Final Report

Final Draft

Cost Benefit Analysis
Department of Defense
Joint Modeling and Simulation System

Provided to the Office of the Under Secretary of Defense for Acquisition and Technology
(OUSD (A&T)) Director, Test, Systems Engineering, and Evaluation (DTSE&E)

May 1998

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Executive Summary

Purpose of the Study. The study was performed to assess the cost benefit of a Department of Defense (DoD) Joint Modeling and Simulation System (JMASS) - a common engineering and engagement modeling and simulation (M&S) system to support acquisition.

Background of the Study. The Department of Defense is seeking ways to improve efficiencies in M&S by creating systems that foster reuse, interoperability, and commonality among model components, models, and simulations. The Services conducted a series of pilot projects using Air Force (AF) JMASS in order to refine the requirements in the DoD Joint Initial Requirements Document (JIRD) and determine if a joint M&S system will support acquisition. It was anticipated that use of AF JMASS would generate benefits in cost, schedule, quality, and productivity.

Principal Results. The recommendation of the study was for DoD to make an investment in the AF JMASS system through the Program Objective Memorandum (POM). Funding would be directed to improve existing tools and services of the system. The improvements will reduce the risk in the acceptance of the system by the analysis community. Rather than trying to cover the entire acquisition process and the huge fiscal burden that initial model development would require, concentrate on populating the model repository with threat and environment models to meet all the Services' requirements in the domains of aircraft, missiles, helicopters, and unmanned aerial vehicles. To minimize cost, leverage AF JMASS's established models and system. Other reasons for making an investment in the current AF JMASS system follow: it is technology for the future - object oriented; it supports a model repository approach; it fosters reuse of model components and models within and outside programs; it eliminates legacy duplication of effort; it is a better product than legacies; and it can be used as a standard for industry.

Time of Study. The JMASS Senior Steering Group (SSG) decided to make a mid-year POM decision on 4 March 1998, the allocated study duration then became 15 September 1997 to 4 March 1998.

Scope of the Study. The study was limited to research within DoD acquisition programs that could provide legacy model cost estimate data across a common domain. The common domain approach provided a way to find common legacy model use examples across the domain by a number of programs, illustrating the duplication in use of legacies and illustrating a side-by-side cost comparison of legacy use to a comparable capability in DoD JMASS. The cost illustration examples were expressed in "rough order of magnitude" estimates.

Study Objective. Examine the benefits to the DoD acquisition community from having a common engineering/engagement model system and model set which meets all the DoD JMASS JIRD requirements.

Basic Approach of the Study. The study was accomplished through cooperation and interviews with the AF JMASS program office, current users of AF JMASS, the Service pilot projects, Service staff organizations, acquisition program managers, the analysis community, and private industry to gain as much information through research as possible. The study effort culminated in a briefing with insights, findings and recommendations to the JMASS SSG to assist them in their POM decision. This report provides documented evidence supporting the study.

The Study Sponsor. Office of the Under Secretary of Defense for Acquisition and Technology (OUSD(A&T)), Director, Test, Systems Engineering, and Evaluation (DTSE&E).

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Objective

What are the benefits to the DoD acquisition community of having a common engineering/engagement model system and model set which meets all the DoD JMASS JIRD requirements?

Vision for the Future

Simulation Based Acquisition (SBA) is the robust, collaborative use of simulation technology that is integrated across acquisition phases and programs. A DoD common engineering /engagement model system and model set would support a SBA Process. The benefits of SBA are intuitive; it is necessary to quantify them in order to clearly determine benefits. The DoD common engineering/engagement model system and model set was originally envisioned to provide a standard for model component developers. Tools within the system would support model development, simulation development and analysis. There is a need to address a long standing question on the quantifiable and qualifiable benefits of a common modeling and simulation infrastructure to support engineering and engagement level simulations. It is desirable to determine the benefits, costs and risks to the DoD in having a common M&S system.

Background

General. OUSD(A&T)/DTSE&E is responsible for an initiative investigating use of a common M&S system within the DoD acquisition process. A JIRD is in place and begins to define such a system. The Services are conducting a series of pilot projects using AF JMASS, the best example of a common M&S architecture for acquisition, in order to refine the requirements in the JIRD and determine if a joint modeling and simulation system will support acquisition. It is anticipated that use of AF JMASS, a common M&S system, will generate benefits in cost, schedule, quality, and productivity. These benefits are intuitive but not documented. There is a need to document these benefits for DoD.

Current M&S Methods. Today program managers use threat information from a variety of sources in an amalgam of models because there is no alternative. Design decisions, tactics, supportability, and acquisition issues are all supported in part by a set of models which may not be valid, which may not be consistent, and which do not interface well with other models.

Recent JMASS work by the U.S. Air Force. AF JMASS is an Air Force directed program to develop and deliver a distributed, object-oriented architecture and system focused on the tactical level of war (engineering and engagement-level simulation). As a system for developing engineering level models primarily of electronic systems, AF JMASS will provide a common environment for tactical modeling across the requirements development, acquisition, and test process spectrum. The Air Force is currently working with the Missile and Space Intelligence Center (MSIC) and the National Ground Intelligence Center (NGIC) to populate the AF JMASS system with authoritative representations of Air Force and threat systems that interoperate and comply with AF JMASS standards. A study of the AF JMASS Program was recently completed by the Air Force Scientific Advisory Board. This study endorsed Air Force JMASS and the purpose of the AF JMASS Pilot Projects.

Assumptions

- The study will quantify the benefits to DoD if a common modeling and simulation system which meets all the JIRD requirements was available to the whole acquisition community.

- Authoritative, quantifiable information about acquisition process benefits will be available.

- There will be costs incurred with the development of this system, specifically in the architecture and conversion of existing capabilities and program databases.

Limitations

- The "quick look" portion of the benefits analysis must be completed in two months.

- Current AF JMASS addresses only engineering and engagement M&S for analysis.

Methodology

Approach. The study will be conducted in two parts: a "quick look" assessment and a "detailed assessment". During the conduct of the study, both qualitative and quantitative information to address the study objective will be collected. The study will be accomplished through cooperation and interviews with the AF JMASS program office, current users of AF JMASS (e.g. MSIC, NGIC, NAIC, B-1B, F-22), service staff organizations and private industry to gain as much information through research as possible. The final assessment will be based on comparative analysis between DoD sources and private industry's successful use of common architecture and models to support cost savings. The private industry examples provide solid credence to any assumptions made since they will be based on real cost savings from authoritative sources. The study team will attend project, program and service IPTs to gather and research information needed in the conduct of the study.

Metrics. The study will measure the benefits of an M&S system as it relates to the acquisition process, specifically what savings can be realized. These measures are documented in Appendix H.

- What is the cost avoidance from eliminating duplication of efforts - improved collaboration among programs and Services?

- What are the cost savings across the Acquisition cycle?

- Do the benefits of a common software toolkit reduce redundant investments in tools and services?

- What are the front end costs of converting existing databases to a new architecture and set of models?

- What are the benefits, such as: schedule, level of effort, quality, and productivity associated with standard model architecture use?

- What are the benefits of reuse and interoperability?

- Can alternative design concepts be readily evaluated on a common "playing field" using a standard model architecture?

- What is the common engineering model architecture and model set to support an advanced Simulation Based Acquisition Process for DoD?

- Are there quantifiable benefits of improved integration across the DT and OT communities, using domain validated common models and common simulation infrastructure?

- Does a standard architecture offer potential for improved requirements definition with the war fighters?

- What are the benefits of improved data handling?

Analysis

General. This section covers the analysis performed to support the study. The basis of the analysis was a data collection effort consisting of interviews with industry and DoD. The interviews allowed the study team to gain quantitative, qualitative, and insightful information to answer the study questions. Interviews were conducted with the Air Force JMASS Program Office, current users of AF JMASS, the Service pilot projects, Service staff organizations, acquisition program managers, the analysis community, and private industry to gain as much information through research as possible. The analysis section is divided into two parts. Part 1, the Background Analysis, is a review of existing information and an analysis of DoD and industry M&S benefits. A review of related studies provided the study team with existing information about the effectiveness of M&S systems and the existence of common systems within the Services. A review of authoritative references allowed the team to put in perspective where DoD JMASS best influences acquisition and whether or not DoD JMASS might be a single system or a system of systems. A look at industry's decisions and investments in common M&S systems allowed the team to understand the order of magnitude costs industry has incurred in moving to common systems, what prompted their decisions to go to common M&S systems, how these order of magnitude costs relate to a common M&S system to support DoD acquisition, whether or not industry already has a system that will support DoD, and whether or not there is some existing linkage between industry and DoD. Part 2, Cost Benefit, is a detailed look into the existing Air Force JMASS development community and provides order of magnitude cost estimate data to illustrate the estimated cost and the benefits of the system through reuse, interoperability and commonality as compared to the current use of legacy systems. The cost benefit analysis resulted in a recommendation to DoD based on analytical results, insights, and findings. Figure 1, Study Schematic, shows what is contained in this report.

