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FINAL REPORT, STUDY ON MANAGEMENT CONCEPTS FOR BROADLY-NEEDED MODELING AND SIMULATION TOOLS

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Final Report, Study on Management Concepts for Broadly-Needed Modeling and Simulation Tools

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EXECUTIVE SUMMARY

The Acquisition Modeling and Simulation (M&S) Master Plan, published by the Department of Defense (DoD) Systems Engineering Forum in April 2006, includes an Action 3-4, stated therein as "Centrally fund and manage the development of high-priority, broadly-needed M&S tools" by first identifying requirements for such tools and then conducting pilot projects. It was felt to be prudent, before embarking on such an initiative, to study DoD's current experience in the management of broadly-needed tools objectively, to capture experiences and lessons learned useful for evolving DoD's management approach to such M&S tools.

This study on Management Concepts for Broadly-Needed M&S Tools was initiated in the fall of 2008 by the Office of the Director, Systems and Software Engineering (D, SSE) in the Office of the Under Secretary of Defense for Acquisition, Technology and Logistics (OUSD(AT&L)), on behalf of the Acquisition M&S Working Group. The Johns Hopkins University Applied Physics Laboratory (JHU/APL) was selected by that office to perform the study. The objectives of the study, as stated in the statement of work, were:

1. To identify best practices for managing broadly-needed M&S tools, and
2. To recommend actions that DoD should take to improve its management of such tools.

In order to gain information from the experiences of existing broadly-used tools, the study team developed a preliminary list of M&S tools that appeared to be broadly used in DoD. This was based on the team's personal knowledge, literature searches of conference proceedings, and a review of tools listed in the M&S Resource Repositories/Registries of DoD and the various. This resulted in an initial list of 36 tools by early February 2009. A web-based survey was developed, and responses were solicited from the government managers and lead contractor developers of the identified tools. The list was later expanded to include additional tools for which to solicit information. In all, responses were received from the managers of 28 M&S tools. A second similar web-based survey for M&S tool users was constructed, and responses were solicited via the Acquisition M&S working group and professional organizations. Twenty-five user responses were obtained.

Based on the surveys, the team identified six different management approaches, each of which has advantages and disadvantages. The team categorized these approaches as:

1. Government Coordinated.
2. Developer Coordinated.
3. Independent Development.
4. Government Open Source Hybrid.

5. Open Source, and
6. Independent "Co-opetition" (see Section 3.1.6, page 10)

In order to assess various M&S tool management approaches, the team developed a taxonomy for judging their success. This involved defining "High," "Medium," and "Low" criteria for the following four categories:

1. Integrating externally-developed enhancements,
2. Model accuracy / verification and validation,
3. Meeting foreseeable needs, and
4. Customer support.

Twelve success attributes were also developed that appeared to contribute to tool management success in one or more of the four categories.

Building upon the survey results, and the above taxonomy, the team then developed a set of recommended best practices for M&S tool management in twelve task categories across the following five management areas:

1. Requirements solicitation (four task categories);
2. Baseline development (three task categories);,
3. Testing, quality assurance, and verification and validation (two task categories);
4. Baseline maintenance (one task category); and
5. Customer support (two task categories).

The best practices in each of the categories and areas are detailed in Chapter 5 of the report.

Finally, the team developed three recommended actions that DoD should take, preferably at an enterprise-wide level, to improve the management of broadly-needed M&S tools:

1. Publish and promulgate a Recommended Practices Guide for the management of broadly-needed M&S tools;
2. Identify and establish a limited number of short-term (up to two years in duration) pilot efforts for selected existing broadly-needed DoD-supported M&S tools, to verify the merits of the recommended best practices; and
3. Establish and maintain an effective M&S tool catalog / registry with metadata to support discovery and potential reuse of M&S tools.

Recommended criteria for the selection and conduct of the pilot programs identified in item 2 were also developed.

1. INTRODUCTION

1.1 BACKGROUND

A number of modeling and simulation (M&S) tools used in the United States (US) Department of Defense (DoD) are common to multiple programs and organizations. Many government-managed models and simulations are already used broadly. However, such broadly-used M&S tools typically suffer from several problems, including a lack of adequate tool manager funding and a stakeholder requirements management council to:

(a) allow the incorporation of tool enhancements developed by users into the standard version ("street version");

(b) improve the model's accuracy by examining discrepancies between the model and actual test results (the "fix" step of the "model-test-fix-model" process); and

(c) build in new capabilities to meet foreseeable needs, such that the capabilities can be delivered by the time users need them.

This situation has prompted a call for a new approach to managing broadly-needed M&S tools. The Acquisition M&S Master Plan (AMSMP) [Reference (a)], published by the DoD Systems Engineering Forum in April 2006, includes an Action 3-4, stated therein as "Centrally fund and manage the development of high-priority, broadly-needed M&S tools" by first identifying requirements for such tools and then conducting pilot projects. However, before embarking on such an initiative, it was felt prudent to study DoD's current experience in the management of broadly-needed tools objectively, to capture experiences and lessons learned useful for evolving DoD's management approach to such M&S tools.

This study on Management Concepts for Broadly-Needed M&S Tools was initiated in the fall of 2008 by the Office of the Director, Systems and Software Engineering (D, SSE) in the Office of the Under Secretary of Defense for Acquisition, Technology and Logistics (OUSD(AT&L)), on behalf of the Acquisition M&S Working Group. The Johns Hopkins University Applied Physics Laboratory (JHU/APL) was selected by that office to perform the study.

1.2 SELECTED EXAMPLES OF DOD M&S TOOL EVOLUTION

The history of the development and usage of M&S tools in DoD now spans decades. A variety of factors often influence how such tools, oftentimes developed at considerable expense, evolve over time. Then-current needs, organizational alignments, and shifting funding priorities often shape this evolution. Purely to provide illustrative examples, the study team notes how two such tools have evolved over time – the tools now known as One Semi-Automated Forces (OneSAF) and the Joint Analysis System (JAS). Figure 1 shows the lineage of OneSAF, derived from the original Modular Semi-Automated Forces (ModSAF), and its development and

continued existence in parallel with the Joint Semi-Automated Forces (JSAF) simulation. Figure 2 shows the lineage of JAS, from its initial development as the Joint Warfare System (JWARS) by the Office of the Secretary of Defense (OSD) office of Program Analysis and Evaluation (PA&E), the transfer of its sponsorship to the U.S. Joint Forces Command (JFCOM), its re-designation as JAS, and its transfer of sponsorship back to OSD(PA&E), now renamed the office of Cost Assessment and Program Evaluation (CAPE).

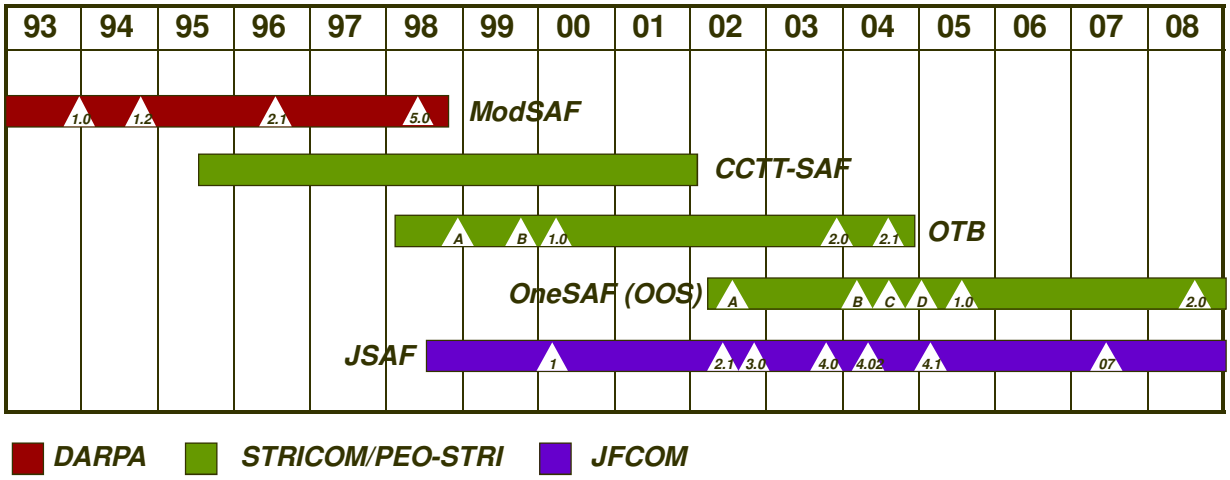

Figure 1: Evolution of One Semi-Automated Forces

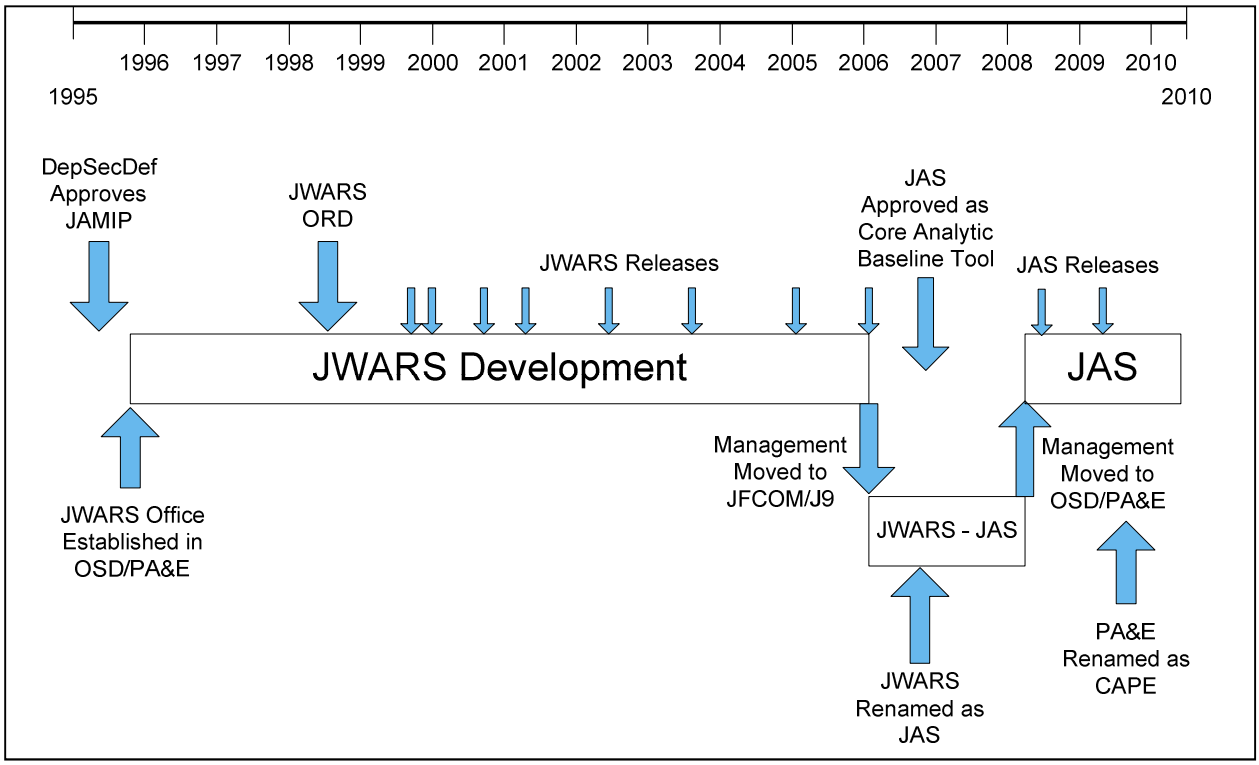

Figure 2: Evolution of the Joint Analysis System

1.3 STUDY OBJECTIVES

The objectives of the study, as stated in the statement of work (SOW) provided by the study sponsor, are:

1. To identify best practices for managing broadly-needed M&S tools, and
2. To recommend actions that DoD should take to improve its management of such tools.

For the purposes of this study, an "M&S tool" is a standalone software application that can be exercised over time to model the behavior and/or performance of a real-world entity, process, or phenomena. Software applications, with which models or simulations may interact, such as terrain or weather servers, are also considered to be M&S tools. Model development environments (modeling toolkits) are likewise of interest. Also, for the purposes of this study, a "broadly needed" M&S tool is one that supports national defense activities, and that is determined to be needed by multiple organizations not under the same chain of command or contract (i.e., where the common use and reuse is voluntary, not directed).

1.4 ORGANIZATION OF THIS REPORT

The balance of this report describes the study and its results. Chapter 2 describes the approach used by the study team. Chapter 3 provides categories of M&S tool management approaches that the study team found to be in use in DoD today. Chapter 4 outlines a taxonomy developed by the team for judging the success of tool management approaches. Chapter 5 provides the key study findings, describing best management practices that the study team identified in the management of current broadly-used M&S tools, and that the team recommends for use by M&S tool managers. Chapter 6 lists the actions that the study team recommends be taken within DoD to improve the management of broadly-needed M&S tools, and lists characteristics of potential pilot programs that could be used to evaluate the efficacy of the recommended best management practices.

Several appendices are provided. Appendix C delineates the contents of two online survey instruments that the study team used to gather information from M&S tool managers and users. Appendix D provides details of nine of the responses from M&S tool managers that the study team found to be particularly comprehensive, and which have been approved by the tool managers for publication in this report. In addition, a list of references used in the report (Appendix A), a glossary of key terms (Appendix B), and a list of abbreviations and acronyms (Appendix E) are also provided.

2. STUDY APPROACH

2.1 OVERVIEW OF THE STUDY APPROACH

Upon initiation of the study, based upon the study's statement of work, the study team developed a project plan, outlining the approach to the study's performance. The significant activities in the approach were as follows:

1. Development of a list of M&S tools that support national defense activities and that are used by multiple organizations not under the same chain of command or contract.
2. Documentation and categorization of the management approaches for the tools identified above.
3. Assessment of the degree of success each of the identified tool management approaches has had in avoiding the problems of
   (a) user-developed enhancements not being made available to other users in an updated standard version of the tools;
   (b) the model's accuracy not being improved by examining discrepancies between the model and actual test results;
   (c) new capabilities not being incorporated sufficiently in advance to meet foreseeable needs; and
   (d) other problems discovered during the study.
4. Because the degree of success in avoiding these problems is difficult to measure quantitatively, development of a taxonomy with relative values for each problem category identified.
5. Identification/development of best practices for managing broadly needed M&S tools.
6. Recommendations for actions that DoD should take to improve its management of broadly-needed M&S tools.
7. Development of a list of desirable characteristics of candidate tools for potential pilot applications of recommended practices and management improvement actions.

