARS was developed by the Missile and Space Intelligence Center (MSIC). This simulation package was touted as a very high fidelity representation of the acquisition and tracking radar systems as well as missile propulsion, guidance, and aerodynamics, but its usage has declined primarily due to its reliance on an expensive simulation language package that must be licensed by each user. MSIC has abandoned support of the model in favor of a new series of SAM models developed using the C++ programming language. These MSIC++ models are intended to be compatible with the Simulation Support Executive being built by the J-MASS program.

DISAMS is a package of emulative level models developed by Georgia Tech Research Institute (GTRI) originally for the Army, but recently with support from the Air Force Operational Test and Evaluation Center (AFOTEC). The individual models are known as *DISAMS-n*, (where n represents the number of an IR missile from 1 through 9). These were stand-alone simulations with point-source inputs to the missile seeker systems, but they have recently been integrated into a framework called GTSIMS. GTSIMS also includes a numerical model for predicting temperatures of objects and background materials (GTSIG) and a library of rendering routines (GTVISIT) for displaying IR scenes produced by the simulations. The level of detail is such that IR scene generation and execution of an engagement can require several hours of computer time, but there seems to be little doubt that the GTSIMS environment represents the state-of-the-art capability for modeling IR missile systems, target signatures, and thermal background characteristics.

JMASS

The Joint Modeling and Simulation System (JMASS) program office is developing a standard architecture for engagement level models and simulations. The principle behind this development is that models will be developed in this architecture by subject matter expert organizations that have the appropriate charter for their subject area. For example, surface-to-air missile models will be developed by MSIC, threat aircraft models will be developed by NAIC, etc. If the JMASS effort is successful, these JMASS models and simulations will eventually replace the existing ESAMS, IMARS, DISAMS engagement level simulations. Currently there are a number of threat system models that have been developed under the JMASS architecture. Integration of these models into simulations is ongoing, as is testing of the latest JMASS architecture version.

Gun System Models

RADGUNS is an acronym for the *Radar-Directed Gun System Simulation* that was developed by the National Ground Intelligence Center (NGIC), and is used to evaluate the effectiveness of anti-aircraft artillery (AAA) systems against penetrating aerial targets. It is also used to analyze effects of target characteristics (RCS, maneuvers, and countermeasures) against specific AAA systems. Analytic clutter and multipath models are implemented and tracking radars, fire control computers, guns, and ballistics are simulated for a wide array of Red, Blue, and Gray systems. In support of tradeoff analyses for the AX, MLR, and JSOW COEAs, large matrices of ESAMS and RADGUNS runs were executed for an array of SAM and AAA threats. The purpose of these studies was to provide a comparative evaluation of the survivability of different aircraft point designs.

RADGUNS is a one-on-one simulation, that includes a weapon system, operators, target (radar cross section, presented and vulnerable areas), flight paths, environment (clutter and multipath), and electronic countermeasures. Components of each weapon system including a search radar, a radar or optical tracking system, a set of antiaircraft guns, a fire-control computer/servo system to aim the guns, and a crew to operate the system are modeled at either the subsystem or circuit level. The models are deterministic, or transfer function type, rather than stochastic (probabilistic). Pulse-by-pulse radar receiver models process the returns from the target, including multipath effects, ground clutter, and signals from jammers. Probabilities of hit and kill are calculated using distribution theory and presented and vulnerable areas of the target.

RADGUNS simulates detection, tracking, and shooting performance of over 30 different AAA systems during engagements with airborne targets. It is typically used to evaluate the effectiveness of AAA systems against aircraft targets penetrating hostile airspace, but it can also be used to evaluate the effectiveness of different target characteristics (radar cross section, maneuvers, use of electronic countermeasures, etc.) against those systems.

Detection, Acquisition and Tracking Models

ALARM is a generic radar detection model whose functionality is controlled by user-defined inputs that control target characteristics including signature fluctuation statistics, propagation effects including clutter and multipath factors, transmitter waveform characteristics, receiver thermal noise, antenna patterns, and threshold signal processing. Noise ECM effects on target detection can also be analyzed, but the model assumes perfect tracking and AGC response, so it is not used to investigate countermeasures aimed at tracking radars.