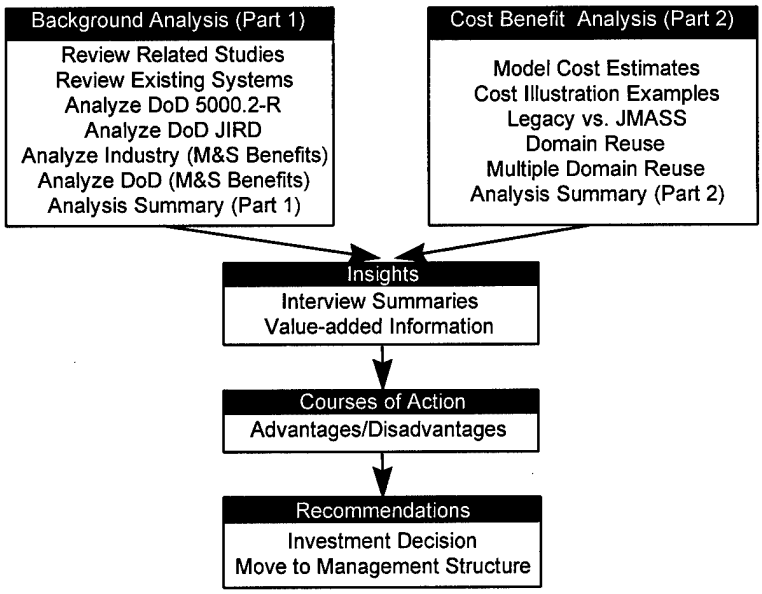

Figure 1. Study Schematic

Part 1 - Background Analysis

Review of Related Studies. A review of related studies provided the study team with existing information about: the effectiveness of M&S systems; recent recommendations from the Acquisition Task Force on M&S; the existence of common M&S systems within the Services; a framework for understanding the major Joint simulation systems; rough order of magnitude cost estimate information from one of the

JMASS pilot projects; and, an endorsement for the use of JMASS to support an acquisition program. This information was gathered from the following studies:

- Christensen, Harold E., et. al., Technical Report, JMASS EO/IR Performance Requirements & Options Study in Support of Aviation Electronic Countermeasure Programs, Part I, (Performance of EO/IR Simulation), September 19, 1997, and, Part II (Implementation of Options Study), October 21, 1997, CAS Inc. *Summary - JMASS EO/IR model development technical approach and rough order of magnitude cost estimates for JMASS model development for the EO/IR environment.*

- Harshberger, Edward, R., Report of the Simulation Technical Review Panel (Draft), DRR-1539-OSD, December 1996, RAND. *Summary - A technical assessment of common M&S systems that currently exist: Air Force, Joint Modeling and Simulation System (JMASS); Army, TACTICS - A Common Object Request Broker Architecture (CORBA)-Based Distributed Processing Infrastructure; Navy, Simulation and Modeling of Operational Needs (SAMSON).*

- Parker, Ted, Vice Admiral, U.S. Navy, Retired, Final Report of the Acquisition Task Force on Modeling and Simulation, June 10, 1994, Chairman, Acquisition Task Force on Modeling and Simulation. *Summary - Recommended that DDR&E work with the Services to establish a Joint Program Office with an associated Joint Mission Needs Statement to formulate a M&S architecture to support the acquisition process.*

- Patenaude, Anne, et. al., Study on the Effectiveness of Modeling and Simulation in the Weapons System Acquisition Process, Science Applications International Corporation, October 1996. *Summary - a study of a representative number of acquisition programs, both within DoD and the commercial sector, provides consistent and pervasive evidence that M&S used effectively provides substantial, quantifiable benefit.*

- Rothenberg, Jeff, A Framework for Understanding JWARS, JSIMS, and JMASS (Draft), December 1997, RAND. *Summary - Analysis of the three systems with respect to their potential to satisfy the need for interoperability among DoD models and simulations and for reuse of model components, data, tools, and environments.*

- United States Air Force Scientific Advisory Board, Report on the Joint Modeling and Simulation System, SAB-TR-97-02, June 1997. *Summary - Found JMASS release 3.1 to be stable and functional and viable for use in the B-1 DSUP Program for testing - an endorsement for the use of Air Force JMASS.*

Review of Existing Common Modeling Systems.

General. The Report of the Simulation Technical Review Panel (Draft), DRR-1539-OSD, December 1996, RAND, cited from the previous paragraph, highlighted the existence of three common M&S systems and provided a technical assessment of the systems: Navy, SAMSON; Army, TACTICS; and, Air Force JMASS. The intent of this section is to provide a brief description of each system and review the technical assessment observations from the review panel.

- Navy, SAMSON - is an object-based simulation framework that provides run-time management for a distributed group of software, hardware, and/or human-in-the-loop players. The system was developed to satisfy the *real-time* integrated ground testing needs of the avionics and electronic warfare test and evaluation (T&E) community. Sponsors for the development of the system are the Air Force Electronic Combat Integrated Test (ECIT) Facility, Edwards AFB, CA and the Navy Air Combat Environment Test and Evaluation Facility (ACETEF), Patuxent River, MD. *Assessment - Prototype software, not implemented for multiple users or multiple facilities, limited documentation and minimal tools. Development tailored to near-term needs of very demanding*

environment - HWIL integration test facility, large numbers of legacy hardware and software systems, tight timing requirements. Design tradeoffs made for speed, not generality. Careful development approach coupled with good prototyping environment. Focused on real-time requirements.

- Army, TACTICS - is a set of interconnectivity services that provides the application-oriented user flexibility and ease-of-use in rapidly configuring simulations composed of custom developed or legacy code. It is based on the object oriented design principles and takes full advantage of the benefits offered by industry object-oriented standards such as CORBA. The system enables the user to construct process flow simulations and event-based simulations using plug & play objects that interact across distributed computing platforms. The sponsor for the development is the U.S. Army Tank and Automotive Command (TACOM). *Assessment - Immature in implementation for development and combination of component models into simulations. Simulation engines not "wrung out", lacks software structural model, minimal development and configuration tools. Most elegant and "modern" approach from a computer science perspective as it uses CORBA - implication of easier interface with industrial design technology an important enabler for simulation-based design. Clearly a capable system not fully implemented.*

- Air Force JMASS - provides a flexible object-oriented simulation infrastructure that assists model developers, engineers, and analysts in the development of digital models, configuration and execution of simulations, and analysis of simulation results. AF JMASS supports varying degrees of model fidelity from the less complex analytic models to highly emulative models which mimic real world systems. The requirement for AF JMASS is to support engineering and engagement level analysis. The sponsor for the development is the U.S. Air Force, Wright-Patterson AFB, OH. *Assessment - More mature than SAMSON and TACTICS in implementation. Relies on a uniquely developed set of interface standards "CORBA-like" APIs and port objects, developed before CORBA was available. Oriented toward model and simulation development, extensive set of tools for development, configuration and analysis, fully defined software structural model and interfaces, simulation engine and environment models defined and implemented. Most capable system, however, there is some concern for technological obsolescence.*

Summary of Existing Systems. The previous reviews and assessments of the existing systems provide documented evidence of the existence of the systems and their status. It was not the intent of this study to draw any correlation or comparison among these three systems, only to recognize the documented strengths and weaknesses of each system as this evidence provides some concern for the long term strategy of a DoD JMASS system to serve the broader acquisition community. It was recognized at the time the study was initiated that the most mature system was AF JMASS and as a consequence was the main point of departure for study. This was especially relevant as the six pilot projects, funded by the Services and DoD, would conduct their investigations using AF JMASS version 3.1, the most current version at study initiation. Insights gained from the pilot use of AF JMASS as well as rough order of magnitude cost estimate data from the AF JMASS model development community served as the most credible data available for the time frame of the study.

Review of Authoritative References.

Definition of the Acquisition Process by DoDD 5000.2R. DoD Acquisition Policy 5000.2R is the current authoritative policy document for acquisition, which establishes a management framework for translating warfighter mission needs into mandatory procedures for major defense acquisition programs and major automated information system acquisition programs. This process is further defined by a logical means of progressing through specific requirements/actions (phases) and decision points (milestones) to ultimately field an operationally effective, suitable and survivable system for DoD. The segments of the process are named Determining Mission Needs (MN), Concept Exploration (CE)-phase 0, Program Definition and Risk

Reduction (PDRR)-phase I, Engineering and Manufacturing Development (EMD)-phase II, and Production, Fielding, and Operational Support (PFOS)-phase III. The milestones are 0, I, II and III, located between MN and CE, CE and PDRR, PDRR and EMD, and EMD and PFOS respectively. Figure 2 describes the acquisition process, showing the five segments, and the actions performed across each segment (summarized at the top of each segment). This information is presented as a quick overview of the acquisition process and provides a foundation for subsequent analysis of the JIRD.