2.2 INFORMATION GATHERING ON M&S TOOLS AND MANAGEMENT APPROACHES

2.2.1 Initial Identification of Broadly-Used M&S Tools

A preliminary list of M&S tools to survey that appeared to be broadly used in DoD was developed, based on personal knowledge of the study team and literature searches of proceedings from the Simulation Interoperability Workshops (SIWs) and the annual Interservice/Industry Training, Simulation & Education Conference (I/ITSEC). In addition, a review of tools listed in

the M&S Resource Repositories/Registries (MSRRs) of DoD and the various Services was conducted. This resulted in an initial list of 36 tools by early February 2009.

2.2.2 Survey of M&S Tool Managers

The survey of managers of broadly-used tools was performed in January-February 2009, using the preliminary list of 36 tools. The survey was sent to both the government managers and contractor developers in cases where the tool development was contracted to private industry. Both were surveyed in order to obtain more perspectives.

The survey questions were developed based on the three areas of concern listed in Section 2.1, list item 3: how to allow the incorporation of tool enhancements developed by users into the standard version of a tool; how to improve the model's accuracy by examining discrepancies between the model and actual test results; and how to build in new capabilities to meet foreseeable needs, such that the capabilities can be delivered by the time users need them. Based on these areas, the survey questions listed in Appendix C, Section C.1, were developed. This survey was conducted using a web survey tool hosted by JHU/APL.

After an evaluation of the initial responses, it was decided to supplement the list of M&S tools for which to solicit information, to include some commercial tools developed to serve DoD M&S users, specifically, High Level Architecture (HLA) Runtime Infrastructure (RTI) implementations. Other tools were solicited based on responses to briefings on the study at the 2009 Spring Simulation Interoperability Workshop (SIW) and the August 2009 Acquisition Modeling and Simulation Working Group (AMSWG) meeting. In general, it was decided to leave the web-based survey form open for the duration of the study so that information on additional M&S tools could be added.

In all, responses were received from 32 individuals on 28 broadly-used M&S tools. For a few tools, both the government manager and the lead contractor developer responded. Table 1 lists the tools for which responses were received.

2.2.3 Survey of M&S Tool Users

The second survey was directed toward M&S tool users. The list of individuals to survey was developed based on personal knowledge of the study team and mailing lists of the National Defense Industrial Association (NDIA) Systems Engineering M&S Committee and the AMSWG. Each individual was encouraged to forward the solicitation to other users who might provide a response. The questions for this survey, which are listed in Appendix C, Section C-2, were derived from the questions for the first survey, but generalized to solicit best practices rather than responses about a particular tool. This survey was also conducted using a web survey tool hosted by JHU/APL. Twenty-five responses were received.

2.3 ANALYSIS OF INFORMATION

In parallel to the survey process, the study team developed a categorization of M&S tool management approaches. A description of this categorization is given in Chapter 3. A preliminary taxonomy for judging the success of the various tool management approaches was also developed, which was later modified somewhat based on the survey results. The taxonomy is discussed in Chapter 4.

Table 1: List of Broadly-Used Tools Responding to Survey

Advanced Joint Effectiveness Model (AJEM)
Advanced Testing Capability (ATC)
Battle Command Management Service (BCMS)
BRL-CAD
Comprehensive Mine and Sensor Simulator (CMS2)
Extended Air Defense Simulation (EADSIM)
Hazard Prediction and Assessment Capability (HPAC)
Intelligence Modeling and Simulation for Evaluation (IMASE)
Joint Analysis System (JAS)
Joint Conflict and Tactical Simulation (JCATS)
Joint Communications Simulation System (JCSS)
Joint Integrated Mission Model (JIMM)
Joint Semi-Automated Forces (JSAF) (JFCOM version)
Joint Theater Level Simulation (JTLS)
Langley Standard Real-Time Simulation in C++ (LaSRS++)
Model for Intratheater Deployment by Air/Sea (MIDAS)
Naval Simulation System (NSS)
One Semi-Automated Forces (OneSAF)
OpenEaagles Simulation Framework
ProtoCore
Role Player Workstation
Run-Time Infrastructure (RTI) (MATREX)
RTI NG Pro (Raytheon)
Simulation Display (SIMDIS)
Spectral Inband Radiance of Targets and Scenes (SPIRITS)
Suppressor
Synthetic Theater Operations Research Model (STORM)
Threat Modeling and Analysis Program (TMAP)

As survey responses were obtained, the study team categorized and synthesized them to determine their general category of approach to tool management, and their applicability to the taxonomy for judging success of approaches. Also, best practices were identified from the survey responses. In addition, the team considered other recent documents related to M&S best practices, including a report on business models to advance the use of M&S resources

[Reference (b)] and a study performed in parallel on M&S development best practices [Reference (c)].

Preliminary sets of best management practices and recommended actions for the DoD M&S community were prepared, and were reviewed and commented upon by representatives of the sponsor's office. In early 2010, as promised in the solicitation of the original survey of M&S tool managers, the modified best management practices and recommended actions were sent to the tool managers responding to the survey for comment, as well as to selected M&S tool users from the user survey. Additionally, requests were made to selected M&S tool managers whose responses to the survey the study team found to be particularly comprehensive, for permission to publish the responses as examples. After consideration of the comments, the study team produced the description of best M&S tool management practices provided in Chapter 5, and the recommended DoD actions in Chapter 6. The recommended characteristics of potential pilot programs, also found in Chapter 6, were then produced. The survey responses for nine of the broadly-used M&S tools are provided in Appendix D.

3. MANAGEMENT CATEGORIES

To begin to digest the survey information, the study team wanted to categorize the "business model" of the M&S tool managers. Survey questions included indicators of the approaches for funding and coordinating tool development.

3.1 CATEGORY DEFINITIONS

Categories that provided a spectrum for two dimensions were desired: the role of the tool manager in coordinating financial transfers between users and developers, and the role of the tool manager in controlling the tool baseline. Survey results were categorized, and the category definitions were adjusted to make crisp distinctions among the categories. Six categories were ultimately needed to address the survey results, as shown in Figure 3.

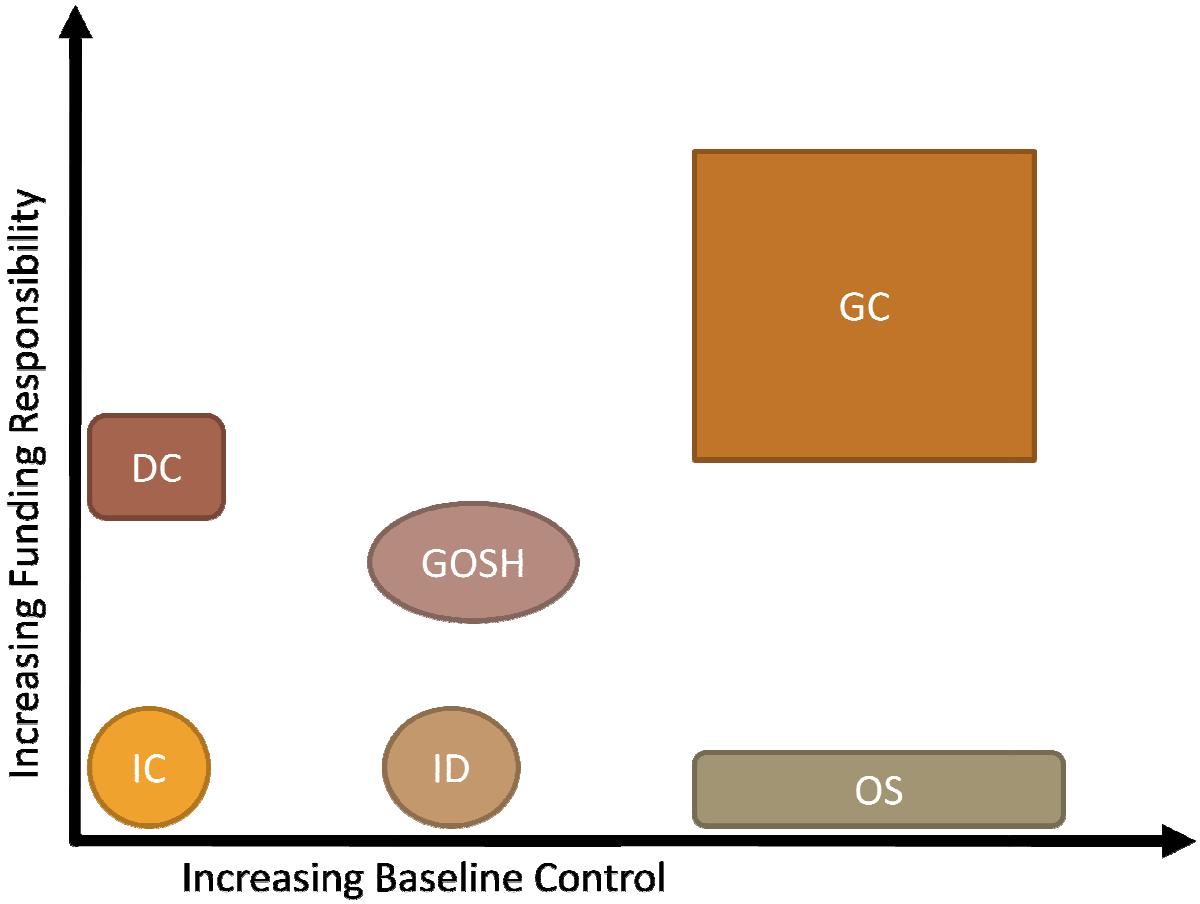

Figure 3: Management categories outlining tool manager's role

3.1.1 Government Coordinated (GC)

A single government office coordinates development of one version of the tool for all users. Government mechanisms, such as Military Interdepartmental Purchase Requests

(MIPRs), are used to contribute funds. Developers (contractors or DoD employees) are paid and/or directed through a single coordinator.

This category covers the traditional government contracting business model, and represents the majority of survey responses. A government program manager plans a budget element to develop the tool, taking money from other government users to expand the available resources. The program manager selects developers, directs their efforts, and pays them. The centralized control makes this approach popular with the primary user, and less so with other users. It can degenerate into competing versions of the tool, an unattractive situation for a broadly needed tool.

3.1.2 Developer Coordinated (DC)

A single development contractor coordinates one version of the tool for all users. Commercial mechanisms, such as license fees or development contracts, are used to contribute funds from users.

This category covers the traditional software product business model. The developer produces the tool with up-front investment. Users are charged fees to recoup the investment and provide profits to the developer. Although this approach is popular with some developers, the risk associated with up-front investment may demand high rates of return that lead to expensive license fees which are very unappealing to DoD users.

3.1.3 Independent Development (ID)

One or more developers (contractors or DoD employees) produce their own versions from a common tool baseline. Each user is free to select a version and/or developer.

This category requires a large enough user community to support multiple competing developers. Although common in generic software categories like operating systems, only a couple of M&S tools could be broadly enough used to utilize this business model. Where it applies, it provides users with significant benefits through competition, at the burden of choosing developers wisely. Developers often attempt to "lock in" users to their specific dialect of the tool by increasing incompatibility with other versions.

3.1.4 Government Open Source Hybrid (GOSH)

A government office authorizes certain developers (contractors or DoD employees) to participate in a shared source effort. Each user chooses a developer and all changes are constantly available to all participants.

This category reflects the philosophy of open source within the policy constraints of DoD acquisition. Participation in the development activity is controlled by the tool manager to implement distribution and information security restrictions. This business model can effectively support a user community with broad interests, provided the interests are distinct enough that conflicts over implementation details are low. Users benefit from the lack of distribution

restrictions or license fees. The tool manager may find it hard to justify funds for ongoing maintenance, whereas money for new features may be more readily available.

3.1.5 Open Source (OS)

One or more developers (contractors or DoD employees) participate in a shared source baseline. Each user chooses a version to use. No contractual relationship necessarily exists between users and developers.

This category reflects the pure form of collaborative self-interest. As applied to M&S tools, it can be an effective business model only when needs can be expressed in public forums. Simulation Interoperability Standards Organization (SISO) standards represent one mechanism for documenting such a need.

3.1.6 Independent "Co-opetition" (IC)

One or more developers (contractors or DoD employees) produce independent changes to a shared baseline. Each user chooses a developer, and the user determines if and when their changes are made available for inclusion in future baselines.

This category reflects a business environment where two approaches are competing for users by offering differentiated services. Such a situation can find the best solution, or shift focus away from the tool in favor of more financially attractive opportunities.

3.2 STRENGTHS AND WEAKNESSES

The various business models distribute value in different ways. Some business models promote efficiency across DoD by reducing the number of overlapping capabilities that need to be supported. Some business models promote project efficiency by making exactly what the project requires. These benefits are mutually exclusive, each viewing the other as a weakness.

Similarly, business models vary in how closely they tie funding to the role of tool manager. In business models with close ties, the tool manager's direct responsibility might be perceived by users as a lack of concern for their problem, although users also feel they are getting "something for nothing." In business models without close financial ties, uncertainty about the future availability of the tool can raise costs through duplicative "backup plans" or result in tools becoming unavailable. Figure 4 highlights these differences and shows where each business model category applies.

3.3 EXAMPLES

The constructed categories have clear boundaries, to facilitate the team's analysis. Real tools have often taken unique directions to build a business model that addresses their needs. The following models are examples near to the definition of the category.

3.3.1 EADSIM (GC)

Many models use similar government coordinated business models. The tool manager has Space and Missile Defense Command (SMDC) funding to make improvements, and other users provide funding to incorporate additional improvements.