RADSIM is the portion of IMARS (see Surface-to-Air Missile Models above) that simulates the monopulse tracking radar of a SAM system. Although capable of calculating detection ranges for SAM radars, it has not been used recently for susceptibility analyses.

AIRADE, the *Airborne Radar Detection* model is an interactive computer program for evaluating radar performance. It is used as a tool for design, analysis, and mission planning for airborne radar surveillance and fire control system. AIRADE accepts the user's specifications of the characteristics of the radar, computes several measures of radar performance, and generates user-specified graphical presentations of the performance data.

Countermeasure Effects Models

ESAMS (described above under Surface-to-Air Missile Models) currently provides the capability to simulate effects of complex ECM waveforms available on most Air Force and Navy equipment and expendable countermeasures such as chaff, flares and decoys. The current version is distributed by SURVIAC with an updated documentation set, that includes an ECM Manual and a Threat Manual. ESAMS has been used extensively over the years to support susceptibility analysis efforts related to AOAs (e.g., AIWS, AX, B-1B, JSOW, MLR) and other studies.

MOSAIC is an acronym for the *Modeling System for ASTE Investigation of Countermeasures* and was developed to perform effectiveness assessment, support test planning, compare the results of digital models with Hardware-in-the-Loop experiments, and perform sensitivity analyses and requirements definitions. The development strategy for MOSAIC emphasized the integration of major portions of software available within the EO community, as well as signal level threat models that were available or in development. A reliance on object-oriented design, a graphical user interface, and visualization tools available from the J-MASS program was emphasized. The classes of objects within MOSAIC include (1) aircraft, (2) aircraft subsystems (e.g., countermeasure dispenser systems CMDs and missile warning systems), (3) expendable countermeasures, (4) threat acquisition systems, (5) threat seekers, (6) threat missiles, (7) the environment, and (8) the electromagnetic signals. The atmosphere and its effect on the propagation of EO/IR energy is included through the LOWTRAN 7 model. The expendable countermeasure objects include the conventional flares carried on most tactical aircraft, all of the ASTE technologies, and two additional experimental Navy expendables.

Electronic Warfare Models

TAC EC, an acronym for the Tactical Electronic Combat program, is a deterministic model that characterizes many-on-many engagements of surface-to-air defenses against ground attack aircraft and supporting electronic combat forces. The model calculates attrition for both friendly aircraft and enemy air defenses. Input data consists of air defense effectiveness data, EC systems effectiveness data and the general scenario data. Model output consist of total sorties flown, attrition of aircraft and air defense units and general scenario information. Its output is used as input to the THUNDER theater campaign model.

TAC ARM an acronym for the Tactical Anti-Radiation Missile model is a Monte Carlo simulation of a High-Speed Anti-Radiation Missile (HARM) engagement against a laydown of threat emitters. HARM 6 Degree-of-Freedom (DOF) flight path data produced by the NAWC model is an input and the HARM engagement footprint is computed at launch and is updated interactively in time increments. The radar emitters in the footprint are cycled on and off by probability distributions using random number generators. HARM effectiveness data generated by TAC ARM is used by TAC EC to determine air defense attrition.

M on N Air-to-Air Models

AASPEM, the *Air-to-Air System Performance Evaluation Model* is a comprehensive analysis tool for examining susceptibility in a realistic, few-on-few engagement environment. Aircraft and missiles are explicitly flown incorporating Air Force specified missile guidance laws and missile propulsion characteristics. AASPEM flies its vehicles using a pseudo five Degree-of-Freedom (DOF) mathematical model and can control mixed environments of aircraft and missile types with different load-outs of missiles on the aircraft. A total of 75 aircraft and missiles combinations comprising six different aircraft types and six different missile types can be simulated at one time. Unlike its predecessor, PACAM (Piloted Air Combat Analysis Model), which was a Close-in-Combat (CIC) analysis tool, AASPEM has both Within-Visual-Range (WVR) and Beyond-Visual-Range (BVR) air engagement capabilities. AASPEM has been used extensively for studies of the effectiveness of new aircraft, missiles, countermeasure system designs, and concept development. These studies have addressed the B-1B, B-2, F-15, and F-16 aircraft and the Advanced Medium Range Air-to-Air Missile (AMRAAM). AASPEM is also used to explore tactics, maneuver versus detection, launch ranges, flight testing and mission planning considerations.