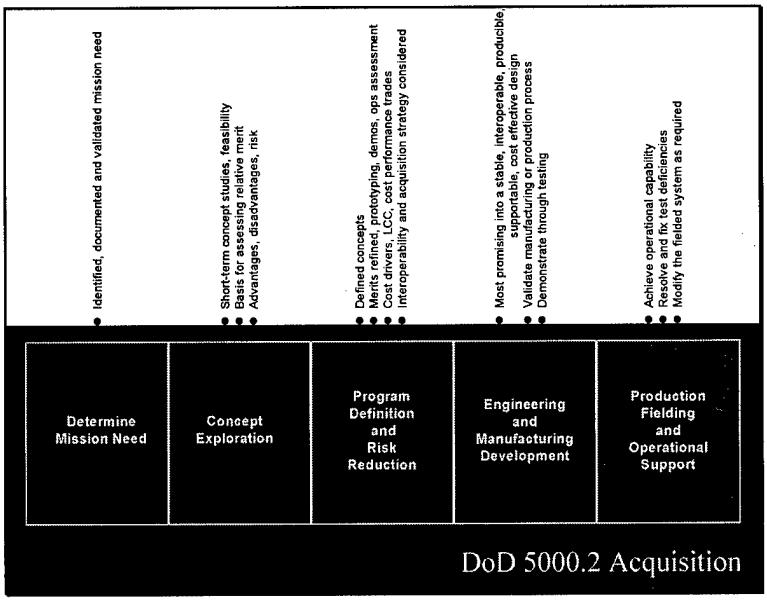

Figure 2. DoD 5000.2 Acquisition Process Summary

JMASS JIRD Analysis. DoD JMASS as defined by the JIRD, is capable of addressing most of the acquisition process except Determination of Mission Needs. At the initiation of the study, the JIRD was the only authoritative reference available that described the overall programmatic requirements, high level capabilities, and operational support requirements for a M&S system to support acquisition. It was also understood from this document that the DoD JMASS Pilot Projects would be used to refine and further specify the requirements for a robust Joint Operational Requirements Document (JORD). The DoD JMASS Pilot Project activities occurred simultaneous to the execution of the study. Therefore, the JIRD was not the final requirements document, but served as the initial requirements. This was the best document available at study initiation.

DoD JMASS JIRD Summary. The JIRD specifies that DoD JMASS is designed to support acquisition as defined in DoDD 5000.2-R. DoD JMASS will provide tools to build models and simulations. Additionally it will foster interoperability and reuse of models from the subsystem/component through the system/engagement level. The main characteristic of the system is to provide a non-proprietary, evolutionary, support infrastructure which will ensure flexibility, openness, and minimal constraint on the users. The major highlights of the DoD JMASS JIRD follow:

- Create a software architecture to develop and configure engineering/engagement models, execute simulations and post process data.
- Provide tools to support computer aided development, configure system and environment, execute simulations and interface to legacy tools.
- Establish standards that include guidelines for DoD JMASS compliant models, tools to implement the compliant models, model-to-model and model-to-system, tool-to-system interfaces, guidelines and tools for porting legacy models to DoD JMASS, and man-machine interface modeling.
- Provide a M&S reuse library of DoD JMASS compliant models.

- Facilitate interoperability with other simulations.

Functionality of DoD JMASS JIRD to DoD Acquisition.. The JIRD specifies that DoD JMASS is intended to support a variety of analysis activities. These analysis activities were correlated with the DoDD 5000.2-R and plotted on the acquisition process to indicate where they logically fit. Figure 3. Functionality of JIRD to Acquisition shows this correlation.

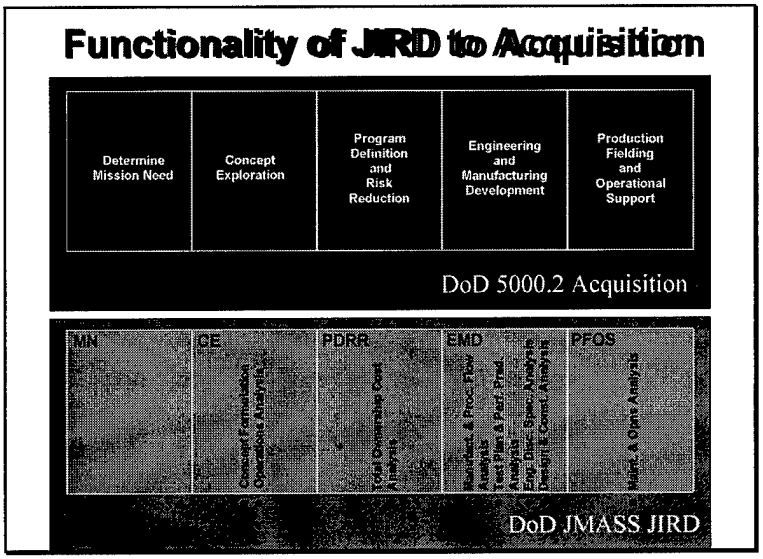

Figure 3. Functionality of JIRD to Acquisition

JMASS JIRD Functionality Issues.

The JIRD specifically delineated eight functional analysis capabilities required of DoD JMASS: 1) operations analysis, 2) concept formulation, 3) engineering discipline specific analysis, 4) total ownership cost analysis, 5) design and construction analysis, 6) test planning and performance prediction analysis, 7) maintenance and operations analysis, and 8) manufacturing and process flow analysis. As these analysis activities were reviewed, some issues as to the JIRD definition of what DoD JMASS is intended to functionally do were raised. Figure 4., DoD JMASS JIRD Functionality Issues, highlights these functionality issues. It is known from the JIRD that DoD JMASS is intended to support engineering/engagement modeling. Acquisition sources note that some engineering/engagement modeling is used early in the acquisition process to support Concept Exploration and Operations Analysis, however it is not used exclusively. Other higher level M&S tools are employed - campaign and mission modeling. These higher level tools are in predominant use during the early stages of the acquisition process. As was discovered, the JIRD encompasses more functional areas than engineering/engagement models can support.

The triangle overlaid on Figure 4 is intended to show, based on the JIRD functional capabilities as depicted in Figure 3, the amount of engineering/engagement M&S use across acquisition. It reflects that there is little use of engineering/engagement early in CE and increasing use of engineering/engagement as a program moves out of CE and into PDRR and EMD. This increase is due to more definition of the weapon system as time goes on and the increased reliance on engineering/engagement tools to address analysis issues for the program. The increased fidelity of these tools depict a more accurate definition of the weapon system as it becomes available, which attempts to further reduce risk in development and maintain the desired military worth for the customer. Engineering/engagement M&S is used to its maximum extent in EMD and then tapers off as the product/weapon system moves to production and fielding.

Besides Operations Analysis and Concept Exploration, Total Ownership Cost Analysis and Maintenance and Operations Analysis are not engineering/engagement M&S. Cost analysis models are

seen as separate from performance modeling. Cost analysis is certainly an important aspect of acquisition, but it is a requirement for the whole process and is driven by a completely different set of parameters. Likewise, Maintenance and Operations Analysis is not engineering/engagement. This area of analysis is viewed as being a part of supportability analysis in the fielding and operational support phase of acquisition. This analysis relates more closely to issues of logistics. This only leaves four of the eight functional capabilities germane to DoD JMASS, and they are predominantly EMD functions.

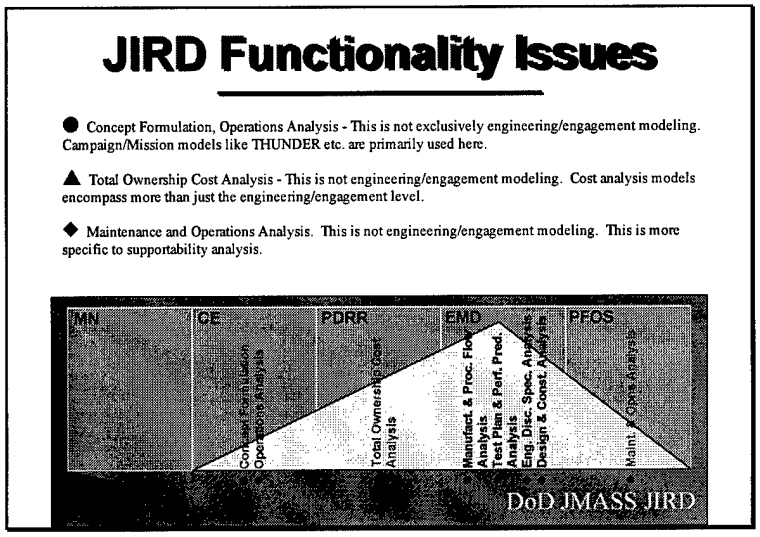

Figure 4. DoD JMASS JIRD Functionality Issues

JMASS JIRD Influence on Acquisition.

The JIRD analysis raised two questions:

1. **Where does DoD JMASS best influence DoD weapons system acquisition?**
2. **Does the JIRD envision DoD JMASS as one system, or a number of systems?**

1. Where does DoD JMASS best influence DoD weapon system acquisition? The JIRD functional capabilities triangle for JMASS clearly places its greatest emphasis in EMD with four of the eight capabilities in that phase of acquisition. It is intuitive, based on this information, that DoD JMASS is to have its greatest influence in the EMD phase of acquisition as shown in Figure 5. The Army's Simulation Support Plan (SSP) Guidelines Engineering Development support this same rationale for engineering/engagement M&S as depicted by its functional capabilities triangle superimposed on the JIRD triangle in Figure 5.