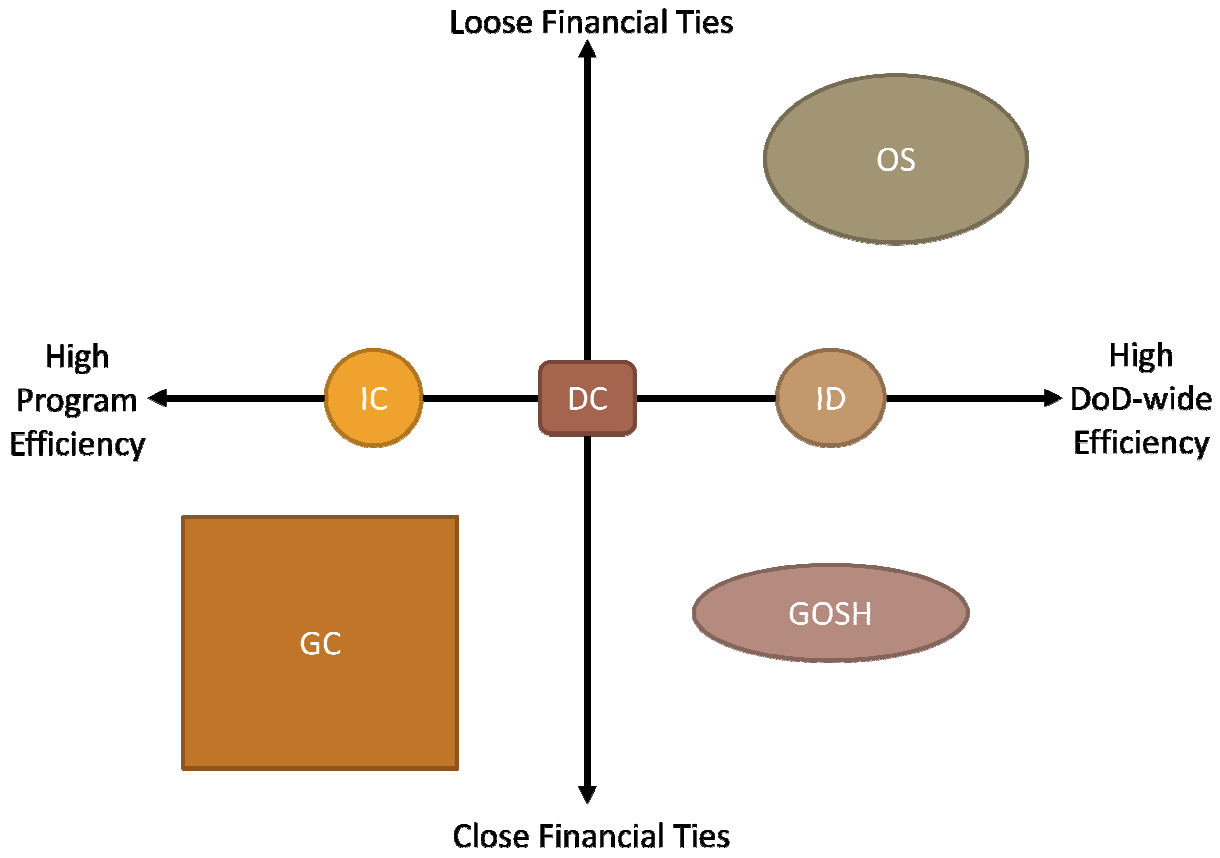

Figure 4: Relationships between Business Models

3.3.2 HLA RTI (DC)

The HLA RTI provides an example of a formerly GC tool that has been commercialized. Several commercial developers have proprietary implementations satisfying the standardized interfaces. Users can pick and choose any tool product, but they must pay license fees so the developers stay in business.

3.3.3 JSAF (ID)

As discussed in Chapter 1, the users of JSAF have continued separate evolution of the tool from its ModSAF roots. The tool has developed broad users, who pursue diverging applications for the tool.

3.3.4 OneSAF (GOSH)

OneSAF explores the benefits of "open source" while maintaining the required controls on a piece of military software. Several developers are involved and actively coordinated by the tool manager. Steps are taken to reduce divergence among the versions of OneSAF in use.

3.3.5 SIMDIS (OS)

Though SIMDIS still has usage controls, it is substantially "open source." Many libraries used by SIMDIS are open source licensed, and there are hundreds of users. The Naval Research Laboratory (NRL) supports the tool management effort.

4. TAXONOMY FOR JUDGING SUCCESS OF MANAGEMENT APPROACHES

One of the goals of the study was to examine the management approach for each identified M&S tool and assess the degree of success each M&S tool's manager had in avoiding the problems of:

- Externally-developed enhancements not being made available to other users in an updated standard version ("street version") of the tools,
- The model's accuracy not being improved by examining discrepancies between the model and actual test results,
- New capabilities not being incorporated sufficiently in advance to meet foreseeable needs, and
- Other problems discovered during the study.

Because the degree of success in avoiding these problems is difficult to measure quantitatively, the study team decided to establish a taxonomy with relative values for each problem.

4.1 TAXONOMY CATEGORIES

The team began by defining criteria for assessing management approaches in each category. These criteria are summarized in Table 2. Notice that the criteria focus on both the experience of the M&S tool manager and the availability of funds for the manager to implement the necessary mechanisms. In the survey responses, the team saw many instances where experienced M&S tool managers knew how to make their M&S tools more effective, but simply lacked the funds to provide the necessary support.

Table 2: Management Approach Assessment Criteria

High	Medium	Low
The M&S tool manager is highly experienced in M&S tool management and committed to maximizing user value and utility. The M&S tool manager has sufficient funds to implement effective mechanisms to achieve these goals.	The M&S tool manager is experienced in M&S tool management and committed to providing user value and utility. The M&S tool manager may not have sufficient funds to implement all the mechanisms necessary to achieve these goals and must make choices about which mechanisms to implement.	Either the M&S tool manager is inexperienced or has insufficient funds to maintain the M&S tool management mechanisms necessary to provide user value and utility.

Using these criteria, the team established the taxonomy detailed in the next four subsections for judging the success of management approaches. Each subsection contains a table similar to Table 2 summarizing what a manager in each of the above categories would do to address the problems identified at the beginning of this section.

4.1.1 Integrating Externally-Developed Enhancements

An M&S tool manager may choose to accept M&S tool enhancements from outside the development team as a way to offset the cost of providing all the functionality required by users for which funding is not available.

Table 3: Integrating Externally-Developed Enhancements

High	Medium	Low
The M&S tool manager has a structured, documented process for evaluating user enhancements and integrating them into the standard version. The process includes regression testing and mediation of differences between submitted changes.	Enhancements from a recognized set of sources are accepted and/or the framework allows for users to individually integrate their own plug-ins or libraries.	Integration of externally-developed enhancements is on an ad hoc basis or not at all.

The most interesting and unexpected finding in this category was the solution at the medium level of providing a framework for users to integrate their own plug-ins or libraries. In the absence of sufficient funding to establish a configuration control board (CCB) and a large regression-testing framework, a plug-in framework allows users to have their own enhancements without endangering the stability of the M&S tool's code baseline.

4.1.2 Model Accuracy

Although this criterion is referred to as accuracy, the definition indicates that the real concern is verification and validation (V&V).

Table 4: Model Accuracy

High	Medium	Low
Validation or testing of the fully integrated tool is required as part of the structured management process.	The model manager accepts validation data where available, but does not require it.	The model management process does not include V&V.

The most interesting finding in this category was that, although few respondents said they performed V&V per se, many of them indicated a level of regression testing consistent with performing V&V.

4.1.3 Meeting Foreseeable Needs

Table 5: Meeting Foreseeable Needs

High	Medium	Low
The M&S tool manager solicits inputs to future needs; manager prioritizes requirements and integration activities to meet projected user community needs.	Priorities are set by a CCB. Users may provide additional funding to meet their specific requirements.	Projected user community needs are not considered in the requirements and integration process.

The most interesting finding in this category was the option for users to provide additional funding to meet their specific requirements at the medium level. As with the results reported in Table 5, this is a means for an M&S tool manager with insufficient funds to do everything desired to meet users' needs.

4.1.4 Customer Support

As indicated at the beginning of this section, the team was also looking for M&S tool manager successes in avoiding other problems. The team identified one such additional success: customer support. It became clear from the responses that successful M&S tool managers go beyond just delivering a valuable and usable M&S tool; they also actively engage with their users.

Table 6: Customer Support

High	Medium	Low
The M&S tool manager provides broad and responsive customer support including live support (help desk) and extensive documentation that supports understanding and use of the M&S tool. The M&S tool manager actively communicates with user community.	The M&S tool manager provides documentation beyond just a technical/user's manual and live support.	The M&S tool manager provides a technical/user's manual. Live support is on an ad hoc basis.

4.2 MEASURES OF SUCCESS

Based on the above categories, the team developed twelve "success attributes" that contribute to M&S tool management success in one or more of the categories. These success attributes are summarized in Table 7. These are specific actions the M&S tool manager can take to support achievement of success according to the taxonomy in Section 4.1. Of course, this assumes that the M&S tool manager has sufficient funding to implement these actions.

Table 7: Success Attributes

M&S Tool Management Success Attributes: "The M&S Tool Manager …"	Meeting Foreseeable Needs	Integrating Externally-developed Enhancements	Model Accuracy (V&V)	Customer Support
Successfully solicits recommendations from users for new capabilities.	X			
Actively communicates with, and engages, users / external developers on a consistent basis concerning tool efficacy and applicability.	X			X
Has a process for managing the tool baseline(s) that prevents irreconcilable divergence.	X	X		
Has implemented into the baseline tool enhancements agreed upon by a peer / user review process.	X	X		
Provides / publishes justification for not including any suggested tool enhancements that were not included in the new baseline tool.	X	X		X
Has implemented a process to acquire and assess (using a peer / user review process) externally developed capabilities for inclusion into the baseline tool.		X		
Publishes a coding standards and style guide with which all externally developed capabilities are required to comply.		X		X

M&S Tool Management Success Attributes: "The M&S Tool Manager …"	Meeting Foreseeable Needs	Integrating Externally-developed Enhancements	Model Accuracy (V&V)	Customer Support
Has developed and implemented a quality assurance process that rigorously evaluates each new baseline tool implementation before final product release.			X	
Receives and expends the funds necessary to conduct verification and validation tests on all new enhancements, and thorough regression tests on all new baseline releases to ensure past functionality has not been compromised.			X	
Updates the User's Guide and / or Technical Reference Manual with each baseline enhancement release, including constraints and limitations.			X	X
Receives consistent and adequate funding to conduct tool baseline maintenance, exclusive of baseline enhancements, to ensure the tool remains compatible with current software and hardware products used within the M&S community.				X
Provides timely customer support upon receiving a request for assistance, e.g. a competent and adequately staffed Help Desk.				X

The team sorted the rows of this table to reflect the chronological order of the M&S tool life cycle, i.e., meeting foreseeable needs strongly correlates with requirements analysis; integrating externally-development enhancements strongly correlates with design and implementation; model accuracy strongly correlates with testing. This helped to verify the assignment of success attributes to the right categories in the taxonomy, because they could be crosschecked with the point in the M&S tool life cycle when they should be implemented. At first glance, it looks like this crosscheck fails for customer support because it is spread across the life cycle. However, customer support should be part of every life cycle phase of an M&S tool.

5. BEST MANAGEMENT PRACTICES

The study defined five overarching M&S tool management areas and twelve associated task categories on which M&S tool managers (MSTMs) should focus their M&S management efforts in order to manage M&S tools in a more efficient and effective manner. The five overarching M&S tool management areas are:

1. Requirements Solicitation
2. Baseline Development
3. Testing, Quality Assurance, and Verification and Validation (V&V)
4. Baseline Maintenance
5. Customer Support

Table 8 lists the five overarching M&S tool management areas and their associated task categories. Each of these overarching areas and their associated task categories are discussed individually in the following sections, and best practices in each category are presented.

Table 8: M&S Tool Management Areas and Associated Task Categories

M&S Tool Management Area	Task Category (The M&S Tool Manager …)
Requirements Solicitation	Solicits requirements from users
	Implements into the M&S tool baseline those enhancements (to satisfy one or more requirements) agreed upon by the CCB review process
	Provides / publishes justification for not including any suggested requirements that will not be satisfied in the new M&S tool baseline
	Communicates with, and engages, users and external developers on a consistent basis concerning tool efficacy and applicability
Baseline Development	Has a process for managing the tool baseline(s) that prevents irreconcilable divergence
	Has implemented a process to acquire and assess (using a peer / user review process) externally developed capabilities for inclusion into the baseline tool
	Publishes a coding standards and style guide with which all externally developed capabilities are required to comply
Testing, Quality Assurance, and V&V	Has developed and implemented a quality assurance process that rigorously evaluates each new baseline tool implementation before final product release
	Receives and expends the funds necessary to conduct thorough V&V regression tests on all new baseline releases to ensure past functionality has not been compromised

M&S Tool Management Area	Task Category (The M&S Tool Manager …)
Baseline Maintenance	Receives consistent and adequate funding to conduct tool baseline maintenance, exclusive of baseline enhancements, to ensure the tool remains compatible with current software and hardware products used within the M&S community
Customer Support	Updates the User's Guide and / or Technical Reference Manual with each baseline enhancement release, including constraints and limitations
	Provides timely and responsive customer support, e.g., a competent and adequately staffed Help Desk

There are several terms used in this chapter, the definitions of which follow, and are included in the Glossary:

Model: A physical, mathematical, or otherwise logical representation of a system, entity, phenomenon, or process. [Reference (d)]

Simulation: A method for implementing a model over time. [Reference (d)]

Modeling and Simulation (M&S): The discipline that comprises the development and/or use of models and simulations. [Reference (d)]

M&S Tools: Software that implements a model or simulation or an adjunct tool, i.e., software and/or hardware that is either used to provide part of a simulation environment (e.g., to manage the execution of the environment) or to transform and manage data used by or produced by a model or simulation. Adjunct tools are differentiated from simulation software in that they do not provide a virtual or constructive representation as part of a simulation environment. [Reference (d)] (Note: A commercial example of an M&S tool that is not a model or simulation is Microsoft Excel, which, among other uses, can be used to create cost models. Other examples include many process modeling tools which, by the input of data and relationships, can be used to create a model or simulation of a process.)

M&S Tool Manager (MSTM): The individual or organization responsible for the management of an M&S tool.

Validation: The process of determining the degree to which a model is an accurate representation of the real-world from the perspective of the intended uses of the model. [Reference (d)]

Verification: The process of determining that a model implementation accurately represents the developer's conceptual description and specifications. [Reference (d)]

5.1 REQUIREMENTS SOLICITATION

Findings – It is through constant interactions with users and external developers of an M&S tool that MSTMs can gauge the impact (both positive and negative) that the M&S tool is having. As a result, MSTMs acquire knowledge about areas where current M&S tool capability is inadequate and needs to be improved. In addition, capabilities the M&S tool is lacking and needs would also be brought to light. All enhancements and new capabilities have to be traceable back to a valid user need. If no user need for an enhancement or new capability is validated as a requirement for the tool, then the proposed enhancement and or capability will not be included in the M&S tool baseline.

Task Categories – The study revealed four task categories in this area that, if adopted, should enable an MSTM to ascertain needed capabilities (i.e., "requirements solicitation"). When creating an updated version of the M&S tool an MSTM should satisfy all valid and peer-reviewed (using the model's CCB to conduct such reviews) requirements to the degree allowed by funding, schedule, knowledge, personnel, technology, and security constraints. The four task categories as they pertain to requirements solicitation are that an MSTM:

1. Solicits requirements from users.
2. Implements into the M&S tool baseline those enhancements (to satisfy one or more requirements) agreed upon by the CCB review process.
3. Provides / publishes justification for not including any suggested requirements that will not be satisfied in the new M&S tool baseline.
4. Communicates with, and engages, users and external developers on a consistent basis concerning tool efficacy and applicability.