BRAWLER provides a detailed representation of air-to-air combat engagements involving multiple flights of aircraft in both the visual and beyond-visual-range (BVR) arenas. Because of the importance of cooperative tactics and the critical role of human factors (such as surprise, confusion, situation awareness, and the ability to innovate tactical responses in unexpected situations), special emphasis has been placed on simulating these command and control aspects of the engagement process. A high level of detail is achieved in the modeling of: Aircraft, including aerodynamics and signatures, Weapon systems, including missile models, gun, and fire control characteristics, Avionics, including radars, IRST, missile launch warning devices, radar warning receivers, IFF, and NCID techniques. In addition to aircraft systems, BRAWLER models the control functions and sensors of GCI and AWACS systems and provides a simple implementation of a surface-to-air missile (SAM) model.

The BRAWLER model is a comprehensive computer simulation tool that provides a detailed representation of air-to-air combat involving multiple flights of aircraft in both the visual and beyond-visual-range (BVR) arenas. In such engagements cooperative tactics and human factors such as surprise, confusion, and limited situation awareness play a critical role in determining combat outcomes. Accordingly, special emphasis has been placed on carefully simulating these aspects of the engagement process. In addition, a high level of detail is achieved in the hardware models, including those of aircraft aerodynamics, missiles, guns, expendables, radars, missile launch warning devices, radar warning receivers, IRST, IFF, NCID, etc. Electronic countermeasures versus radars, missiles, and communications are also handled. Hardware models are largely data driven, and data bases describing most current generation US and threat systems for air-to-air engagements are available. The modular nature of the BRAWLER model facilitates the incorporation of new hardware models at various levels of fidelity. Databases describing aircraft, weapons, avionics, etc. are available through SURVIAC.

IVIEW is a graphical playback program designed to provide real-time (or scaled time), interactive, three-dimensional *interactive views* of a scenario. It displays interactions among any number of moving objects, but is currently limited to a maximum of 100 entities for conservation of computer resources. IVIEW is a general-purpose display tool and can display any objects for which location and orientation data are specified as functions of time, whether they are aircraft, ground vehicles, or stationary objects. It is capable of displaying platform flight paths from a variety of input sources, including BLUEMAX, ESAMS, BRAWLER, SUPPRESSOR, and test range data. Realistic icons represent objects in the scenario.

In addition to displaying engagement history data from a file, the latest version of IVIEW has the capability to operate in real-time displaying the scenario as the data is collected on the range. All of the views, multiple windows, graphs and data computations are supported in this real-time version as well. Recent enhancements to display signature and other test range data have been added.

HELIPAC, the *Helicopter Piloted Air Combat* model, simulates helicopter performance limits, three-dimensional flight dynamics, and body rates and trim. The Army tactics baseline extracted from Flight Manual 1-107 has been integrated into HELIPAC. The key helicopter parameters represented include rotor aerodynamic performance limits, engine installed power, body decoupled from flight path, pitch, roll and yaw dynamics, observables, and vulnerability. Unique features include helicopters versus either other helicopters or fixed-wing aircraft. Engagement simulations include helicopter agility, helicopter tactics, and turret guns. The detection models have been expanded to include such visibility effects as night vision laboratory clear line-of-sight models for terrain, sun blinding, and clouds. HELIPAC is a helicopter air combat version of the Piloted Air Combat Analysis Model Version 8.0 (PACAM 8).

HAVDEM was developed by the Army, and uses the same value-driven decision theory that BRAWLER uses for fixed-wing combat simulation. It also contains waypoint and tactical path planning algorithms that utilize terrain masking. Physical models include 6-DOF aerodynamics and a wide selection of weapons and sensors. HAVDEM is an analytical tool for exploring the value of new hardware systems, aerodynamics, or tactics in the context of their contribution to combat effectiveness. Similar studies using man-in-the-loop simulation or test range exercises are much more expensive and less controlled. HAVDEM's modular organization allows for straightforward integration with training or embedded simulations as a computer controlled adversary. HAVDEM can run engagements containing up to twenty helicopters and runs a 2v2 engagement in real time on a workstation class computer.

TRACES is an updated version of HAVDEM and HELIPAC combined. This model combines the best features of both previous models, and it is the currently accepted helicopter air combat analysis tool. TRACES is available through SURVIAC, and it replaces both HAVDEM and HELIPAC.