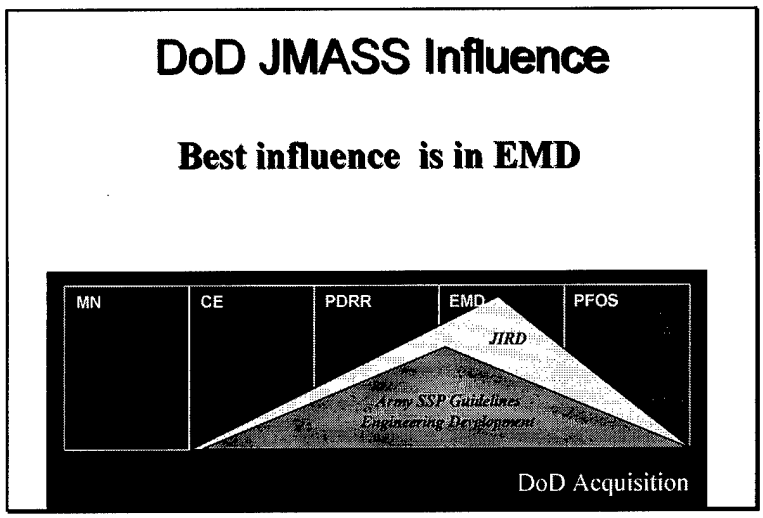

Figure 5. DoD JMASS JIRD Influence on Acquisition

2. Does the JIRD envision DoD JMASS as one system, or a number of systems? The acquisition process requires low fidelity M&S (campaign and mission) and high fidelity M&S (engineering/engagement) to cover all the analysis requirements. As has already been determined from the only authoritative document to be distributed on DoD JMASS, the JIRD, DoD JMASS is specifically defined as an engineering/engagement M&S system only. The campaign and mission M&S requirements will come from some other system so as to cover all aspects of M&S analysis for the acquisition process. Figure 6, DoD JMASS, a System of Systems, depicts the JIRD with its functional capabilities imposed on the acquisition process against the bubbles of acquisition analysis requirements. For DoD JMASS to cover the entire spectrum of acquisition analysis, its general description of operational capability would have to be expanded to the campaign and mission level. DoD JMASS, because it is defined with a narrow scope, can not be the only M&S system for the acquisition process; it will be one of a yet to be determined number of systems that will work in concert to cover the entire acquisition process.

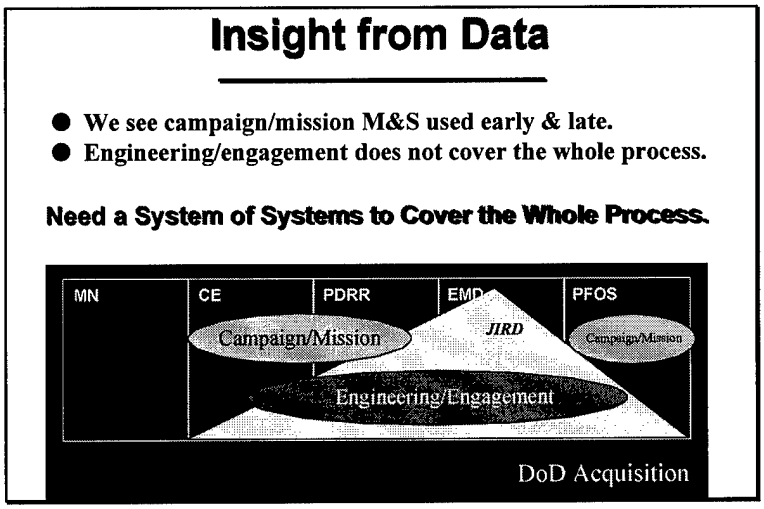

Figure 6. DoD JMASS A System of Systems

Acquisition Context. Having confirmed DoD's definition of the acquisition process and what M&S analysis it requires from the authoritative sources available, the larger picture to be determined was the acquisition relationship of industry and DoD. In the acquisition process, industry and DoD are concerned with two diverging interests as each progresses to a final product for consumer use (see Figure 7). DoD is primarily

concerned with military worth - the ability of the product to increase the warfighting capability of the DoD organization which defined the need for the product. Industry is primarily concerned with profit - the sum remaining after all costs, direct and indirect, are deducted from the income of producing the product. Military worth is founded upon military operational context - the ability to wage war successfully; and industry is founded upon the manufacturing context - the ability to make a quality product while maximizing cost efficiencies. *Both DoD and industry share the same three goals in respect to their products: high quality (better), made in the shortest amount of time possible (faster), and at the least amount of cost (cheaper).* As the figure illustrates, both DoD and industry start as two very distinct and separate interests: military worth vs. profit; yet narrow across the acquisition process as the two interests merge. This merging results from the trade-offs that DoD and industry are faced with as they each try to maximize the three distinct goals while facing fiscal reality. In other words, the added performance the warfighters want may be cost prohibitive, so they accept a little less performance for a much better product/weapons system price from the manufacturers.

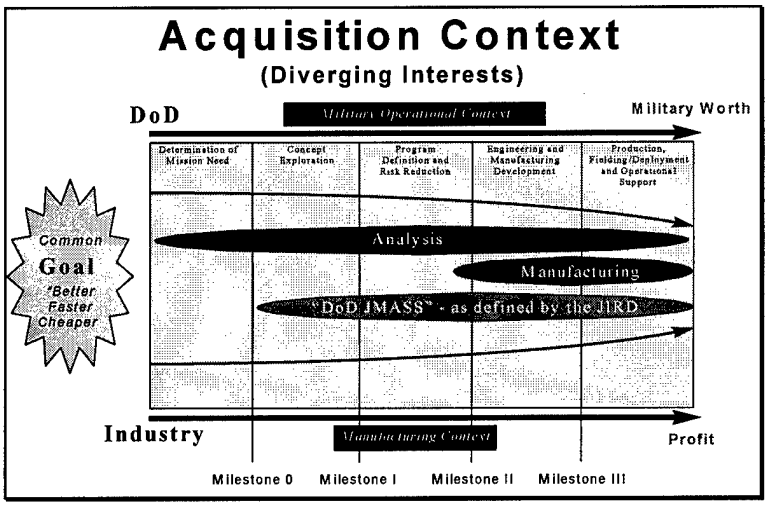

Figure 7. Acquisition Context - Military Worth and Profit

M&S Benefits to the Acquisition Process . The acquisition process demands analysis throughout, with manufacturing emphasized in phases II and III (see Figure 7). Analysis is a tremendous part of the early stages of the acquisition process, especially in determining military worth. M&S analysis will shorten cycle time, run more iterations, collect more data, and use less manpower - all cost efficiencies, not necessarily direct cost savings. The manufacturers are today saving money (increasing profit) by producing products using M&S to maintain their edge in the marketplace. Industry's management understood that M&S would require a big front end cost; but the long term savings and ability to maintain market share were deemed worthy of the investment. Industry successes are direct savings to DoD because their products are better, faster and cheaper - the common goals of both. Concrete examples are the best ways to justify a position and make a point. Figure 8 shows data points, only examples, spread across the acquisition process illustrating how M&S can potentially save time and money for DoD and industry. The magnitude of these cost savings is hard to quantify because they are based on potential and not necessarily concrete figures. The best example collected of a single system and process across manufacturing which assimilates the DoD JMASS JIRD requirements of interoperability and reuse is CATIA. This system is used by Boeing, national, and international automotive industries, and many others. The data points, shown in Figure 8, Example data - Benefits of M&S Use in Acquisition, come from a variety of sources:

- Joint Strike Fighter (JSF) - Joint Analysis Support Team (JAST) Operations Analysis Study Plan Apr 95. M&S to a virtual manufacturing environment.
- Non-Line of Sight (NLOS) Missile "Modeling and Simulation", Sept 94. Distributed Virtual Simulation on a common terrain database.

- AEDC Missiles - AEDC Trip Report, Martha Simmons, '95. Physics based simulation tools anchored to a high quality test model.
- B2/USAF - Manufacturing and the NII (National Information Infrastructure) Report 94. Digital data with a common data management, storage, retrieval, and exchange service.
- Boeing - PBS Broadcast "21st Century Jet, 777" 96-97 and an AW&ST Report 94. A single set of M&S tools and a process.