Each of these four task categories is discussed below, and best practices for each of the four categories are provided.

5.1.1 Canvass Users for Needed Changes

In order for any MSTM to ensure adequately that his/her tool is capable of meeting the current and future needs of customers, the MSTM should put into place a process that facilitates users and external developers conveniently and expeditiously expressing their thoughts concerning improved or additional capabilities the M&S tool should provide. Failure of MSTMs to develop and implement capabilities that can fulfill valid needs will eventually lead to users and external developers migrating away from this M&S tool to one that provides the capabilities they need. To aid an MSTM in this endeavor, the study team has developed the following recommended activities:

1. Develop a website with a direct link in the tool distribution package that enables tool users and external developers to quickly and easily document as they become evident capabilities they would like to see included;
2. Send hard copy questionnaires on a periodic basis to users and external developers to supplement the website to query customers about capabilities to be included in the next version of the M&S tool.

Often users and external developers become aware of M&S capabilities they prefer in the tool only during the operation of the M&S tool. If the ability to submit and document these capabilities immediately isn't made available, the idea or thought is lost before the MSTM is informed. The M&S tool website link would afford users the option of utilizing the website while the idea is still fresh in their minds, document it for the MSTM, create an electronic copy to which the users could refer to revise the recommendation as necessary (so as to capture the full meaning of their initial idea) and expound upon it. The website should have an embedded link in the M&S tool distribution package to ensure users could access it quickly and easily.

The periodic hard copy questionnaire would serve as a reminder that user and external developer feedback and suggestions for improving the M&S tool are always welcome. The hard copy is mostly to remind users and external developers that don't or haven't used the website to submit new capability suggestions. The questionnaire would also provide the M&S customer the opportunity to reflect back and review past M&S tool usage and determine if there were situations in which the M&S tool could be used if it contained additional capabilities and what those capabilities need to be.

5.1.2 CCB Approved Recommendations Implemented

Users and external developers need to be included in discussions regarding integrating recommendations for additional M&S tool capabilities. Failure to involve peers and users in any M&S tool decision-making body responsible for reviewing recommendations may lead eventually to an M&S tool with many capabilities, few of which are applicable to the current M&S tool users.

Having implemented a process for acquiring requirements for needed changes (discussed previously), the tool manager should implement a process designed to accomplish the following activities regarding those requirements:

1. Evaluating them;
2. Prioritizing the needed changes and judging the impact that waiting to implement high priority capabilities would have on the customer base.

The following specific actions are recommended:

1. The MSTM should establish a CCB that meets periodically (at most quarterly, at least annually) to review requirements for new M&S tool capabilities. The board membership should include the MSTM, at least two representatives from the developers of the tool, at least one representative from each major user organization (with an option for additional members left to the discretion of the MSTM), and a minimum of one external developer from each user who customizes the M&S tool. The periodic meeting, for which participation is not mandated but should be highly encouraged, could be accomplished in a multitude of ways as agreed upon by the CCB with a majority vote: face-to-face, teleconference, or videoconference. All major user organizations delineated earlier should be advised and encouraged to provide the minimum required personnel. All representatives should avail themselves for each periodic meeting or appoint an alternate to represent them in their absence.
2. The MSTM should act as the chair and discussion facilitator of the CCB. His/her responsibilities should include gathering all recommendations (from the website and the periodic hard copy questionnaires) for the CCB board to consider. The CCB should then evaluate each proposed new capability to gauge requirement validity (any new capability must be traceable to a valid need) and determine if it should be integrated into the M&S tool. Only those new capabilities selected for inclusion should proceed further in the process. Having determined which new capabilities will be integrated, the CCB should then prioritize the changes.
3. Once the recommended capabilities have been prioritized, the CCB should determine a timeline for implementing the new capabilities based on the level of user demand for the new M&S capabilities and to the degree allowed by funding, schedule, knowledge, personnel, technology, and security constraints. Once the timeline has been established, the MSTM should instruct the M&S tool developer to begin implementing the new M&S capabilities.

5.1.3 Justification for Excluding User Requirements is Promulgated

Once the CCB has made its decisions regarding which recommended new changes will be included in an updated version of the M&S tool, the MSTM should notify all users of all the recommendations that were submitted and those that were approved. The CCB should provide, to all user groups and users, its justification for not satisfying certain requirements. This information should be disseminated by the MSTM using the same website where recommendations were submitted by users and external developers as well as an “all-users” e-mail. Each user that submitted a requirement that was rejected should be contacted by the MSTM to explain why it will not be integrated into the next version of the M&S tool. This step is believed to be important in ensuring that recommendations for further capabilities continue to be submitted, and that the user base remains engaged in the process.

5.1.4 Tool Manager Engages Users and External Developers

The MSTM, by his/her position, has the ability to greatly influence the M&S tool's ability to remain a viable, usable, and productive M&S resource. One of the most effective means to achieving this objective an MSTM can employ is to consistently interact with M&S tool users and external developers. By establishing and maintaining dialog with users and external developers, the tool manager can cultivate an environment in which the M&S tool is discussed in a candid and open manner.

The following actions are recommended to assist an MSTM in establishing and maintaining relationships with users and external developers:

1. Establish an on-line "User Forum." This forum should be used by users / external developers to pose questions to the tool manager and developer(s), as well as to discuss problems or difficulties they are encountering when using the M&S tool. The tool manager and developer(s) should monitor on-line forum frequently (perhaps twice per week with tools with large user bases) to answer questions and to familiarize themselves with issues that are arising with users of the M&S tool. If a user, gauging by the comments posted on the "User Forum," appears to be dissatisfied with the M&S tool, the tool manager should contact the user directly to discuss their issues and attempt to resolve the situation.
2. Host a periodic (perhaps monthly) teleconference to augment the online forum. This user teleconference should be voluntary, but all users should be highly encouraged to participate. The teleconference should allow users to raise issues, promote new ideas, and foster a collaborative environment among users and external developers.
3. Host face-to-face User Group Conferences periodically. The User Group Conferences should be open to all users and external developers of the M&S tool. To minimize travel, the conferences and CCB meetings should occur back-to-back. Depending on the size of the tool's user base, the frequency and location could vary. For tools with smaller user bases, there might be one per year at the MSTM's or developer's location. For tools with larger user bases, there might be two (or even four) per year, and the locations might be rotated geographically to facilitate user participation. The MSTM and developer should be present at these user group meetings to facilitate M&S tool discussions and the exchange of ideas both within the user community and among users and developers.

5.2 BASELINE DEVELOPMENT

Findings – The source code baseline of an M&S tool may be allowed to "fork" or diverge into multiple, non-interoperable versions (though, for short durations) as long as there is a plan of action in place to merge the forks back into a single-source baseline ("the street version") in the near future. In order to prevent unnecessary M&S tool forking, to facilitate the

merging of forks, and to ease the work required to integrate externally-developed capabilities into the M&S tool baseline, the MSTM should establish and publish a software coding standard and style guide.

Task Categories – The study revealed that MSTMs, like all software managers, need to adhere to sound software engineering practices. The risk of baseline forking increases the need for strict adherence to these practices, and foresight to prevent irreconcilable divergence. The three task categories as they pertain to baseline development are that an MSTM:

1. Has a process for managing the tool baseline(s) that prevents irreconcilable divergence.
2. Has implemented a process to acquire and assess (using a peer / user review process) externally developed capabilities for inclusion into the baseline tool.
3. Publishes a coding standards and style guide with which all externally developed capabilities are required to comply.

Each of these three task categories is discussed below, and best practices for each of the three categories are provided.

5.2.1 Managing Divergence

Irreconcilable divergence of an M&S tool's baseline eventually leads to divergence into two or more separate tools with the predictable and undesirable effect of correspondingly dividing the user community and resources. This bifurcation also creates confusion for potential new users who might be confused by two tools with the same name but different functionality. This is not to say that temporary divergence for the purpose of experimenting with new functionality or architectures is a bad idea; but such excursions should include a plan and process for achieving convergence when the excursion is complete.

This practice is closely tied to incorporating externally-developed enhancements, because externally-developed enhancements from different sources increase the probability of conflict between enhancements that must be harmonized by the tool manager. Potential divergence mitigation strategies are therefore correspondingly tied to strategies for incorporating enhancements.

First, the MSTM should evaluate the costs and risks of accepting externally-developed enhancements. While allowing externally-developed enhancements may offset development costs and increase functionality, there are additional infrastructure and process costs associated with managing such enhancements. Accepting such enhancements usually requires distributing source code, but this has the attendant risk of enabling more divergence. This risk can be mitigated by requiring signed agreements before providing source code, e.g., to submit modifications for integration back to the baseline.

In the case where the MSTM has sufficient funding and scope to accept enhancements from many sources, a CCB (as recommended in Section 5.1.2) that includes technical experts is in order. The technical expert members of the CCB must be sufficiently experienced in the both the M&S tool architecture and the modeling domain to be able to fully assess potential impacts of proposed changes. The CCB would be aided in its work by coding standards and by regression testing activities.

Some MSTMs may only accept inputs from a restricted set of "trusted sources." A CCB is still useful in this circumstance, but its workload should be less since the trusted sources can be expected to be more compliant with coding standards. The tool manager may restrict the scope of enhancements that these trusted sources are allowed to submit, reducing the probability of conflicts between submitted changes. The tool manager may also off-load some of the unit testing responsibility to the trusted sources.

One of the more innovative solutions that the study team saw in this category was providing a framework for users to integrate their own plug-ins or libraries. In the absence of funding sufficient to establish a CCB and a large regression-testing framework, a plug-in framework allows users to have their own enhancements without endangering the stability of the M&S tool's code baseline.

Finally, any planned experimental excursion should only be undertaken with a clearly written plan delineating the purpose and scope of the excursion, including what M&S tool elements will be affected and the process by which modifications from the baseline will be resolved back into the baseline, e.g., whether the excursion or the baseline will generally be given precedence.

5.2.2 Incorporating Externally-Developed Enhancements

Although the CCB and regression testing ensure that enhancements don't negatively impact the stability of the code baseline, they don't address how enhancements are initially considered for inclusion. If the tool manager accepts enhancements from the entire user community, "advertising" this option should be part of the tool manager's regular communication with the user community. If enhancements are only accepted from trusted sources, this advertisement may include restrictions on what types of enhancements will be accepted from which sources.

As discussed in Section 5.1.2, the tool manager should use the CCB to assess the desirability of submitted enhancements. This is separate from assessing the implementation of the enhancement. Rather, this review is to determine if the proposed enhancement provides functionality of general interest and value to the user community, and therefore deserves to have additional resources applied to have it integrated into the baseline.

In all cases, the tool manager should publish the process for assessing enhancements including criteria and schedule. The process should include forms or templates for submissions to ensure that all the information necessary to support the CCB is available when needed.

5.2.3 Coding Standards

Having coding standards is generally considered to be a sound software engineering practice and, as noted previously, it is particularly important in this case because enhancements may be accepted from sources outside the direct control of the tool manager. In addition to the usual elements of a software coding standard and style guide, the tool manager may include tool-specific guidance such as fidelity considerations and algorithm documentation.

Failure to adhere to the coding standards and style guide may be grounds for preliminary rejection of a submitted enhancement.

5.3 TESTING, QUALITY ASSURANCE (QA), AND V&V

Findings – A rigorous quality assurance process was identified in the study's survey as being required to ensure the quality and viability of an M&S tool. QA, and a supplemental V&V process, was most often cited as necessary to ensure that an M&S tool remains credible and broadly employed within the user community. Releasing a product that has not been thoroughly tested may result in an M&S tool that provides its users erroneous data. Earning the confidence and trust of any M&S tool user is a difficult and time-intensive task. However, this hard-earned confidence can be lost very quickly if the M&S tool is not tested adequately to ensure the quality of its output.

Task Categories – The study showed that MSTMs understand the importance of producing and maintaining tools of high quality and credibility, although they often struggle to find the resources to perform some of the more routine tasks, such as regression testing. The two task categories pertaining to baseline development are that an MSTM:

1. Has developed and implemented a quality assurance process that rigorously evaluates each new baseline tool implementation before final product release.
2. Receives and expends the funds necessary to conduct thorough V&V regression tests on all new baseline releases to ensure past functionality has not been compromised.

Each of these two task categories is discussed below, and best practices for each of the two categories are provided.

5.3.1 Quality Assurance Process

QA applies not merely to testing of an M&S tool just before each release (although that is clearly necessary), but to the quality management process employed throughout the M&S tool's development. QA processes for software products that have been developed over many years in the software engineering community clearly also apply to M&S tools that are themselves

software products. An MSTM may apply, and tailor to his/her own tool's specific situation, a software QA process available in the software engineering literature.

A QA process incorporates many if not all of the aspects of verification, which ensures that the software product meets its requirements and was correctly implemented. The QA foundation is extended through a supplemental validation process that ensures that the M&S tool results provide sufficient representation to meet the intended uses of the tool ("fitness for purpose"). M&S tools that are not models or simulations (see definition of M&S tools in Appendix B) are sufficiently covered by the verification inherent in the QA process. However, for M&S tools that are models or simulations, the additional validation function is focused on ensuring that the tool adequately represents the real world from the perspective of the intended uses of the model or simulation. The DoD M&S Verification, Validation and Accreditation (VV&A) Recommended Practices Guide (RPG) [Reference (g)] contains many useful best practices in the area of V&V that are not repeated here, but that are incorporated in these recommendations by reference. Similarly, templates have been developed in the DoD M&S VV&A community to aid in VV&A documentation, including templates for VV&A Plans and VV&A Reports [References (e) and (f)].

From a best-practice standpoint, the QA process for each new release of an M&S tool should include the following elements, as a minimum, with the level of detail and degree of formality tailored to the specific tool:

1. Each release should have a set of requirements that are defined at the start of the effort, which is maintained and updated as needed throughout the development process.
2. A QA plan (that includes V&V) should be developed soon after work on the release has been initiated, and should be followed throughout the development of the release.
3. A test database should be developed that supports both verification and validation activities.
4. Design meetings and reviews should be scheduled, conducted, and documented at appropriate points in the development of the release.
5. Testing should include tests of individual software units prior to integration testing.
6. Acceptance test cases for new functionality implemented in the release should be documented, along with expected outcomes, prior to the commencement of testing, and the results of the testing for each test case should be compared to expected outcomes and documented.
7. For releases that include fixes for known defects, acceptance tests should include a test case which has been demonstrated to fail with the previous release containing the defect.
8. A QA report (that includes V&V) documenting test activities that were performed should be written for each release.