Susceptibility to DEW Models
LTM, the *Laser Threat Model,* is a few-on-few surface-to-air survivability engagement simulation model of one or more ground laser weapon systems against a dynamic airborne target. The model simulates high- and low-power laser weapons, laser propagation and attenuation effects, probabilistic terrain, and a variety of visibility conditions (day, night, fog, smoke, dust). The model determines a number of possible laser damage effects. Laser weapon performance is based on sensor performance (Thermal Imaging System, TV/Image Intensifier, IRST, Eye, or Radar) and laser weapon fire control tracking, point, and firing. The model considers radar clutter, ground and airborne target signatures (infrared, visual, radar), terrain and sky background, and sensor damage due to laser effects. The simulation can be run in either deterministic or Monte Carlo mode. LTM has been archived by SURVIAC due to low usage.

LELAWS, the *Low Energy Laser Weapon Simulation* is an engineering level model used to evaluate the item-level effectiveness of low energy laser weapons in the anti-sensor role. The primary measure of effectiveness generated by LELAWS is the probability that a given pulse reaching the sensor will exceed the damage threshold of the sensor. In the case of bio-optical damage, a variety of thresholds, corresponding to various damage levels or effects, may be selected. For electronic sensors such as Tvs or NVDs, the threshold can be chosen to provide for partial degradation or total destruction of sensor functions.

Signature Prediction Models
SPIRITS, the *Spectral and In band Radiometric Imaging of Targets Scenes* Aircraft-1 code is an integrated system of computer programs designed to predict IR/UV/visible and spatial data of aircraft (only IR data delivered). It utilizes the SPF-II code to calculate plume radiation predictions. SPIRITS is maintained and distributed by the High performance Computing Facility (HCF) at John Hopkins University.

McPTD is the acronym for *RCS Computation Based on Physical Theory Diffraction*. It is a basic component to a much larger family of models that perform high frequency radar cross section (RCS) computations based on the physical theory of diffraction. The primary function of McPTD is to perform far-field, single-bounce RCS modeling. The other related models were written to specialize in other areas such as near-field, semi-nearfield, and multiple bounce RCS modeling.

XPATCH is a shooting and bouncing ray (SBR) based code that has been distributed to over 300 governmental and industrial organizations in the U.S. The SBR method is a high frequency electromagnetic technique for predicting the radar scattering from realistic targets and propagation in complex environments. While the basic idea behind the SBR methodology is simple, when combined with CAD tools for geometrical modeling and fast ray-tracing algorithms developed in computer graphics, this technique becomes a very powerful tool for characterizing the scattering from large, complex targets. This model has not been widely used in survivability analysis, but it should be applicable to signature analysis of low observable vehicles.

Lethality, Vulnerability and Endgame Models

The MECA endgame analysis computer program is derived from the earlier REFMOD reference model used for computing the effectiveness of anti-air weapons against an air target. The model was developed under the auspices of the Missile Evaluation Group of the JMEM/AA and represents a composite of methodologies recommended by that committee. It was developed to establish a standard by which other endgame computer programs could be compared and evaluated. It is also intended to be a program wherein new methodologies may be incorporated as better understanding or new modeling techniques are applied to particular areas of the endgame problem. As new data become available through test programs or theoretical efforts, they have been added to the MECA program as appropriate. MECA has been assembled by combining methodologies from several existing simulations and has been constructed in modular fashion to facilitate addition and/or modification of new or changed mathematical models. The newer Joint Service Endgame Model (JSEM) has replaced MECA.

JSEM, The *Joint Service Endgame Model,* generates weapons effects data for air-to-air and surface-to-air weapons and represents an integration of MECA and SHAZAM methodologies. Inputs are weapon encounter conditions, target descriptions, and warhead characterizations. The P_k for a specific terminal encounter is the output. An interface (cradle) for JSEM has recently been developed for use under DIME and an interface option has been added to use JSEM as the missile endgame simulation in ESAMS. JSEM is available through SURVIAC.

SCAN simulates the endgame portion of the encounter between a missile and an airborne target. It outputs the probability of hit and kill with varying levels of damage severity. It uses as input the geometric and the missile fuzing parameters and conditional kill probability functions.