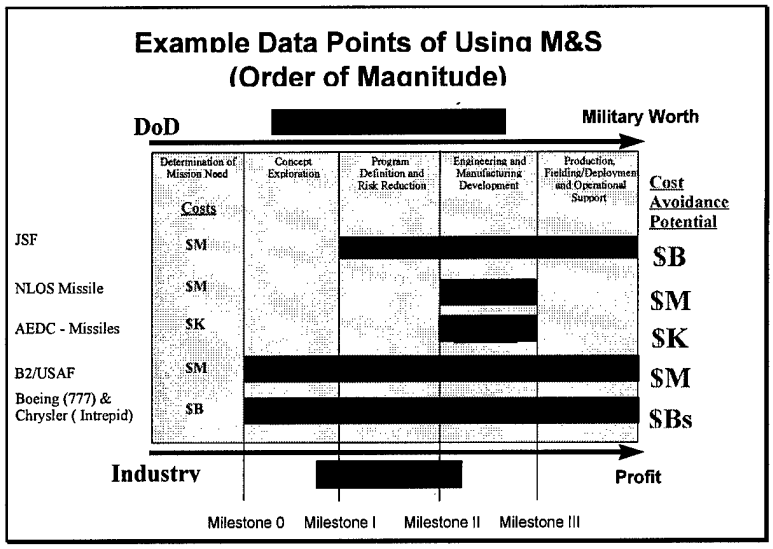

Figure 8. Example Data - Benefits of M&S Use in Acquisition

Industry Investment in M&S. Industry is embracing the M&S revolution as a part of its acquisition reformation. In the previous examples of Figure 8, potential savings were noted so that the benefit could be depicted for industry and DoD. This allows the reader to see that DoD is moving forward in this technology arena. DoD program managers make M&S investments when and where it makes sense. Their decisions are based on good business practice - if it achieves the goals of better, faster and cheaper, they will invest in it. Looking at specific examples in industry can add clarity and better tell the M&S story. Chrysler and Boeing have made huge investments in M&S. They invested in CATIA, a CAD/CAM system in use by over 9000 commercial companies across the world. This M&S system significantly reduces the need for prototypes and replaces that old technology with computer models. Computer models allow for reuse within a program, interoperability between new product lines, and the elimination of duplication of effort. As an example of this technology, Chrysler took the computer model door from the line of one type of car and used it to craft the shape of a door for another line. Chrysler has used M&S to reduce testing by 50%. Boeing and its 777 have been the M&S product standard bearer for major industry. Boeing was faced with being driven from the aircraft market place by Airbus if they could not find a better, faster and cheaper way of doing business. Top level management moved to Integrated Product Teams and M&S technology to regain their hold on the market place. Figure 9 illustrates the investment and return that CATIA has brought to Boeing. It required a huge front end cost ~$5B and training for 10,000 employees for 6 months. The risk was that 239 aircraft had to be ordered to break even; orders for aircraft have surpassed that mark.

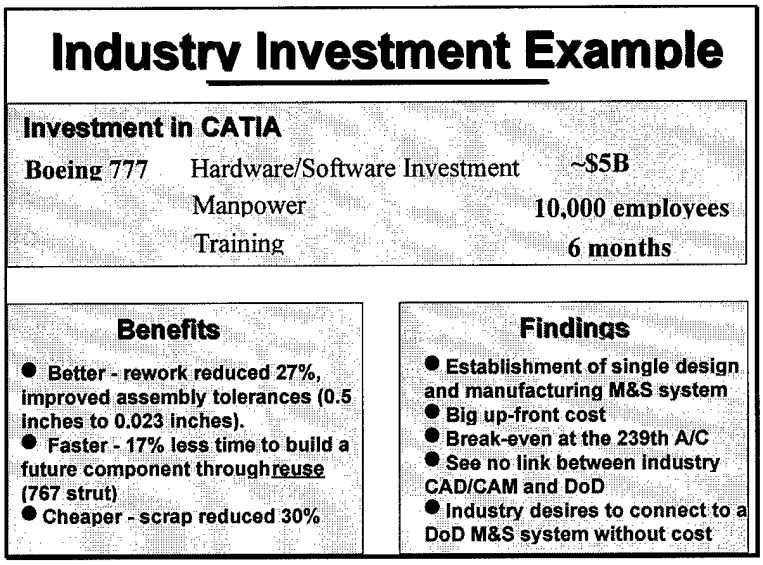

Figure 9. Boeing CATIA Investment Example

DoD Investment in M&S. Acquisition reform is alive and well in DoD; program managers are making business decisions using best business practices so that their product will be better, faster and cheaper to the DoD customer. Program managers are leveraging off industry and business standards are replacing government standards. This will in fact move DoD toward a better, faster and cheaper product, but it does not establish any M&S standards. It allows program managers to move forward based on their budgets and visions, but industry has no common process to connect directly with the DoD acquisition M&S. Since the program managers of the over 200 major programs are making M&S decisions without a common standard and industry is the manufacturer of the product, it makes good, common sense that *a standard needs to be in place to facilitate DoD/industry cooperation.* On more than one occasion, industry representatives, many of which attended the DoD JMASS Industry Days, have asked that DoD establish a single M&S system with which they can easily and cheaply connect their concept models to DoD's threats and environments so that every industry concept model would get a fair and impartial evaluation. If DoD maintained a repository of verified, validated and accredited threat and environment models, reuse of these models would ensure consistency within a program, save money by only having to create a single model, and allow all the programs needing the same models to use them (interoperability). Industry is the definitive source for manufacturing and the M&S technology that is evolving in this area; DoD is the definitive source for operational analysis and should focus on the M&S technology needed now and for future contingencies. The establishment of a single system for DoD acquisition would give industry a standard for M&S interface, promote reuse and interoperability among the DoD acquisition process phases and programs, and foster the seamless transition between DoD operational analysis and industrial manufacturing.

DoD M&S System Realities. Reuse, interoperability, elimination of duplication of effort, seamless transitions between industry and DoD, and better, faster and cheaper products - all these benefits are possible through M&S. Can DoD afford the cost that a single system would demand? *Chrysler spent millions and Boeing 's estimate is in the billions for the CATIA M&S system. They are manufacturers and they found a system that meets their needs. The return on investment (ROI) they envisioned could be directly linked to maintaining market share and profit - future and near term gain. They were also willing to step out smartly with new M&S technology and scrap all their old M&S systems.* DoD is a different story. DoD is faced with a shrinking budget and must find ways to economize. Millions of dollars have been invested in legacy M&S systems, government analysts have used them for years and are resistant to change to new systems. The competition for the shrinking budget is very keen due to the numerous priorities vying for the dollars within each Service in DoD. Many government officials see only the additional cost that a new M&S system demands, and are not willing to wait for the ROI that will come with time. They also would like to see legacy systems folded into the new system so that prior investments in

M&S can continue to be used. Services are not easily swayed to invest the large up front dollar amounts required for a DoD wide M&S acquisition system, unless they individually get some return on their investment. The only way that can happen is to find products/platforms that will cross Services' boundaries.

M&S can certainly save time and money, but M&S carries with it the risk of technological obsolescence. Translators change every six months, hardware every year and one-half, and software every five to six years. Yet, the longer DoD waits to find the "perfect, single" system, the more out of touch it will be with the advances being made in the commercial sector. In the review of the JIRD, DoD JMASS is not functionally capable of covering the entire acquisition analysis process. The JIRD is not the final requirements document. The JORD and the Mission Needs Statement (MNS) will be the defining documents for DoD JMASS. It is apparent that DoD acquisition will require a set of M&S systems to cover the whole process.

Analysis Summary Part 1. How does DoD move into the M&S future with the constraints that are realities of today?

Establish a Joint Program Office (JPO)/Task Force. If the DoD acquisition community is going to move forward with a M&S technology standard, it will not come about from the program managers. DoD management, like industry's management has already done, must take positive steps to aggressively seek out and discover the set of systems that will support all the facets of DoD acquisition and interconnect with commercial industry. The establishment of a JPO will keep the focus on a DoD acquisition M&S system that can come to fruition. This will work if DoD stakeholders/users (Services, OSD, acquisition community, analysis community) are represented within the JPO. Timing the implementation so that the users want the new M&S because it is as easy to use as the legacy systems they are accustomed to and it adds capability will minimize the risk of investing in M&S that will not be used or lacks the capability to meet the goals of the acquisition community. The JPO must maintain flexibility to incorporate current technology. A methodology must be designed by the JPO that maximizes benefit across the acquisition process and Services, yet minimizes expense due to the shrinking DoD budget and the investment already made in legacy M&S systems.

Part 2 - Cost Benefit

Time Limitation. Due to the limited duration of the study, the aircraft related survivability analysis domain was identified as the sample domain to examine.

Cost Benefit of DoD JMASS.

This portion of the study will document "order of magnitude" cost estimates of DoD JMASS as applied in a common weapon system domain and the benefits of the system. A series of cost illustration examples will be presented in order to show:

- the cost of DoD JMASS models
- the cost of DoD JMASS models compared to legacy models
- the cost and benefit of reuse of DoD JMASS models within a common domain
- the cost and benefit of reuse of DoD JMASS models across multiple domains

The cost estimates are related in a real-world setting. In other words, they show the potential benefit to acquisition by showing cost examples within a setting of today's program status. The cost benefit is conveyed with consideration of the timing and implementation of DoD JMASS in the current acquisition picture. Note however, the DoD JMASS system itself, as represented in the upcoming cost examples, is strictly a notional representation of the system and is yet to be defined. The notional representation of DoD JMASS should consist of the three distinct model entities: the digital system model (DSM) or the representation of the DoD weapons platform, the threat model, and the environment model. All three of these model entities must be built and made available to interact with each other to make the complete

simulation. The cost examples to follow will use this notional representation as the criteria for establishing cost profiles. The closest object-oriented simulation system that afforded concrete cost figures was AF JMASS and this became the basis of DoD JMASS costs. Also, from this point forward through Part 2, DoD JMASS will be referred to as simply JMASS.