The following additional best practices should be considered as M&S tools develop a more experienced and involved user base, and for tools with co-development agreements:

1. User representatives (and co-developers, where applicable) should be invited to participate in review meetings held throughout the release development process.
2. Supplemental testing should be done by selected expert users from the tool's user community prior to each release.

For M&S tools that are models or simulations, the QA process for each new release should also include the following elements, as a minimum, with the level of detail and degree of formality tailored to the specific tool:

1. A conceptual design should be created prior to the initiation of detailed software design, to help ensure that the new functionality will support a valid representation of the portion of the real world that it represents.
2. To the degree that a real-world referent is available for new functionality, validation should include comparison of model/simulation results with these data. If a real-world referent is not available, and validation is performed by SMEs, the qualifications of the SMEs should be documented.
3. Results of validation testing should be documented. [See Reference (f) for a template.]

The following additional best practices should be considered for models and simulations with user bases involving multiple constituencies with potentially competing interests:

1. Supplemental validation testing may be performed by SMEs with the appropriate domain knowledge to insure that the M&S tool supports the intended applications of the user community(ies).
2. V&V by an independent third party on selected model/simulation implementations may be performed and documented.

5.3.2 Regression Testing

There are two distinct parts to the best practices associated with regression testing, the first of which is primarily technical in its motivation, and the second of which is more focused on management planning. The need for regression testing is well-understood in the software engineering community, as introduction of new functionality can sometimes have unintended negative consequences for existing functionality. So the first part of the regression testing challenge is to determine the appropriate set of regression tests to perform for each new release. Although performing a "complete" set of regression tests may be the ideal situation from a technical perspective, there are clearly trade-offs between the cost of more complete regression testing and the risk of not performing a test that might uncover a key unintended consequence.

The second part of the best practices associated with regression testing, which was cited as a problem by a significant number of MSTMs in the survey conducted as part of the study, is the programming and use of funding to support thorough regression testing. Chapter 6 includes a recommended action on the provision of funding, geared toward an initial set of pilot programs. Although the actual allocation of funding for an M&S tool may be performed outside an MSTM's direct authority, advocacy for an appropriate level of funding, and the use of available funding, for performing regression testing best practices is within the MSTM's purview.

From a best-practice standpoint, regression testing for each new release of an M&S tool should include the following elements (to the degree they apply, as noted in each description), with the level of detail and degree of formality tailored to the specific tool:

1. When new releases are funded in whole, or in part, by individual users seeking new functionality, the MSTM should obtain funding from those users for an appropriate amount of regression testing. (See also the related recommended action on funding for pilot programs in Chapter 6.)
2. The QA plan for each release should include plans for a set of regression tests that has been evaluated for its cost effectiveness, based on the scope of M&S tool modifications included in the release.
3. If the M&S tool's release development process is an incremental one, in which integration is performed multiple times during the development, regression testing should be performed incrementally as well, so that problems can be isolated earlier in the development process.
4. If the M&S tool is expected to operate in multiple operating system or computing system environments, regression testing should include testing in each of those environments.
5. In conjunction with introducing new functionality into a release, a set of regression tests to ensure that functionality is maintained in future releases should be developed.

Not all regression testing best practices can be performed in isolation for each release of an M&S tool. Regression tests need to be built in a cumulative fashion as a part of the ongoing M&S tool management process. The following elements of an effective regression test program are best practices that apply across multiple release development cycles:

1. The MSTM should advocate for a recurring funding stream from his/her management (or collective user base, depending on the nature of the particular M&S tool) to permit ongoing regression testing not directly related to a particular release of the M&S tool. (See also the related recommended action on funding for pilot programs in Chapter 6.)
2. The MSTM should maintain a cumulative set of regression tests across all releases of the M&S tool, which includes documentation of the specific functionality that each regression test is designed to address.

5.4 BASELINE MAINTENANCE

Findings – Baseline maintenance of an M&S tool is required to maintain the tool's currency. Advances in technology necessitate that this maintenance be conducted on a regular basis in order to maintain the M&S tool's ability to adapt to these new technologies as they become the new standard in the M&S community. The failure of MSTMs to conduct this maintenance will ultimately result in users migrating away from legacy tools that have failed to stay abreast of recent advances in the field. As potential users become aware of this lack of M&S tool maintenance, they will not be inclined to adopt this tool for their M&S needs.

Task Category – The study showed that MSTMs, like other software development managers, were often not adequately funded to maintain the tool's functionality. Maintenance funding was often perceived by sponsors as nonessential to their requirements. The task category pertaining to baseline development is that an MSTM:

- Receives consistent and adequate funding to conduct tool baseline maintenance, exclusive of baseline enhancements, to ensure the tool remains compatible with current software and hardware products used within the M&S community.

This task category is discussed below, and best practices are provided.

Software Baseline Maintenance Funding

The tool manager needs to receive an adequate, dedicated funding stream for maintaining the software. Maintenance activities include correcting of faults, refactoring of the code, reengineering of parts of the code to improve performance, porting the code to new operating environments and deletion of functionality that is no longer needed. This also allows the tool to remain compatible with current software and hardware products, as well as evolving standards (such as the High Level Architecture).

Three needed attributes of this funding stream are that it is adequate, that it is dependable, and that it is dedicated, as described in the following.

1. The funding stream needs to be adequate for the required level of effort. As the software functionality increases, the amount of the baseline maintenance funding must also increase.
2. The funding stream needs to be dependable. Although the amount spent on maintenance will vary from year to year, the fact that there will be funding must be assured. Some maintenance efforts may be multi-year projects, and a dependable funding stream is the only way to allow long-term planning.
3. The funding stream needs to be dedicated strictly to baseline maintenance. This stream must be guarded from being used to fund functionality enhancements.

The tool manager may either have a group of software engineers who are dedicated to maintaining the baseline or require all of the software engineers to spend a percentage of their time on maintenance efforts.

Users should be encouraged to migrate to the latest version as maintenance occurs. However it is possible that there will be a need to maintain multiple versions of the tool while users migrate. The older versions need to be dropped from being maintained after sufficient notice to the users.

5.5 CUSTOMER SUPPORT

Findings – If M&S tools are to be broadly used, potential users are going to need access to comprehensive sets of M&S tool documents to determine whether or not a tool is capable of meeting their specific needs. Timely customer support further facilitates the broad use of M&S tools, as users are going to be drawn to M&S tools that offer their users timely support and assistance.

Task Categories – The study illustrated two styles of user support. The users associated with the initial development, use, and funding of the tool were "insiders," well known by the tool developer, and their support came with an understanding of their problem. Users who adopted the tool once it was established were not as well known, and were expected to translate their problem into the perspective of how the tool works. The two task categories as they pertain to customer support are that an MSTM:

1. Updates the User's Guide and / or Technical Reference Manual with each baseline enhancement release, including constraints and limitations.
2. Provides timely and responsive customer support, e.g., a competent and adequately staffed Help Desk.

Each of these two task categories is discussed below, and best practices for each of the two categories are provided.

5.5.1 Technical Documentation

Technical documentation provides the reference frame for the MSTM to support the tool users. The documentation required depends on how the tool is used. Tools that provide sophisticated user interfaces to define and control their behavior will have users who never work below the user interface. In this situation, the user documentation must provide adequate guidance to address the user's concerns without presuming that the user knows how the tool works. Many tools for which source code is made available will have users who need to know, or to change, how the tool works to apply it to their problem. Programming documentation, specific to the implementation and kept up to date with changes, must explain how the tool

works to a knowledgeable software engineer without presuming that the software engineer knows how the original users planned to use the tool.

Adopting a tool represents a significant investment on the part of a potential user. The cost to examine multiple candidates and then tailor one to the problem must be traded off against the cost to make a potentially duplicative tool from scratch. It is in the best interest of the DoD to minimize duplicative tools, and, as a result, tool managers should seek to minimize the investment needed to adopt a broadly applicable tool. The documentation needed for a potential user should be distilled from user and programmer documentation, rather than simply providing potential users with encyclopedic manuals and forcing each potential user to spend more effort learning the tool. Conference or workshop papers and the corresponding presentations provide one common form of this potential user documentation.

Tool managers can adopt this best practice through implementation of the following activities:

1. Common software engineering practices that develop software engineering documentation as part of the tool's software development process should be mandated. Each release of the tool should include a complete documentation package, and common software engineering utilities should be employed to produce the package. Each release should also provide documentation of the changes made to the previous release. These "release notes" should provide existing users details of the defects fixed and the features added, and should help to identify potential conflicts with their local modification and practices.
2. User documentation should be produced by users of the tool, rather than its developers. Tool managers may need to establish separate funding accounts in order to achieve this allocation of work. Test cases and results are the software engineering artifacts most applicable to users, but separate user documentation provides superior readability. User documentation should describe how to use the tool's capabilities as well as comprehensive descriptions of constraints, assumptions, and limitations. User interface or procedure change documentation for each release should include both new features and incompatible changes to existing features. User testing, verification and validation, and user documentation have significant overlaps, and tool managers should seek synergies when tasking these activities.
3. Since broadly useful tools can only become broadly used if new users can effectively find out about them, mechanisms for discovery of an M&S tool and awareness of its capabilities need to be leveraged, as in the case of the DoD M&S Catalog, or developed. Potential user documentation should start with an informative tool website. From there, potential users can be directed to the appropriate points of contact (PoCs) for access to the tool and its materials. The writing and presenting of professional papers, regardless of formality, from user case studies to technical

algorithm details, provide self-contained documentation very helpful to potential users. Re-purposing the release notes or user documentation changes for each release into these forms need not be an expensive undertaking once the documentation is produced for existing users.

The tool manager can assure that developers and users who are funded to produce the needed documentation have deliverables for their tasks that include both the formal documentation and the corresponding presentations or white papers.

5.5.2 Help Desk

Static information, from an informative website to detailed documentation, cannot take the place of expert advice. The best tool managers provide direct interaction with users and potential users. Dynamic interaction serves the users, by quickly pointing them to relevant information. It also serves the tool manager, building a list of user contacts, identifying common questions or problems, and contributing to requirements as described in Section 5.1.

Modern technology should be used to minimize the cost of the Help Desk activity. Rather than a physical facility, the Help Desk capability can be provided through a virtual organization. The first level of static information can be distributed through a public website or, for access control, through an authenticated web portal. The technical documentation can be supplemented on the web with frequently asked questions culled from previous Help Desk interactions. The second level of dynamic information can be accessed through a form on the web site or a Help Desk phone number. Phone calls could be routed to an administrator or messages recorded for electronic distribution. Electronic distribution to a screening contact provides a mechanism to respond quickly to user requests. Routine information or access queries can be handled by referring the user to available static information. After a response indicating that the question is being investigated, queries without off-the-shelf answers can be forwarded to a mailing list of expert developers and users. The tool manager should define the extent of effort applied to a query, and approve additional research if the Help Desk correspondent is sufficiently important.

6. RECOMMENDED ACTION ITEMS

One of the objectives of this study is to recommend actions DoD should take to improve its management of broadly-needed M&S tools. The following recommended actions would best be implemented at the DoD enterprise level. However, they could also be implemented in a smaller DoD M&S community of interest for M&S tools that are broadly needed within that community. There are three recommended high-level actions that DoD should execute in order to further facilitate the broad use of M&S tool resources:

1. Publish and promulgate a Recommended Practices Guide for the management of broadly-needed M&S tools;
2. Identify and establish a limited number of short-term (up to two years in duration) pilot efforts for selected existing broadly-needed DoD-supported M&S tools, to verify the merits of the recommended best practices; and
3. Establish and maintain an effective M&S tool catalog / registry with metadata to support discovery and potential reuse of M&S tools.

The first two recommendations concern actions that currently are not being implemented and need to be. The third recommendation is not expected to be implemented as part of this initiative, but is currently underway and is considered important to the management of broadly-needed M&S tools.

6.1 PUBLISH A RECOMMENDED PRACTICES GUIDE

A Recommended Practices Guide for the management of broadly-needed M&S tools is a means to provide MSTMs with a resource they can reference to improve their management of broadly-needed M&S tools. The guide should contain the twelve best practices previously discussed in Chapter 5, as well as additional resources. To reemphasize, the guide is not designed to inhibit or restrict a tool manager in executing the responsibilities as tool manager, but merely to furnish the tool manager some foundational building blocks in managing a broadly-needed M&S tool. The guide is not intended to be all-inclusive of best practices. The tool manager still has the option (and is encouraged) to explore additional M&S tool management approaches, techniques, and other ideas he/she feels may improve the overall management of broadly-needed M&S tools. Given the fact that tool managers are free to explore and implement innovative ideas with regard to M&S tool management, successfully implemented novel ideas should be documented and shared across the M&S tool management community.

6.2 ESTABLISH SHORT-TERM PILOT PROGRAMS (UP TO TWO YEARS)

The following actions should be taken to aid the pilot programs:

1. Allocate a limited amount of funding for the broadly-needed M&S tools identified as pilot efforts to conduct baseline M&S tool maintenance activities, such as regression testing and ensuring that the tool remains compatible with evolving software and hardware used within the M&S community. This recommendation would provide funds to tool managers so that they can perform basic M&S tool maintenance and update the M&S resource in order to keep it current and applicable as technological advances in software and hardware lead to incompatibilities between the M&S tool and current technological advances being introduced within the M&S community. The goal is to prevent and alleviate obsolescence of the M&S tool resource prematurely. In addition to performing M&S baseline maintenance, the tool manager must ensure the integrity of the M&S tool has not been compromised when performing baseline maintenance. Regression testing must be performed to guarantee previous M&S tool functionality has not been compromised or corrupted. Failure to validate the correct operation of an M&S tool after conducting baseline maintenance could result in a "loss of confidence" in model output within the M&S tool user community and the larger M&S community, as well. This "loss of confidence" would be catastrophic to any M&S tool.
2. Allocate a limited amount of funding to help defray the costs incurred by the managers of the broadly-needed M&S tools identified as pilot efforts to implement improvements to M&S tool management practices. The allocation should be based on plans of action submitted by the MSTMs that explain the practice improvements to be implemented. Such plans should be consistent with the Recommended Practices Guide in Section 6.1 and may include "discovery tasks" to implement and assess the effectiveness of innovative M&S tool management approaches of potential benefit to the broader M&S community. DoD can use the pilots as a means to test and validate, on a small scale and for a limited time, the recommendations contained within the Recommended Practices Guide. The intent is to ensure the recommended practices are cost effective and achieve the goal of fostering the broad use of M&S resources across government agencies and within DoD. If the pilot programs prove the effectiveness and validity of the recommendations, DoD can then consider promulgating the recommendations as a standard for the management of broadly-needed M&S tools.
3. Provide for the services of an M&S tool management subject matter expert cadre to assist the pilot efforts in implementation of the best practices, as needed. The subject matter expert cadre is provided to aid new or inexperienced tool managers implementing some or all of the best practices during the pilot programs
4. Provide a configuration management system, if not already implemented by the pilot efforts, at no charge to the pilot efforts (such as is currently available through forge.mil via the Defense Information Systems Agency).