SHAZAM simulates the interaction of an air-intercept missile with an air target during endgame. Probability of kill is output for a specific level of damage. Target geometric and vulnerability descriptions, missile warhead and fuzing characteristics, and input parameters are inputs to SHAZAM. Monte Carlo sampling is employed, and a warhead detonation position is determined by the fuzing algorithm for each sample. Various forms of this model are currently in use by Air Force components and Sandia Labs.

AJEM, the Advanced Joint Effectiveness Model, is a lethality, vulnerability, and endgame computer simulation code capable of analyzing one or more threats attacking a single rotary-wing or fixed-wing aircraft or ground-mobile system. It combines elements of target model viewing, threat modeling, encounter kinematics, generation of weapon burst points, propagation of damage mechanisms to the target, damage mechanism / target interaction (penetration, fire, blast, etc.), target system relationships (functionality, redundancies, etc.), and target remaining capability or loss of function.

AJEM was designed to be the DoD standard computer simulation for evaluating the lethality and terminal effectiveness of munitions and the vulnerability of aircraft, missiles, and ground-mobile systems, including battle damage repair (BDR). AJEM produces results that are applicable during all phases of weapon system acquisition from research, design, and development to production test and evaluation. AJEM produces results which are observable / measurable for testing and real-world events. AJEM is designed to run in conjunction with BRL-CAD® and the MUVES environment, capitalizing on work already performed by ARL/SLAD.

Fuzing Models

GTD is a model that uses the *Geometrical Theory of Diffraction* to perform an electromagnetic analysis of the radiation from radio frequency antennas in the presence of complex geometrical structures. The model uses uniform asymptotic techniques to predict the near/far zone radiation patterns of antennas in the presence of scattering structures, calculate EM coupling parameters between antennas, and determine potential radiation hazards. This calculation method is used in these analyses because only the basic structural details of what may be a very intricate configuration need to be modeled. This is because optical ray tracing techniques are used to determine the components of the field incident on, and diffracted by, the various structures. Scattering structures in the model are simulated by using combinations of perfectly conducting flat plates, finite elliptic cylinders, composite cone frustums, and finite composite ellipsoids. The model also has a limited thin dielectric slab capability. The GTD model uses as inputs the physical missile and engagement geometry, antenna pattern specifications, and diffraction term selections to calculate the radar diffraction patterns. It is planned to enter GTD into SURVIAC.

SAFUZE, a *Semi-Active Fuze* simulation that combines the GTD model, a semi-active fuze model, and a graphics package to calculate and display the fuze point for a specified missile was recently developed. SAFUZE incorporates the GTD model as implemented in the Near Zone - Basic Scattering Code (NEC-BSC) Version 3.3-02, from the ElectroScience Laboratory at Ohio State University, Columbus, Ohio. The semi-active fuze is modeled using complex algorithms that represent fuze components down to the individual circuit transfer functions. The graphics package displays voltage waveforms occurring within the fuze model that are indicative of the actual missile fuze point.

Mission Effectiveness Models

EADSIM, the *Extended Air Defense Simulation* is an M-on-N model of a two-sided conflict involving air-to-ground, air-to-air, surface-to-air, and surface-to-surface missile warfare. Designed to evaluate C^{3}I systems, EADSIM models each platform in the scenario individually and simulates the interaction of command and control nodes, weapons systems, communications nodes, and intelligence sensors. Command and control decision processes and the communication among Red and Blue forces are handled on a message-by-message basis, and intelligence gathering is also modeled. EADSIM has been used to model both few on few and many on many strike scenarios. One-on-one model results including RADGUNS and ESAMS are integrated into many-on-many models like EADSIM.

The EADSIM is an analytical tool for evaluating the effectiveness of various Command, Control, Communications and Intelligence (C3I), Theater Missile Defense (TMD), and air defense architectures, as well as weapon systems in the full context of an environment of sensors, Command and Control (C2) centers, communication systems, platform dynamics and weapons performance. The software is owned by the Army and has over 300 register user sites. The Government also maintains configuration control of the software.

EADSIM is used for scenarios ranging from few-on-few to many-on-many. Each player, called a platform, is individually modeled, as is the interaction among the platforms. EADSIM models the C2 decision processes and the communications among the platforms on a message-by-message basis. Intelligence gathering is modeled to support the deployment and employment of surface-to-surface missile (SSM) artillery.