Cost Estimate Data Collection. The basis of the cost estimates came from interviews and research with the AF JMASS Program Office, the JMASS Pilot Projects, and the existing AF JMASS model development community consisting of MSIC and NGIC, both representatives of the Modeling and Simulation Executive Agent (MSEA) for threat. The greatest challenge in data collection was finding legacy model cost data that were comparable to JMASS. The legacy data were collected through interviews and research within a number of acquisition program offices. The main challenge faced was the willingness of the various programs to share cost information from their respective programs. Additionally, the challenge in legacy cost data collection was to find legacy models that would relate closely enough to JMASS and to make a comparison between JMASS use and legacy use over time in order to assess the cost benefit. All of the cost data are measured in rough order of magnitude estimates. Cost estimate data were successfully collected and put in context in the following cost benefit analysis.

Cost Benefit Analysis Foundation. First, a foundation upon which the cost benefit was based was established. Since the main concern was supporting weapon system acquisition, the OSD T&E Oversight List which lists common domains for the major weapon system acquisition programs in ACAT I and II provided the best starting point. Figure 10, OUSD DTSEE T&E Oversight List, displays the ACAT I and II program domains under T&E oversight by DTSEE. It was logical to compile this list into common domains as you see on the left side of the chart. It was also logical to break out the number of programs in each domain along the time line of acquisition milestones and show the distribution of programs across each domain. The list displays on the horizontal axis the quantity of programs in time bins by milestone. Each milestone time bin contains the quantity of programs at or earlier than the milestone listed. These common domains form the foundation upon which the analysis was built. The list was compiled in this manner to give a picture of commonality, the potential to share resources, and the sense of time where numbers of programs fell within the acquisition process. This break out serves to:

- Show logical groupings
- Provide a basis to understand the common threads of analysis and models
- Find a common legacy model example used extensively throughout a domain
- Calculate JMASS costs in viable areas that demonstrate a potential for reuse

Best Domain Example. The focus of attention was in the aircraft domain because this is where the most readily available example was found. Figure 11, Specific Domain of Investigation, highlights the aircraft domain and the distribution of programs across the domain. Based on research of weapons system acquisition programs in this domain, the JSF program proved to be the best example for several reasons: the program was the most forthcoming with M&S data; it provided a viable common thread across the domain - commonality in aircraft survivability analysis and modeling; and it provided the most specific dollar cost estimate data on a legacy model that is commonly used across the whole aircraft domain. Additionally, AF JMASS model development has focused in the air domain with the recent development of environment models for electronic combat and a number of surface-to-air threat models. All of these conditions provided information needed to conduct the analysis. Following are the specifics of the legacy modeling in the JSF program used in the cost illustration examples.

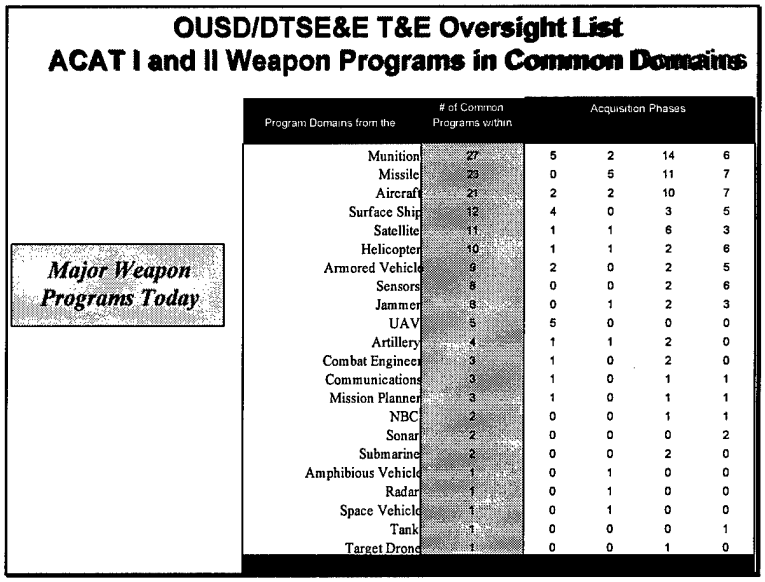

Figure 10. OUSD DTSEE T&E Oversight List

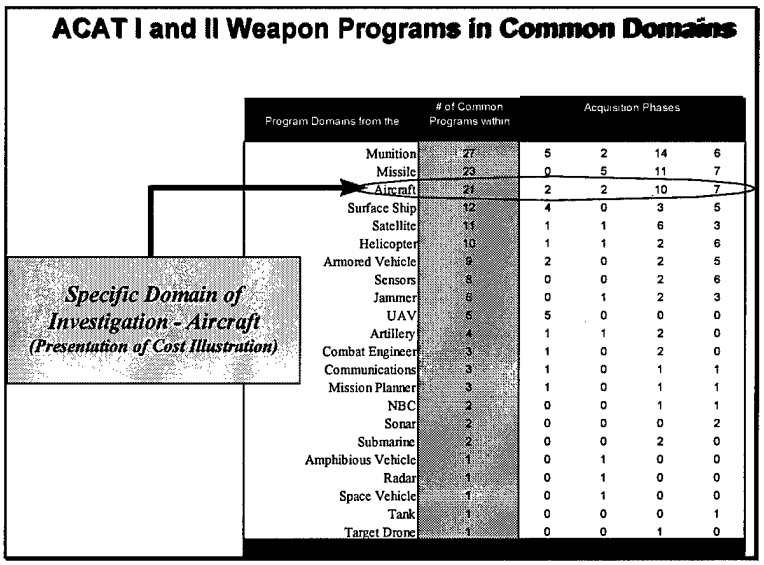

Figure 11. Specific Domain of Investigation - Aircraft

Legacy Modeling in the JSF Program. The JSF program provided information about M&S and analysis plans. Figure 12, Joint Strike Fighter Legacy M&S Suite, displays the models used by JSF to address analysis issues. From the JIRD, the JMASS focus is engineering/engagement. The focus in the study was to find a common model supporting a common area of analysis used throughout a common domain that has specific cost estimate data available to use in the study to compare with JMASS. The research with the JSF M&S staff yielded the match of all the conditions sought. The match within the engineering/engagement area allowed for the best comparison possible.

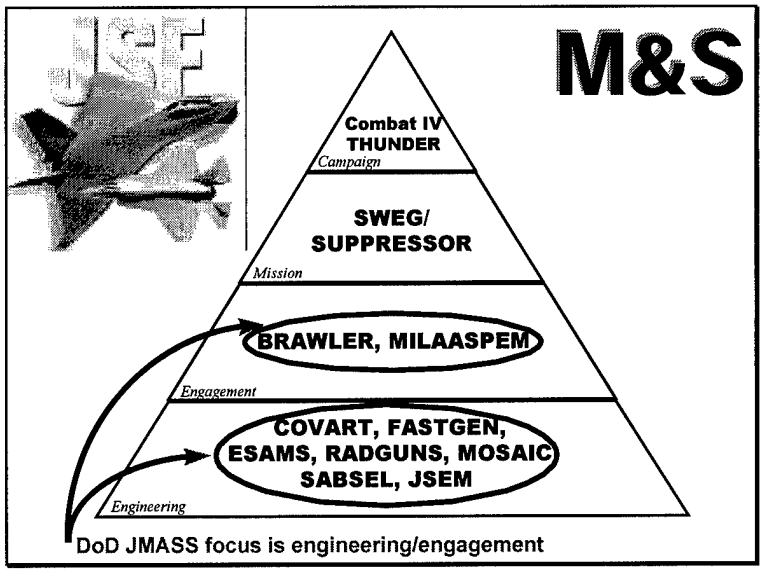

Figure 12. Joint Strike Fighter Legacy M&S Suite

Legacy Common Thread - Enhance Surface-to-Air Missile Simulation (ESAMS) . The best common thread found in the engineering/engagement suite of models was ESAMS - a SURVIAC model used widely across the aircraft domain by all the Services to address aircraft survivability analysis issues. Figure 13, Specific Area of Investigation - ESAMS, highlights that the model is found within the engineering/engagement hierarchy and addresses aircraft survivability issues. It should be noted also that the SURVIAC program office verified that ESAMS is used extensively across the aircraft domain by all the Services for aircraft survivability analysis. So, the first stepping-stone in the analysis process was completed with the identification of a viable legacy model with which to compare to JMASS. The second stepping-stone was to determine the cost estimate expenditure of ESAMS use within the JSF program over time.

ESAMS - Legacy Cost Estimate Data from JSF. The JSF M&S office provided order of magnitude cost estimate data on the use of ESAMS over the life of the program. This information was verified with the SURVIAC program office which oversees the development, configuration control, use and modification of the model. The SURVIAC office found these estimates to be reasonable. The legacy cost estimates of ESAMS will be used in a series of side-by-side cost comparisons with JMASS in the sections to follow. The assumptions of cost estimate data on JSF use of ESAMS are:

- ESAMS will support analysis of JSF aircraft survivability issues over a 10 year period.
- The cost of ESAMS modifications were estimated to be between ~$35K - $150K twice a year for each of the 10 years. In other words ~$70K - $300K per year over the 10 year period of use. A low-to-high range was established because modifications vary due to the complexity of the analysis issue.