5. Develop a Continuous Learning Module (CLM), appropriate for hosting by the Defense Acquisition University (DAU), on lifecycle support for M&S resources, suitable for both MSTMs and M&S resource sponsors. This CLM should include material on the need for M&S testing, documentation, V&V, maintenance, and help-desk services, and should draw on materials in the Recommended Practices Guide.

6.3 RECOMMENDED CRITERIA FOR PILOT PROGRAM SELECTION

The study team identified three recommended criteria for the selection of M&S tools for participation in the pilot programs recommended in the previous section.

1. Each M&S tool selected must exhibit the potential to be broadly used or be currently used broadly within the M&S community. Selecting M&S tools that aren't currently broadly used, and that in all likelihood will never be broadly used (e.g., because of their very specialized area of application), would be counterproductive to the study's overall goal. Selecting M&S tools that could be (and probably should be) broadly used is more aligned to the study's objectives.

2. Of the M&S tools that pass the initial requirement, one M&S tool currently implementing a minimum of eight of the Recommended Best Practices should be included in the pilot program. The selected M&S tool should then receive the centralized funding necessary to implement the remaining Recommended Best Practices. The centralized funding should only be allowed to be used to implement recommended best practices not currently implemented. The additional funding should not be able to be used by the M&S tool manager to offset the funding of current program requirements. It is anticipated that this M&S tool could then become the "exemplar" for how to manage an M&S tool that meets the needs of its customer base while simultaneously being broadly used by numerous organizations. A second M&S tool (also meeting criterion 1, above) that currently implements five or fewer of the Recommended Best Practices should be chosen as well. The M&S tool selected would be used as a "bootstrapping effort" to gauge the effectiveness of providing additional centralized funding to M&S tool managers to help implement additional Recommended Best Practices.

3. Two M&S tools that are representative of the range of model complexity within the community should be selected for the pilot program. In order to determine the efficacy that both centralized funding and the Recommended Best Practices will have on improving the management and increasing the broad use of a tool within the community, the pilot programs should include M&S tools that have different levels of complexity that are found within the community. An M&S tool with a highly complex architecture, (i.e., many interactions between multiple simulated entities, multiple data sets and databases, and entity interactions that are highly variable and dynamic in nature) should be included in the pilot program. A second M&S tool with a moderate level of complexity should also be included in the pilot program.

Selecting an M&S tool that has a moderate level of complexity and another with a more intricate architecture (leading-edge technology) will ensure the pilot program has adequately addressed a large segment of the range of model complexity when assessing the effectiveness of both centralized funding and the implementation of the Recommended Best Practices on improving the management and broad use of M&S tools.

If the pilot programs cannot be funded at a level that would allow all of the Recommended Best Practices to be implemented, then M&S tools that are similar to each other and that currently implement a different subset of the best practices should be used as a criterion for inclusion into the pilot program. Selecting M&S tools using this characteristic would allow DoD to make a reasonable assessment regarding which of the Recommended Best Practices have the greatest impact on improving the management and broad use of M&S tools. Armed with this knowledge, DoD could prioritize (and possibly mandate) the precedence in which an M&S resource manager implements the Recommended Best Practices with the centralized funding provided.

In order to help determine the impact that centralized funding could have on improving the management and facilitating the wide use of broadly-needed M&S tools, a pilot program "control group" is recommended. This group should consist of the same number of M&S tools that are selected to participate in the pilot program. The control group M&S tools should mirror the pilot program's M&S tools as much as possible (i.e., the same selection criteria should be used). The only discernible difference should be that the control group would not be required to implement the Recommended Best Practices and would receive no additional funding from a centralized source to implement the Recommended Best Practices, other than the normal funding that the tool receives from its usual sources. The control group should be provided a copy of the best practices guide that delineates and discusses the Recommended Best Practices. If and how the M&S tool manager implements the best practices would be entirely up to the M&S tool manager. The control group M&S tool managers and a subset of their users need to agree to complete a self-assessment of the M&S tools in question, at both the commencement and conclusion of the pilot program. This requirement also needs to be placed on M&S tools selected to participate in the pilot program.

As part of the overall pilot implementation, the effectiveness of these actions should be evaluated, to determine if they would be beneficial in the long term.

6.4 ESTABLISH AN EFFECTIVE DOD M&S TOOL CATALOG / REGISTRY

As mentioned earlier, another DoD effort is currently underway to improve how potential users can locate M&S resources, establish contact with MSTMs, assess the M&S resource, and

gauge if a current M&S tool resource may be capable and available to meet a modeling and simulation need, before attempting to develop a new M&S resource. Although not expected to be implemented as part of this initiative, the establishment and maintenance of an effective DoD M&S tool catalog/registry with metadata to support discovery and potential reuse of M&S tools is considered important to the management of broadly-needed M&S tools.

APPENDIX A: REFERENCES

(a) Systems Engineering Forum, Office of the Under Secretary of Defense (Acquisition, Technology and Logistics), Defense Systems, *Acquisition Modeling and Simulation Master Plan* (April 2006).

(b) Shea, D. P., and Graham, K. L., "Business Models to Advance the Reuse of Modeling and Simulation Resources," Center for Naval Analyses, CRM D0019387.A1/SR1, January 2009.

(c) Morse, K. L., et al, "Best Practices for the Development of Models and Simulations – Final Report," Johns Hopkins University Applied Physics Laboratory, NSAD-R-2010-037, June 2010.

(d) Department of Defense, "DoD Modeling and Simulation (M&S) Management," DoD Directive 5000.59.

(e) Department of Defense, "DoD Modeling and Simulation (M&S) Verification, Validation, and Accreditation (VV&A)," DoD Instruction 5000.61.

(f) Department of Defense, "Documentation of Verification, Validation, and Accreditation (VV&A) for Models and Simulations," Military Standard (MIL-STD) 3022.

(g) Department of Defense, "The DoD M&S Verification, Validation and Accreditation (VV&A) Recommended Practices Guide."

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APPENDIX B: GLOSSARY

Model: A physical, mathematical, or otherwise logical representation of a system, entity, phenomenon, or process. [Reference (d)]

Simulation: A method for implementing a model over time. [Reference (d)]

Modeling and Simulation (M&S): The discipline that comprises the development and/or use of models and simulations. [Reference (d)]

M&S Tools: Software that implements a model or simulation or an adjunct tool, i.e., software and/or hardware that is either used to provide part of a simulation environment (e.g., to manage the execution of the environment) or to transform and manage data used by or produced by a model or simulation. Adjunct tools are differentiated from simulation software in that they do not provide a virtual or constructive representation as part of a simulation environment. [Reference (d)] [Note: A commercial example of an M&S tool that is not a model or simulation is Microsoft Excel, which, among other uses, can be used to create cost models. Other examples include many process modeling tools which, by the input of data and relationships, can be used to create a model or simulation of a process.]

M&S Tool Manager (MSTM): The individual or organization responsible for the management of an M&S tool.

Validation: The process of determining the degree to which a model is an accurate representation of the real-world from the perspective of the intended uses of the model. [Reference (d)]

Verification: The process of determining that a model implementation accurately represents the developer's conceptual description and specifications. [Reference (d)]

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APPENDIX C: OVERVIEW OF SURVEYS

Two web-based surveys were developed to collect input on M&S tool management practices. The first survey was directed toward M&S tool managers, and the second survey was directed toward users of M&S tools.

C.1. M&S TOOL MANAGERS SURVEY

A survey was conducted of M&S tool managers to solicit input on current practices for managing the development and maintenance of broadly-used M&S tools. The tool managers comprised both government program managers and contractor managers. Broadly-used was defined as those tools being used by more than one command or program within DOD.

The initial list of managers contacted was developed based on the experience of the study team and a literature survey of the Interservice/Industry Training, Simulation and Education Conference proceedings (1995-2008), the Simulation Interoperability Workshop proceedings, and the DoD and Service M&S Resource Repositories/Registries. This initial list was expanded based on recommendations from tool managers who responded to the survey.

Survey Overview

The survey begins with indentifying data of the responder, government sponsor, contractor information and tool identification. The remainder of the survey is given below.

Requirements Development

- How are user's requirements prioritized when funding and/or schedule are insufficient to meet all requirements (e.g., a management board made up of program sponsors and users)?

Design Development

- How does your architecture facilitate integration of externally developed functionality (e.g., incorporate source, libraries, or executable)?

Configuration Management

- Is the tool managed as one baseline or are parallel forks permitted?
- Is the code distributed as source or executable or both?

Code Development

- Describe the processes for integration of externally developed code vs. internally developed code.
- What have been the biggest challenges to maintaining a cohesive software baseline in this tool?
- How are conflicts between modifications submitted by different users/co-developers mediated?

Testing

- Describe how V&V is a formal part of the integration process.
- How are new releases of this tool tested (e.g., regression testing, reference data)?

Lessons Learned

- Positive or negative lessons learned
- Any other comments

C.2. M&S TOOL USERS SURVEY

A second survey was conducted of M&S tool users to solicit input on best practices for managing the development and maintenance of broadly-needed M&S tools. There was no requirement that these best practices be currently used.

Survey Overview

The survey begins with identifying information of the responder. The remainder of the survey is given below.

Requirements Management

- How should user requirements be prioritized when funding and/or schedule are insufficient to meet all requirements?

Configuration Management

- Is it critical to maintain a single source baseline, or are there circumstances under which multiple forks should be permissible? What criteria should be used to make this decision?
- Identify good tool distribution mechanisms/methods (for source, executable, or both).
- How frequent should releases be? Please describe the criteria upon which the frequency may depend, e.g. tool maturity, criticality of bug fixes.

Code Development

- Should externally developed code (by users or others) be integrated into the code baseline?
- How should conflicts between modifications submitted by different users/co-developers be mediated?

Test Management

- Should V&V be a formal part of the integration process?
- What processes/products are critical prior to product release, e.g., regression testing, reference data?

Lessons Learned

- Please describe any other management best practices that are critical to successful model management.

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APPENDIX D: SUMMARY OF SELECTED M&S TOOLS

After the survey results were analyzed, nine of the tools were selected as examples for detailed discussion in this report. The tools were selected based on the thoroughness of the responses, and the granting of permission to publish the information by the M&S tool manager.

D.1. EXTENDED AIR DEFENSE SIMULATION (EADSIM)

EADSIM is a workstation-hosted, system-level simulation which is used by combat developers, materiel developers, and operational commanders to assess the effectiveness of Theater Missile Defense (TMD) and air defense systems against the full spectrum of extended air defense threats. EADSIM provides a many-on-many theater-level simulation of air and missile warfare, an integrated analysis tool to support joint and combined force operations, and a tool to provide realistic air defense training to maneuver force exercises at all echelons.

EADSIM is used by operational commanders, trainers, and analysts to model the performance and predict the effectiveness of ballistic missiles, surface-to-air missiles, aircraft, and cruise missiles in a variety of user-developed scenarios.

Requirement prioritization

EADSIM relies on users to fund most enhancements. The EADSIM configuration control board (made up of program sponsors and representatives from all services) determines priorities for some SMDC funds. Most user-funded enhancements have the funds earmarked for that purpose. The model manager determines schedule priorities in consultation with the users.

External code

EADSIM is maintained as a single baseline. EADSIM provides for shared object / Dynamic Link Library (dll) use for code in some areas, with the code then retained by the user that develops the functionality. Externally developed tools for sensors and nuclear weapon effects have been integrated into EADSIM directly. Some classified functionality is provided as shared objects, allowing for separate distribution.

Verification & validation

EADSIM is tested by subject matter experts from the agencies sponsoring the modifications and by high-capability users before deploying new versions. There are limited independent V&V examinations.

Testing

A large, growing set of standard regression tests has been established by the developers.

Distribution

Releases for specific application deadlines happen many times every year. The general distribution release is at least yearly. Only executable is distributed.

Lessons learned & other comments

The biggest challenge has been multiple machine versions (Silicon Graphics, Sun, Windows, Linux).

D.2. JOINT ANALYSIS SYSTEM (JAS)

JAS is a C4ISR-centric, joint regional (campaign-level) model with integrated Strategic Mobility, Theater Logistics, and Joint Operations encompassing a broad range of military operations (ROMO). JAS is designed to support balanced representations of joint operations in a realistic environment. JAS considers all levels of war (strategic, operational, and tactical), but its focus is on the operational level. JAS is sufficiently flexible to deal with current, near-term, and future warfare concepts, doctrine, systems, and organizations of the United States, its Allies, Non-Governmental Organizations / Private Voluntary Organizations (NGOs / PVOs), civilians and potential adversaries. JAS represents multiple nations in multiple coalitions as well as neutral and opposing forces. JAS was formerly known as the Joint Warfare System (JWARS).

The representations of C4 and ISR form the foundation for how objects perceive and interact with one another in JAS. JAS maintains ground truth and current perceptions for each side. A side's ability to make and execute informed decisions is directly attributable to that side's perceptions of the battlefield.

The management responsibility and funding falls under the Office of the Secretary of Defense, Cost Assessment and Program Evaluation. The primary development lead is CACI International, Inc.

Requirement prioritization

A CCB reviews requests for new functionality. Extensive coordination and discussions occurs between users and developers. Over the 12-year development period, very few items that were submitted for integration have not been fully integrated. Some items were never submitted for integration due to their prototypical nature.

External code

JAS is maintained as a single baseline with extensions for specialized functionality. JAS is written in Smalltalk, an object oriented language using open architecture. Externally

developed functionality can be integrated into Smalltalk libraries or use dlls. Other proven interfaces: XML-compatible, and HLA RTI. Addition of new code, whether external or internal, begins with a conceptual software design followed by a detailed software design. Once developed, the code is tested and validated prior to release. The JAS Support Office (developers) reviews externally developed code, makes a recommendation to the CCB, and upon CCB approval ,performs detailed review and integration, followed by developmental testing of the baseline configuration.

Verification & validation

Each new release is tested in accordance with a V&V plan. Additionally, each modification includes a conceptual design to ensure the new functionality is a valid representation of the real-world system.

Testing

Service releases are tested using unit-level testing for new code prior to integration. Developmental testing is conducted after integration for all new functionality, and regression testing for legacy code is conducted against the full suite of unclassified and classified scenarios (some being Analytic Agenda developed). Each new release is tested using a number of unclassified and classified test scenarios and results are compared to those of previous versions. Entirely new functionality is tested by comparing simulation results to expected outcomes.