SUPPRESSOR is a many-on-many simulation of a multiple-sided conflict involving combinations of air, naval, ground, and space forces. Unlike many models in which weapon characteristics and employment doctrine are hard coded, SUPPRESSOR uses a flexible input language that allows the user to define the characteristics and tactics of each individual player as well as the interrelationships and interactions among participants in the conflict. The level of detail modeled for each player is dictated primarily by the requirements of the study and the data available to the analyst rather than by the design of the simulation. Originally developed for the US Air Force, Assistant Chief of Staff/Studies and Analyses (AF/SAGR), SUPPRESSOR has been used extensively by Air Force Studies and Analysis (AFSAA) and the many-on-many modeling community for a wide variety of analysis projects.

The Suppressor simulation is owned and controlled by the Air Force, Aeronautical Systems Center, Wright-Patterson AFB, OH. Suppressor is chiefly a mission level simulation which has been applied in order to evaluate weapon systems, electronic combat systems, or tactics in many-versus-many scenarios. It has been used to simulate scenarios having a variety of military systems, including surface-to-air missile systems, antiaircraft artillery, fighter aircraft, bombers, anti-radiation missiles, electronic combat systems, and naval vessels.

SWEG, the *Simulated Warfare Environment Generator* is a mission-level simulation system that was derived from an earlier version of SUPPRESSOR. It may be used as a constructive simulation to model combat-related interactions between forces. SWEG is a general purpose conflict simulation, designed for use in a wide variety of applications. The model is most commonly used for mission- or raid-level analysis. SWEG simulates the interactions between any number of entities (players). Player functions are simulated using generic functions representing sensing, talking, shooting, jamming, moving, and thinking. Since the functional processes are generic, specific platforms and weapon systems, as well as their relationships, how they communicate, and how they react to the changing battle environment, are described in a set of user-configured databases, using the SWEG Conflict Language (SCL).

SWEG players can be configured at various levels of detail, and players' perceptions and tactics are a significant element of SWEG. Each player's current perception of his conflict problem affects the set of tactical actions chosen from among his available tactical options, which in turn affects other players' perceptions. Command chains and communications networks can be defined, so that perceptions can be shared and players can be controlled and coordinated by other players.

JIMM is the Joint Interim Mission Model, originally developed for the Joint Strike Fighter (JSF) program from the SWEG model. It contains a number of improvements over SWEG.

Campaign Models

TAC RAM is a deterministic campaign analysis model used primarily to provide quick-turn analysis support for budgeting, programming, and evaluation decisions. Inputs include force structure, electronic combat capabilities, expected effectiveness and attrition, and a theater target set. The force structure is assigned missions and the results of a twenty-day campaign can quickly be assessed. TAC RAM uses systems dynamic code that allows quick adjustment of effectiveness levels to explore the impact of changing force structure capabilities as they relate to budgeting and programming decisions.

THUNDER is a two-sided theater level model designed to simulate conventional war. It is two-sided, in that operation of Red and Blue forces are simulated independently of each other. THUNDER operates stochastically at the theater level. While the model was designed primarily to simulate air operations, it contains a ground combat module based on the Concepts Evaluation Model (CEM). The inclusion of the CEM module enables THUNDER to simulate all of the battlefield functional areas, including logistics. The model can also allocate resources (sorties) based on objectives. This allows for dynamic mission planning based upon objectives set by commanders. Another key feature at the campaign/theater level is the model's ability to evaluate strike force effectiveness as a function of the number of targets destroyed. THUNDER is used to analyze campaign effectiveness by providing inputs to this process from ESAMS, RADGUNS, MOSAIC, and BRAWLER.

Experience with these (and other) M&S, builds an awareness of the constant state of change in their respective capabilities and documentation, and trends toward increased use of M&S in the support of analysis and T&E objectives. In the course of using M&S in the T&E process, it is important to understand and produce data that supports specific measures of effectiveness (MOEs) that are applicable to and appropriate for the problem at hand.

THUNDER was developed under the auspices of the Air Force Studies and Analyses Agency (AFSAA). The simulation was designed and built expressly to examine issues involving the utility and effectiveness of air and space power in a theater-level context. THUNDER results and analyses support senior decision-makers across the acquisition, policy and operations communities.

For More Information:

More information on survivability models and simulations can be found at the SURVIAC web-site: http://bahdayton.com/surv1/