JMASS Cost Estimate Data. This section provides a detailed break-down of the estimated development cost of AF JMASS models. This information was provided and verified by the Air Force JMASS program office and the threat model developers at MSIC. AF JMASS models are organized into three areas: the digital system model (DSM) - the representation of the blue weapon system; the threat model - in this case the representation of surface-to-air missile (SAM) threat systems; and, the environment model. AF JMASS models can be built at varying levels of fidelity from a low resolution, "analytic" model, to the most robust, "EC capable", or electronic combat capable. Following is the cost estimate data for JMASS models:

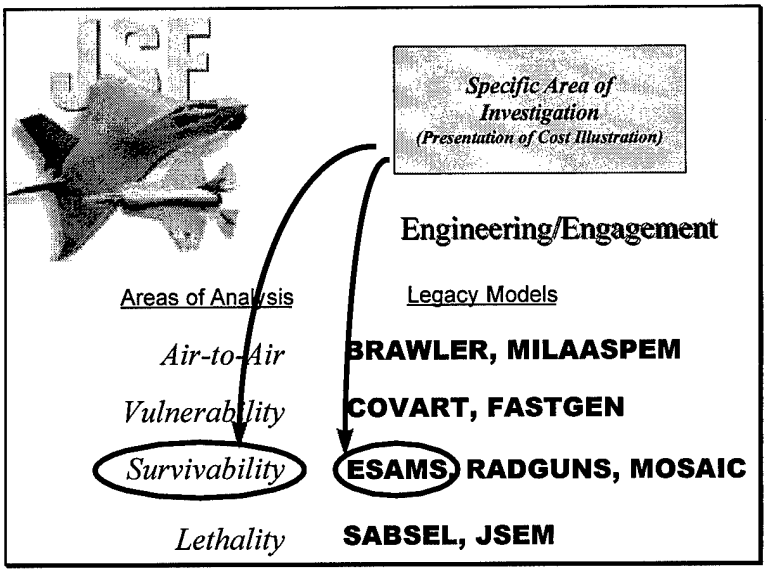

Figure 13. Specific Area of Investigation - ESAMS

- Analytic model - cost estimate is ~$400K per model whether it is DSM, threat, or environment.
- EC Capable model - the EC Capable cost is the cost of the analytic model (~$400K) plus an additional $600K to bring the model to full robust capabilities for a total of ~$1M.
- Model component reuse - there is a model component reuse advantage with the analytic model. If you are building multiple models of a like system you can reuse model components. For example, if you are building five SAM threat systems at the full EC capability, the first model costs a total of ~$1M (~$400K for the analytic + ~$600K to add on the EC capability = ~$1M) and the other 4 cost only ~$600K each. This is realized because the analytic piece of the SAM system is generic enough as a basis for use in developing the other four models. The added cost of ~$600K for each of the other four SAMS is necessary to add on the detailed unique characteristics required for an accurate, detailed, fully robust representation of the other four SAMS. Therefore the total cost to build five EC capable SAMs is ~$1M for the first SAM + (~$600K x 4 other SAMS) = ~$1M + ~$2.4M = ~$3.4M. So, the total cost of building five EC capable SAMS is ~$3.4M.

Cost Illustrations. The next stepping-stone in the analysis was establishing a baseline comparison between the ESAMS capability and cost over time versus the JMASS capability and cost over time. Figure 14, Cost Illustration Example - Side-by-Side Comparison (Legacy vs. JMASS) highlights this baseline comparison. The intent in making this comparison is to make as close to an "apples-to-apples" comparison as possible, understanding of course, that there are some differences between ESAMS and AF JMASS. The two systems are, for the most part, comparable at the analytic level in capability. However, when making comparisons at the EC capable level, the models do not compare. This is because ESAMS does not have the same highly detailed robust EC capabilities as JMASS. It should be noted at this point that this is where AF JMASS stands out as having a greater benefit than the legacy system. As JMASS is an object-oriented system, it provides a more disciplined approach in programming. Although it is possible the legacy could be modified to a similar EC capability it would be cost prohibitive to do so because of the extensive re-coding and verification in a non-object language.

Side-By-Side Cost Illustration (Legacy vs. JMASS). Figure 14. Cost Illustration, Side-by-Side Comparison (Legacy vs. JMASS) shows the baseline comparison. The JSF program is concerned with addressing aircraft survivability analysis issues, using ESAMS, to model five different SAM threats. The side-by-side comparison shows the cost of ESAMS compared to a similar capability in JMASS over the same life cycle, in rough order of magnitude, over 10 years.

Criteria and Assumptions. The criteria and assumptions for the comparison are listed at the top of Figure 14. The criteria established for this cost illustration were designed to focus the analysis into a specific and comparable situation.

Funding of Models. Funding of JMASS models is assumed to be shared by the PM and DoD. The PM would fund the build of the DSM and DoD would fund the build of the threat and environment models; All of these models would be placed in the JMASS modeling repository and made available for reuse. Because JMASS establishes a coding standard, model components and models, all HLA compliant, would be available for reuse to the community. Currently, PMs fund the modification of the legacy models.

Cost Comparison. The left side of the figure shows the cost range of modifying the ESAMS model to address the aircraft survivability analysis issues. These cost estimates were introduced in the previous section. The right side of the figure shows the comparable cost of building JMASS models to address the same analysis issues. These cost estimates were introduced in the previous section also. The cost encompasses the build of the three JMASS model types: the DSM, the threats - in this case five SAMs, and the environment. As depicted in the figure, there is a cost comparison at the analytic level and a cost comparison at the EC Capable level. When analyzing each cost comparison, note that, at the analytic level, the cost of the three JMASS model types is ~$2.8M. This cost falls within the upper range cost of ESAMS, ~$0.7M - $3.0M. PMs are concerned with costs within their programs and would be interested, based on the funding information in the previous paragraph, that in the JMASS system they only pay for the DSM - in this case ~$0.4M, a cost which falls below the lower range of the legacy cost. DoD pays for the threats and environment. *If a PM needs only an analytic level capability to address his analysis issues, then JMASS is a more cost effective solution.* The EC capable cost of the three JMASS model types is ~$5.4M. This cost is above the upper range of the legacy cost. Given that PMs only pay for the DSM, in this case a cost of ~$1.0M, this cost falls within the lower range cost of ESAMS, ~$0.7M - ~$3.0M.

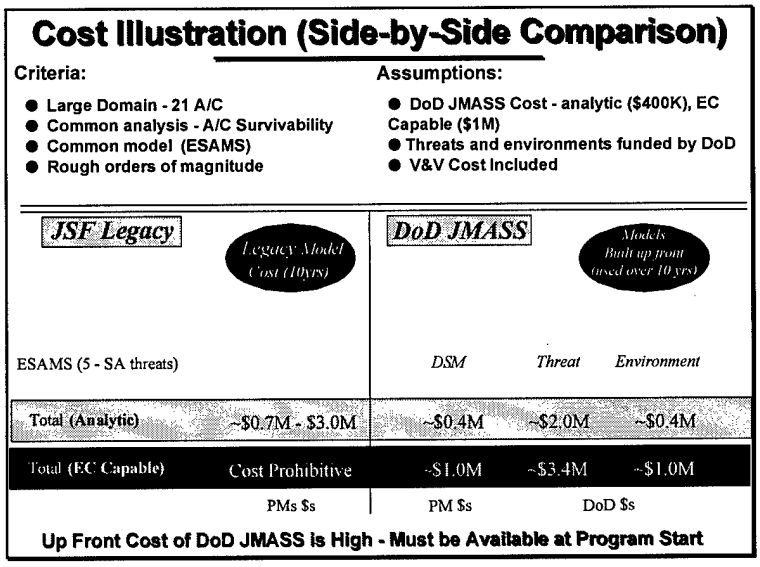

Figure 14. Cost Illustration, Side-by-Side Comparison (Legacy vs. JMASS)

Domain Reuse (Four Programs). The next cost illustration will demonstrate the benefit of model reuse in the JMASS system. The previous cost illustration established a foundation upon which this illustration will be built. The key points to bring forward from the previous illustration are the same basic model cost estimates for ESAMS and JMASS used in the same context. The added information in this illustration is the benefit of reuse of models already funded and built, and available in the model repository for sharing. This cost illustration is framed using the OUSD T&E Oversight List and identifying multiple programs in the aircraft domain that show potential for model sharing - reuse. Figure 15, Selection of Programs in a

Common Domain, highlights four programs in the aircraft domain early in acquisition that could possibly share models. The focus was narrowed to programs early in acquisition, because PMs plan and budget their M&S and analysis for their program early. The following cost illustration example demonstrates the benefit through reuse of threat and environment models in a common domain.