Distribution

JAS is distributed as both source code and executable, usually one to two times annually. Patches are distributed frequently on an as-needed basis.

Lessons learned & other comments

Successful M&S efforts require consistent funding. The lack of a reliable funding stream makes it difficult to plan software modifications in a coherent fashion. Once government management is stable and adequate staff is made available, software configuration and responsiveness to user requests have to be very effective. Smalltalk is a very flexible language that makes modification (both small and large) relatively straight forward. The simulation engine is extremely robust and very supportive of numerous cross-cutting applications, from analysis to war gaming and real-time course of action analysis; the architecture has been extremely agile and adaptive. As a result of its open and flexible architecture, JAS has been successful in demonstrating how the warfighting engine within the model can be interfaced across many of the DoD M&S communities at significant savings to the government.

There needs to be stronger coordination between advanced technologies and emerging doctrinal implications and modifications to the M&S tools. The outputs from the Defense

Science Board and the Services' equivalents need to be reviewed and considered under the DoD M&S tool long-term maintenance and enhancement plan. The M&S tools should lead the delivery of weapon systems, even if some of the technologies never get fielded.

In addition, there needs to be greater emphasis on model architecture. Many tools are designed and implemented in a manner that makes it very costly to upgrade to meet new and emerging technologies and doctrinal concepts. Ensuring that models are designed and developed with an open, flexible architecture, will greatly reduce future enhancements.

D.3. JOINT INTEGRATED MISSION MODEL (JIMM)

The management responsibility and funding of JIMM falls under Naval Air Systems Command (NAVAIR) 542, Battlespace Modeling & Simulation Division.

Requirement prioritization

Software Change Requests (SCRs) and Software Trouble Reports (STRs) are prioritized by a CCB made up of members of the user community. Final decision rests with the JIMM Model Manager.

External code

JIMM is maintained as a single baseline. JIMM does not incorporate external sources directly within the model. When such functionality is needed, it is integrated with the model through a shared memory interface. The JIMM model maintains a library of functions for use in creating interface programs to communicate between JIMM and external assets.

The model is configuration controlled using a configuration management (CM) tool (currently CVS, transitioning to AccuRev). For internal development, coders are required to check out the latest revision from the repository and develop and unit-test the code with their workspace. Once completed, the coder must run a set of integration tests to insure no unexpected changes in previous model behavior. The coder then checks the code back into the repository. The JIMM Model Manager Office (JMMO) currently does not fund external organizations to develop code. However, the JIMM source code is distributed with the release, and users are free to modify the code for their own purposes, provided they do not distribute the modified code, and they provide any such changes back to the JMMO. Such modifications are reviewed by the CCB for applicability to the user community as a whole. The code is reviewed by the Development Lead for accuracy and compatibility with the current baseline. If approved by the Model Manager, the software changes submitted by the user are assigned to an internal developer for integration into the baseline, using the same procedures as used for internally developed code. If there is a conflict, the impacted coders are required to resolve the difference. If they are unable to, it is the responsibility of the Development Lead to resolve the issue.

Verification & Validation

For STRs, the coder must have an example scenario that exhibits the reported behavior. This scenario must run correctly before the coder can merge his development back into the baseline, and must run correctly on the merged baseline. For an SCR, the coder must have a scenario which tests the new functionality, complete with an expected set of results that prove correct functionality. This scenario must run correctly before the code can merge his development back into the baseline, and must run correctly on the merged baseline. The scenario is then added to the Parallel Acceptance Test Plan (PATP) (see new release testing, below). There also exists a set of scenarios that must be run for both STRs and SCRs to insure that no unexpected changes occur in model behavior (repeatability checks). In addition, if the modification is considered to be extensive enough, the Model Manager may require the PATP, or some subset of it, be run after merging into the baseline.

Testing

The JMMO maintains a PATP. This consists of an extensive set of vignettes testing individual functionality. Each test has an expected set of results that indicates correct functionality. The PATP also contains a set of shell scripts (Perl) that run the vignettes, in a multi-processor environment, and check that the results match the expected behavior.

Distribution

JIMM is distributed as both source code and executable approximately twice a year.

Lessons learned & other comments

There are two primary challenges, one systemic and one transitory. The systemic challenge lies in developing and reintegrating major modifications to the code that may remain separate from the baseline for long periods. The transitory problem lies in integrating code modifications to the previous baseline (JIMM2x) into the current baseline (JIMM3x) due to the large architectural differences between the baselines.

Originally, the PATP was a set of vignettes that were run serially. This required a long period of time. Thus, the tests were only run prior to release. This meant that when failures occurred, the coders had to search the entire set of changes since the last release to find the offending code modification. With the PATP, the ability to use multiple processors significantly reduced the time necessary for a full test run. This allowed us to start using the PATP on a weekly or even nightly basis. This allowed errors to be caught earlier, when the field of possible candidates was smaller.

D.4. NAVAL SIMULATION SYSTEM (NSS)

The NSS Model Manager is the Space and Naval Warfare Systems Command (SPAWAR 051). Funding comes from each specific activity paying for a specific update to satisfy its mission and is coordinated by the NSS Model Manager.

Requirement prioritization

Each improvement is funded by the specific user requesting said improvement, upon approval by the NSS Model Manager. Industry-funded improvements are implemented on a not-to-interfere basis with improvements directed by primary government sponsoring organizations. The developer notifies the NSS Model Manager whenever a sponsor indicates an intention to fund a specific software upgrade. The NSS developer is responsible to the NSS Model Manager for identifying any known or potential conflicts arising from said upgrade requests and the Model Manager adjudicates a resolution that considers NSS stakeholder needs and software design objectives.

External code

NSS is maintained as a single baseline. Most development is performed by the prime contractor. NSS accepts plug-ins for sensors and other systems that are implemented using Win32 COM dlls or via the Perl scripting language, and it is assumed developers familiar with COM/Perl development will build these plug-ins. NSS is HLA-compliant, and has participated in numerous HLA federations. NSS is compatible with the Defense Modeling and Simulation Office (DMSO) 1.3 NG v6 RTI as well as the MAK 1.3 v. 3.0.1 (or later) RTI. NSS supports import of externally generated modeling data via a variety of file formats, including .xls, .csv, and .xml.

Verification & validation

Most V&V is done by the sponsoring activity. However, each new software release undergoes a moderate level of factory testing (including new feature testing and regression testing for legacy capabilities) to ensure requirements compliance and code stability. In addition, each new feature and associated user procedures is fully documented in the Analyst Guide and User Manual, respectively.

Testing

Most testing is done by the prime contractor, as funded by the sponsoring activity. Since FY06,the Office of the Chief of Naval Operations (OPNAV) N81 has funded a limited factory software integration test process with each major release via its World Class Modeling initiative. A formal NSS Factory Test Plan is prepared for each release. The test plan explicitly addresses

the test schedule, environment (site, hardware/software environment, facilities), personnel (management/tester responsibilities and specific test assignments), and detailed procedures. NSS Factory Testing may include (as funding permits) the following test batteries:

- Software Unit Testing
- New Features Scenario Testing & Fix Verification Testing
- Software Integration Testing; Software Installation Testing; Study Execution Procedure Testing; Batch Run Stress Testing; Results Consistency Testing; Model Engine Regression Testing; Graphical User Interface (GUI) Functional Testing; End-to-End Analysis Testing
- Database Content Testing
- Documentation Completeness/Accuracy Testing

Distribution

The NSS executable is distributed approximately annually to registered users. Model Manager authorization is required to obtain the source code.

Lessons learned & other comments

It would be helpful to the user community for the model manager to have a stable funding line to perform CCB and user group activities, formal VV&A, full-scope factory testing, acceptance testing, comprehensive user documentation updates, full-service help-desk/tech support, and maintenance (i.e., bug/issue resolution).

D.5. ONE SEMI-AUTOMATED FORCES (ONESAF)

OneSAF is a computer-generated forces constructive simulation. It models and simulates combat entities and systems. The entities have some level of autonomy that allows them to react based on their situational awareness. These entities are semi-automated in that they generally require human operators to do holistic planning, provide goals for goal-directed behaviors, etc.

The mission of the OneSAF program office is to create a unified computer-generated forces simulation to meet a broad spectrum of simulation needs across multiple modeling and simulation domains. These domains include the Advanced Concepts and Requirements (ACR) – Research and Development (R&D) laboratories and Training and Doctrine Command (TRADOC) analysis centers; Training, Exercises, and Military Operations (TEMO) – battle simulations centers, course of action analysis, etc.; and Research, Development, and Acquisition (RDA) – the various battle laboratories. By having a single Semi-Automated Forces (SAF), a new weapon, system, enemy capability, etc., can be implemented once and shared among many

applications. Additionally, a common SAF shared among the TEMO domain contributes to the Army's overall goal for an Integrated Training Environment.

The management responsibility and funding falls under the US Army, PEO-STRI.

Requirement prioritization

TRADOC Project Office (TPO) OneSAF works with the M&S domain representatives in a Requirements Integration Board (RIB) to prioritize the annual version release requirements. The Program Management Office (PMO) works with the co-developers during the code handover review process to integrate capabilities into a single annual release.

External code

OneSAF is maintained as a single baseline with extensions for specialized functionality. These extensions allow for inclusion of capabilities that may not be of value across multiple M&S communities. All code and documentation progresses through a peer review process. The internal code updates occur continuously through the build cycle. Externally developed code is "handed over" to the Architecture & Integration team, who takes the package through a variety of compliance assessment peer reviews. When ready, Change Requests (new capabilities) and Problem Trouble Reports (defect fixes) for both internally and externally developed code are discussed in an Engineering Integration Review (EIR) meeting.

Verification & validation

The OneSAF user/domain representatives, as well as those from co-developer organizations, are invited to participate in peer reviews throughout the software development process, i.e., conceptual modeling/knowledge engineering, requirements analysis, design, code & unit test, and software integration & test. As such, there is a high degree of confidence that not only are the user/customer capabilities in line with requirements, but that the co-developers can understand upcoming baseline changes, surface issues, and leverage/collaborate on the development of new capabilities. These organizations are also involved in requirements testing of the baseline.

Testing

Testing happens more or less continuously on the program. Unit tests are performed prior to code being accepted for integration into the trunk. The Software & Integration team performs system -level thread and distributed operations tests weekly. Thread tests are selected for weekly regression based on the degree that a given capability impacts other parts of the system. Program Manager (PM) OneSAF executes formal system tests involving users for the

interim "dot" releases. TPO OneSAF executes all of these, plus their own battery of tests, with user involvement for the full version releases.

Distribution

OneSAF is distributed as source code approximately three times annually. Two of these are more informal "dot" releases, e.g., v3.1, v3.5. The other is a formal full version release, e.g., v1, v2, v3. The frequent releases help the co-developers stay more closely aligned with PM OneSAF's core baseline. The biggest challenge is that externally developed code and associated documentation is delivered with varying degrees of maturity. Code standards and a style guide are published. However, handover code has been assessed that spans from highly structured to nearly ad hoc.

Lessons learned & other comments

Communication with, and involvement by, users and external developers is key. Sometimes tough decisions need to be made in order to maintain a high level of quality in the baseline code and documentation. Not all organizations agree with those decisions.

The OneSAF managers are sold on the value of distributing source code and working with external developers to extend/integrate their capabilities into the OneSAF baseline. However, with integration and test comes a cost. To date, performance has been good in integrating these capabilities. However, as OneSAF becomes more popular as a DoD M&S tool, tougher decisions will need to be made regarding what is integrated and what might sit on a shelf and wait. Unfortunately, the baseline will continue to move forward and the shelved capabilities may begin to grow stale. The inclusion of extensions has partially addressed this concern. As the community grows with their code handovers, additional resources will have to be applied to ensure forking of the baseline doesn't occur.

D.6. SIMULATION DISPLAY (SIMDIS)

SIMDIS is a set of software tools that provide two- and three-dimensional interactive graphical and video display of live and post-processed simulation, test, and operational data. SIMDIS has evolved from a Naval Research Laboratory display tool for the output of missile models.

Requirement prioritization

The Naval Research Laboratory (NRL) is a working capital organization. Sponsor requirements are directly attributed to funding received. For specific requirements, NRL drafts a

rough order of magnitude (ROM) document that is finalized into a Statement of Work (SOW) for the requesting user. A CCB mediates any conflicts between sponsor requirements.

External code

A plug-in based architecture is used to facilitate the integration of externally developed functionality. Externally developed code must be able to be compiled with the latest C++ compilers. The software use must not incur a fee nor can its use be restricted. In order for open source libraries to be used within SIMDIS, software must have permissive licenses such as the Berkeley Software Distribution (BSD), Massachusetts Institute of Technology (MIT) or the GNU Lesser General Pubic License (LGPL). SIMDIS requires that one baseline be maintained across all supported operating systems.

Verification & validation

SIMDIS is a three-dimensional (3-D) display tool more so than an actual model or simulation. It has been used to display M&S data and in some respects contains externally developed models. V&V of the externally developed models are the responsibility of the host organization. The display and coordinate conversion libraries used internal to SIMDIS have gone through the V&V process when the tool has been used by the Commander, Operational Test and Evaluation Force (COMOPTEVFOR) for analysis of development and operational test data. The process is performed by an external agency, the Joint Accreditation Support Activity (JASA).

Testing

Test harnesses, also known as unit tests, have been developed to compare the output of specific modules versus a standard set of reference data. Test scripts and tool configurations have also been developed to exercise the user interface and display functionality. Additional regression testing is performed using both file- and network-based data for comparison.

Distribution

Only executable and source code Application Programming Interfaces (APIs) are distributed. The frequency of software release is every twelve months.

Lessons learned & other comments

The automation of the test harnesses has been extremely useful. Since the tool is graphics-based, complete automation of testing is not possible. The performance and graphics effects are also very dependent on the hardware and video drivers that are used.

D.7. SYNTHETIC THEATER OPERATIONS RESEARCH MODEL (STORM)

Requirement prioritization

The Configuration Control Management Team (Leads of Air Force and Navy) determine the prioritization of funding for all requirements within the limits of the contract.

External code

The Configuration Control Team will either accept or deny inclusion of externally developed functionality which will then go to the configuration managers (contractors) for implementation. The Configuration Manager takes the code and the Modification Design Document (MDD) for the initial review. After changes are made from this review, the Configuration Management team then integrates the code (that has already been tested). STORM permits parallel forks.

Verification & Validation

There is no formal independent V&V done on the model. Contractors perform testing to ensure the model is validated against design documents. It is rather hard to validate a campaign model other than to compare it to previous results. While some of this testing is done, it is not recorded.

Testing

Minor testing is done to ensure the model doesn't "bomb" on test data. Because the contractors cannot use the detailed classified data, full testing takes place at A9.

Distribution

There is a plan to have major releases of the primary code every 9-12 months. Approximately halfway through a cycle, a secondary release is sent that accumulates all the changes made to "fix bugs." Both source and executable are distributed.

Lessons learned & other comments

As STORM grows in the community, there will be more and more bugs found. The challenge is how to get this information to the entire community in the easiest and quickest way. Currently, this can be done via patches, but these take time to install and may change what previous runs have given for answers. However, not all players, especially foreign, can get access to the military site to download those patches.

Model management needs to be held very tightly. Contractors may be motivated to push the envelope in certain directions. With multiple people trying to modify the model, it will only

cause problems in the long run. The other concern is "when is the model finished?" There is a constant outcry from the user community that things change too fast and they can't keep their data files up to speed. There needs to be a way to "put the brakes on" at some time to let the field catch up. However, the development team may be motivated to incite the field for more.

D.8. SUPPRESSOR

Requirement prioritization

Suppressor is owned by ASC/ENDA. There is no steady stream of funding for Suppressor model maintenance. Requirements are usually defined during a study and implemented if funding is allocated under that study for model enhancements. Requirements are prioritized by the ASC/ENDA model manager, analysts, developers, and the study customer.

External code

Suppressor has integrated three classified external codes: High Speed Anti-Radiation Missile (HARM) flyouts, missile flyouts, and Joint Munitions Effectiveness Manual (JMEM) (air-to-surface) munitions effectiveness. In each case, an interface routine was developed and called from the regular Suppressor code. Stubs of these interface routines are available when Suppressor is executed in an unclassified environment. Suppressor permits parallel forks.

Verification & Validation

Over the 20+ years of Suppressor development and use, there have been multiple instances where functionality has been calibrated with established data sources (e.g., range data, man-in-the-loop, test data, specification data, FME data).

Testing

After a software change is developed, unit testing is performed to ensure that the new/modified code is performing as expected. Then, prior to distribution, a standard suite of scenarios is executed which tests a variety of situations. If the new results differ from the previous run, then an investigation is performed to determine if the differences would be consistent with the new code.

Distribution

The Suppressor Distribution Community of Practice (CoP) (a website available to anyone with a Common Access Card (CAC) or access through the Air Force Portal) is updated with point release changes as soon as they are integrated and tested. Both source and executable are distributed.

Lessons learned & other comments

It is important to distribute code changes as soon as they are developed. Prior to widespread use of the internet, changes were batched and distributed periodically. This made it difficult to help customers who were having problems due to differences in code configurations. Timely customer support is a must. If the model is to succeed, the user needs to be able to access a help desk with knowledgeable support staff. All of Suppressor funding comes from project/study funds. The positive effect is that this forces them to really focus on the customer requirements, which keeps the model streamlined. The negative effect is that some extras, like a Graphical User Interface, do not get implemented due to priority and lack of funds.

D.9. THREAT MODELING AND ANALYSIS PROGRAM (TMAP)

TMAP is a DoD intelligence community (IC) initiative to embed M&S within the core intelligence analysis process resulting in authoritative threat models that are derived from all-source intelligence and owned by the responsible intelligence organization. This permits threat representative information to be captured in a flexible form enabling intelligence discovery and analysis, prediction of threat system characteristics, behaviors and dynamic performance, and the provision of threat baseline models for use by IC customers.

The Missile and Space Intelligence Center (MSIC), National Air and Space Intelligence Center (NASIC), National Center for Medical Intelligence (NCMI), National Ground Intelligence Center (NGIC), and the Office of Naval Intelligence (ONI) have management responsibility for TMAP and the threat models developed within the program.

Requirement prioritization

Users requiring intelligence data and/or models must submit a Production Requirement (PR) through their Scientific and Technical Intelligence Liaison Officer (STILO) in COLISEUM. COLISEUM is a web-based application for automating assignment and tracking of PRs within the IC. This PR is then evaluated by the appropriate Intelligence Production Center (IPC) and a dialogue initiated with the customer to clarify the request. A Proposed Product Response (PPR) is then created that identifies the requirements that will be met and the completion date(s). PRs are prioritized and added to the production schedule as time and resources permit. The product requirements that cannot be fulfilled and the production shortfall(s) (i.e., resources, data, etc.) are then identified. TMAP production requirements will be handled using the same process. When a customer requests a model, the respective IPC will discuss their requirements to ensure the resulting model's fitness for the stated purpose.

Responsibility for Scientific and Technical Intelligence on threat systems is administered via the Defense Intelligence Analysis Program (DIAP). Thus, modification conflicts are infrequent because there are rarely two developers working on the same system model.

However, the TMAP promotes commonality, sharing and reuse of ideas within the IC. When co-development does happen, conflicts are mediated through a configuration management tool and a body of Subject Matter Experts (SMEs) on the various subject areas.

External code

TMAP models are maintained as a single baseline and built upon the Commercial-off-the-Shelf (COTS) MATLAB/Simulink® product family from MathWorks. Simulink®, as a visual programming language, and TMAP's strict decomposition methodology enables TMAP customers to make modifications or additions to the threat models, but these modifications must be made under the Intelligence Community's supervision. As the producers of authoritative threat models, the TMAP development community discourages customers from modifying TMAP models. Unauthorized modifications to the models may invalidate the threat representation. Therefore, customers are encouraged to submit PRs when additional functionality or changes are required. For low-level functions or reuse of legacy code, TMAP organizations can use Simulink's® capability to import traditional programming languages (C++, C, FORTRAN, etc.) when the clarity of Simulink® block diagrams is not required for analyst comprehension or is perhaps not considered appropriate for the specific application.

TMAP's emphasis on Architecture Independent Modeling (AIM) practices make the threat models easily extensible to the broader simulation needs of DoD M&S customers. This M&S approach enables the IPCs to quickly perform updates to the models as new intelligence information is obtained and analyzed. TMAP focuses on reducing duplication of effort, model development and maintenance costs. TMAP provides authoritative threat models in an executable form easily adapted to user applications. TMAPs emphasis on the development of threat models rather than simulations alone, promotes the merits of reusability and extensibility bringing commonality and consistency to threat representations throughout engineering, engagement, mission and campaign level simulation architectures. Migration away from legacy languages to MATLAB/Simulink® now allows the IPCs to work within a modeling paradigm geared toward system analyst engineers rather than toward simulation developers. This improves analyst comprehension of the system and leads to greater confidence in the subsequent all-source threat assessment. This M&S approach also enables the IPCs to flexibly support a broader set of M&S customers with authoritative threat models through the use of the MathWorks Real-Time Workshop (RTW) automatic code generation feature. Auto-coded models can be embedded as C/C++ objects and shared libraries (.dll or .so) into many coding languages (C, C++, ADA, Fortran, etc.) and are multi-platform compatible (Windows, UNIX, IRIX, etc.).

The code development process at each IPC varies depending on the resources available and local organizational structure, but each center maintains rigorous control over the process. MSIC, NGIC and ONI augment their government personnel with contractor support to help

develop TMAP models. NASIC develops the majority of their models using government personnel, employing contractors when necessary to increase production capability. Once development is complete, and the product is accepted, the IPC takes ownership and maintains the baseline under strict configuration management.

Testing

Under the IPC's configuration management process, TMAP models are built using rigorous analytical standards and system engineering processes. Each model is verified against the conceptual design and validated against available intelligence at all levels of classification to ensure the model appropriately captures the threat system performance for the intended use of the model. The tests and results are documented in a Verification and Validation Support Package (VVSP) document that also includes the model's intended use, assumptions, limitations and subsystem descriptions.

Verification & validation

As part of a TMAP model package, IPCs include a set of robust and documented test cases that enable TMAP users to verify the model behaves as intended when integrated into a simulation. The test cases are documented in the TMAP VVSP. When a customer requests a model, the respective IPC will discuss their requirements to ensure the resulting model's fitness for the stated purpose. The customer, usually with IPC help, will integrate the model into the customer's simulation, and will then verify performance using the provided test cases and data. Depending on the circumstances, it may be possible for the IPCs to supply a letter of certification after the customer demonstrates their verification efforts and results. It is up to customers to accredit the use of the model in their simulation for a specific purpose.

Distribution

TMAP products are distributed as MATLAB/Simulink® models. Throughout the IPCs, there are many models on various release schedules. High-interest subjects often lead to steadily evolving critical intelligence information and result in frequent model updates. As new models are finished or updates completed, the new models are released and advertised on the IPCs' TMAP websites.

Lessons learned & other comments

Previous threat model developments that relied heavily on contractors with little or no IPC interaction wasted government resources and resulted in multiple-inconsistent threat representations across the DoD (often even within the same weapons program life cycle). TMAP's emphasis on AIM and object-oriented decomposition has enabled the IPCs to develop and deliver authoritative threat models that are reusable, extensible, and interoperable across DoD simulations.

On-going dialogue with customers is essential to successful integration of threat models into customer applications. The TMAP can be broken down into four cyclic processes: development cycle, configuration management cycle, infrastructure cycle, and customer cycle. The IPCs' biggest challenge is in obtaining sufficient resources to manage these four cycles.

APPENDIX E: ABBREVIATIONS AND ACRONYMS

3-D	Three-Dimensional
ACR	Advanced Concepts and Requirements
AIM	Architecture Independent Modeling
AJEM	Advanced Joint Effectiveness Model
AMSMP	Acquisition Modeling and Simulation Master Plan
API	Application Programming Interface
ASC/ENDA	Aeronautical Systems Center / Engineering Directorate
ATC	Advanced Testing Capability
BCMS	Battle Command Management Service
BSD	Berkeley Software Distribution
C4ISR	Command, Control, Communication, Computers, Intelligence, Surveillance, and Reconnaissance
CAC	Common Access Card
CAPE	Cost Assessment and Program Evaluation (formerly PA&E)
CCB	Configuration Control Board
CCTT-SAF	Close Combat Tactical Trainer – Semi-Automated Forces
CLM	Continuous Learning Module
CM	Configuration Management
CMS2	Comprehensive Mine and Sensor Simulator
COMOPTEVFOR	Commander, Operational Test and Evaluation Force
CoP	Community of Practice
COTS	Commercial-off-the-Shelf
CVS	Concurrent Versions System
D, SSE	Director, Systems and Software Engineering
DARPA	Defense Advanced Research Projects Agency
DAU	Defense Acquisition University
DC	Developer Coordinated
DepSecDef	Deputy Secretary of Defense
DIAP	Defense Intelligence Analysis Program
dll	Dynamic Link Library
DMSO	Defense Modeling and Simulation Office (now M&S CO)
DoD	Department of Defense
EADSIM	Extended Air Defense Simulation
EIR	Engineering Integration Review
FME	Feature Manipulation Engine
GC	Government Coordinated
GOSH	Government Open Source Hybrid

GUI	Graphical User Interface
HARM	High Speed Anti-Radiation Missile
HLA	High Level Architecture
HPAC	Hazard Prediction and Assessment Capability
I/ITSEC	Interservice/Industry Training, Simulation & Education Conference
IC	Intelligence Community
ID	Independent Development
IMASE	Intelligence Modeling and Simulation for Evaluation
IPC	Intelligence Production Center
JAS	Joint Analysis System (formerly JWARS)
JASA	Joint Accreditation Support Activity
JCATS	Joint Conflict and Tactical Simulation
JCSS	Joint Communications Simulation System
JFCOM	Joint Forces Command
JHU/APL	Johns Hopkins University Applied Physics Laboratory
JIMM	Joint Integrated Mission Model
JMEM	Joint Munitions Effectiveness Manual
JMMO	JIMM Model Manager Office
JSAF	Joint Semi-Automated Forces
JTLS	Joint Theater Level Simulation
JWARS	Joint Warfare System (now JAS)
LaSRS++	Langley Standard Real-Time Simulation in C++
LGPL	Lesser General Public License
M&S	Modeling and Simulation
M&S CO	Modeling and Simulation Coordination Office (formerly DMSO)
MDD	Modification Design Document
MIDAS	Model for Intratheater Deployment by Air/Sea
MIL-STD	Military Standard
MIPR	Military Interdepartmental Purchase Request
MIT	Massachusetts Institute of Technology
ModSAF	Modular Semi-Automated Forces
MSIC	Missile and Space Intelligence Center
MSRR	M&S Resource Repository/Registry
MSTM	M&S Tool Manager
NASIC	National Air and Space Intelligence Center
NAVAIR	Naval Air Systems Command
NCMI	National Center for Medical Intelligence
NDIA	National Defense Industrial Association
NGIC	National Ground Intelligence Center
NGO/PVO	Non-Governmental Organization / Private Voluntary Organization

NRL	Naval Research Laboratory
NSS	Naval Simulation System
OneSAF	One Semi-Automated Forces
ONI	Office of Naval Intelligence
OOS	OneSAF Objective System
OPNAV	Office of the Chief of Naval Operations
ORD	Operational Requirements Document
OS	Open Source
OSD	Office of the Secretary of Defense
OTB	OneSAF Test Bed
OUSD(AT&L)	Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics
PA&E	Program Analysis and Evaluation (now CAPE)
PATP	Parallel Acceptance Test Plan
PEO-STRI	Program Executive Office – Simulation, Training, and Instrumentation (formerly STRICOM)
PM	Program Manager
PMO	Program Management Office
PoC	Point of Contact
PR	Production Requirement
PPR	Proposed Product Response
QA	Quality Assurance
R&D	Research and Development
RDA	Research, Development and Acquisition
RIB	Requirements Integration Board
ROM	Rough Order of Magnitude
ROMO	Range of Military Operations
RPG	Recommended Practices Guide
RTI	Runtime Infrastructure
RTW	Real-Time Workshop
SAF	Semi-Automated Forces
SCR	Software Change Request
SIMDIS	Simulation Display
SISO	Simulation Interoperability Standards Organization
SIW	Simulation Interoperability Workshop
SMDC	Space and Missile Defense Command
SME	Subject Matter Expert
SOW	Statement of Work
SPAWAR	Space and Naval Warfare Systems Command
SPIRITS	Spectral Inband Radiance of Targets and Scenes
STILO	Scientific and Technical Intelligence Liaison Officer

STORM	Synthetic Theater Operations Research Model
STR	Software Trouble Report
STRICOM	Simulation, Training, and Instrumentation Command (now PEO-STRI)
TEMO	Training, Exercises, and Military Operations
TMAP	Threat Modeling and Analysis Program
TMD	Theater Missile Defense
TPO	TRADOC Project Office
TRADOC	Training and Doctrine Command
V&V	Verification and Validation
VV&A	Verification, Validation and Accreditation
VVSP	Verification and Validation Support Package
XML	Extensible Markup Language

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