OUSD/DTSE&E T&E Oversight List
ACAT I and II Weapon Programs in Common Domains

Program Domains from the	# of Common Programs within	Acquisition Phases			
Munition	27	5	2	14	6
Missile	23	0	5	11	7
Aircraft	21	2	2	10	7
Surface Ship	12	4	0	3	5
Satellite	11	1	1	6	3
Helicopter	10	1	1	2	6
Armored Vehicle	9	2	0	2	5
Sensors	8	0	0	2	6
Jammer	6	0	1	2	3
UAV	5	5	0	0	0
Artillery	4	1	1	2	0
Combat Engineer	3	1	0	2	0
Communications	3	1	0	1	1
Mission Planner	3	1	0	1	1
NBC	2	0	0	1	1
Sonar	2	0	0	0	2
Submarine	2	0	0	2	0
Amphibious Vehicle	1	0	1	0	0
Radar	1	0	1	0	0
Space Vehicle	1	0	1	0	0
Tank	1	0	0	0	1
Target Drone	1	0	0	1	0

MS I and earlier programs will be used in the following cost illustration on Domain Reuse (4 programs)

MS I and earlier programs are illustrated because PMs plan M&S use early and are not likely to introduce new M&S past MS II

Figure 15. Selection of Programs in a Common Domain

Criteria and Assumptions. The criteria and assumptions for the comparison are listed at the top of Figure 16, Cost Illustration, Domain Reuse. The criteria established for this cost illustration focused the analysis into a specific comparable situation to consider the benefits of reuse. In this illustration it should be noted that the threat and environment models are built for the B-1 Defense Systems Upgrade Program (DSUP) and shared with the other three programs. At the writing of this report, the threat and environment models had already been developed and delivered to B-1 DSUP. The B-1 DSUP program will be the first to use AF JMASS.

Funding of Models. As discussed in the previous cost illustration, the method of funding remains the same conceptually. The difference in this illustration is the Air Force has already funded all the AF JMASS models for B-1 DSUP and made them available to the model repository. The threat and environment models are assumed to be funded and are available for reuse to other programs, in this case, to the other three programs. The PMs would still fund the build of the their own unique DSM.

Cost Comparison. The left side of Figure 16 shows the cost range of modifying the ESAMS model to address the aircraft survivability analysis issues. The cost estimate figures were used from the JSF ESAMS example as this cost range is a reasonable rough order of magnitude estimate for all four programs. These same cost estimates were introduced in the previous section. Interviews with PMs revealed that they use their own version of ESAMS and modify for their specific need. This fact underscores the redundant investment and duplication of effort made in ESAMS among these four programs. The right side of Figure 16 shows the comparable cost of building JMASS models to address the same analysis issues. In this case, the threat and environment models are already funded and available and the only cost to the PMs is the funding of their unique DSMs. As you see from the Figure 16, there is a cost comparison at the analytic level and a cost comparison at the EC Capable level. When analyzing each cost comparison, each of the four PMs would be interested to note, at the analytic level, the cost of the DSMs is ~$0.4M. This cost falls below the low end range of the legacy expenditure. As stated previously, if a PM needs only an analytic level capability to address analysis issues, then JMASS is a more cost effective solution. The EC capable cost of the four JMASS DSMs is ~$2.8M. This cost falls exactly on the low end cost range of the collective

redundant investment made in ESAMS among the four programs. The investment in JMASS at the EC capable level would be cost effective for these four programs as the cost is equal to the low end legacy cost. *JMASS provides a better, more robust capability at the EC capable level and provides a cost benefit if threat and environment models are reusable within the domain.*

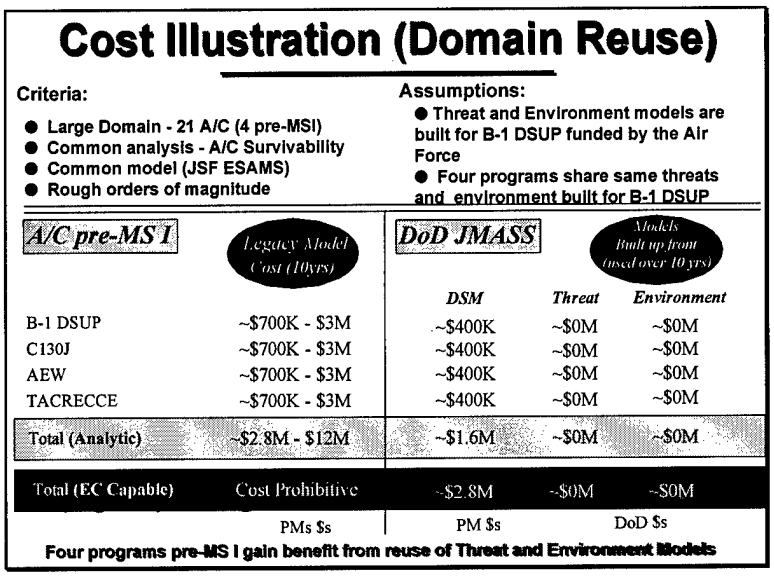

Figure 16. Cost Illustration, Domain Reuse (Legacy vs. JMASS)

Multiple Domain Reuse (16 Programs). The next cost illustration will demonstrate the benefit of model reuse of threat and environment models across multiple domains sharing similar interests. The previous cost illustration established a foundation upon which this illustration will follow. The key points to bring forward from the previous illustration are the basic model cost estimates for ESAMS and JMASS used in the same context. The added information in this illustration is the benefit of reuse of models among 16 programs. This cost illustration is framed by using the OUSD T&E Oversight List and identifying multiple programs in the aircraft domain that show potential for model sharing - reuse. Figure 17, Selection of Programs in Multiple Common Domain, highlights there are 16 programs in the air related domains early in acquisition that could possibly share models. The focus was narrowed to programs early in acquisition, because, based on interviews with various PMs, they plan and budget the M&S and analysis for their program early and don't typically initiate expenditures later in the program. The following cost illustration example demonstrates the benefit through reuse of threat and environment models in multiple domains.

Criteria and Assumptions. The criteria and assumptions for the comparison are listed at the top of Figure 18, Cost Illustration, Multiple Domain Reuse. The criteria established for this cost illustration were designed to focus the analysis into a specific comparable situation and consider the benefits of reuse. In this illustration it should be noted that there is a larger sample of programs to support. It is assumed that the 16 programs will share the same 10 threat models. The 10 threat models are different than those were built for B-1 DSUP from the previous cost illustration. In this example, there are new builds of threats and environment models.

Funding of Models. It is assumed that the funding of JMASS models would be divided between the PM and DoD. The PM would fund the build of the DSM and DoD would fund the build of the threat and environment models. All of these models would be placed in the JMASS modeling repository and made available for reuse. Because JMASS establishes a coding standard, model components and models would be available for reuse. Currently, PMs fund the modification of the legacy models.

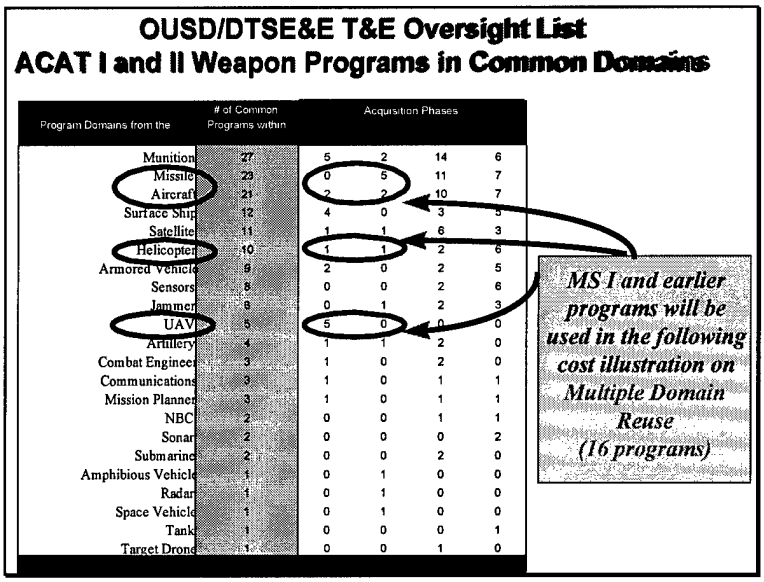

Figure 17. Selection of Programs in Multiple Domains

Cost Comparison. The left side of the Figure 18, shows the cost range of modifying the ESAMS model to address the aircraft survivability analysis issues. The cost estimate figures from the JSF ESAMS example were used as a reasonable rough order of magnitude estimate for all 16 programs. These same cost estimates were introduced in the previous section. The cost encompasses the build of the three JMASS model types: the 16 DSMs, 10 threats, and one environment. As you see from the figure there is a cost comparison at the analytic level and a cost comparison at the EC Capable level. When analyzing each cost comparison at the analytic level, the cost of the three JMASS model types is ~$10.8M. This cost falls below the low range cost of ESAMS ~$11.2M - $48.0M. PMs concerned with costs within their programs would be interested to note, based on the funding method, that in the JMASS system they only pay for the DSM - in this case at a lower cost than the legacy. DoD pays for the threats and environment. Again, if a PM needs only an analytic level capability to address analysis issues, JMASS is a more cost effective solution. The EC capable cost of the three JMASS model types is ~$18.6M. This cost is within the low end range of the legacy cost. PMs only pay for their DSM. In this case, cost of the DSMs is lower than the legacies because of the reuse of model components and models. Intuitively, with more programs and sharing, the greater the cost benefit.

Cost Benefit. The data represented in Figure 19, Cost Benefit, show the relationship of legacy costs to DoD JMASS costs from the previous example of 16 programs. The costs represent the total package of DSM, threat, and environment models. The bar on the top depicts the range of cost of the legacy model from low to high - the redundant investment of 16 programs in the legacy system. The bar under the legacy depicts the range of cost of building a suite of JMASS models (16 DSMs, 10 threats, and one environment). The range represents the low, the analytic level, to the high, the EC capable, clearly depicting a long term benefit to the department.

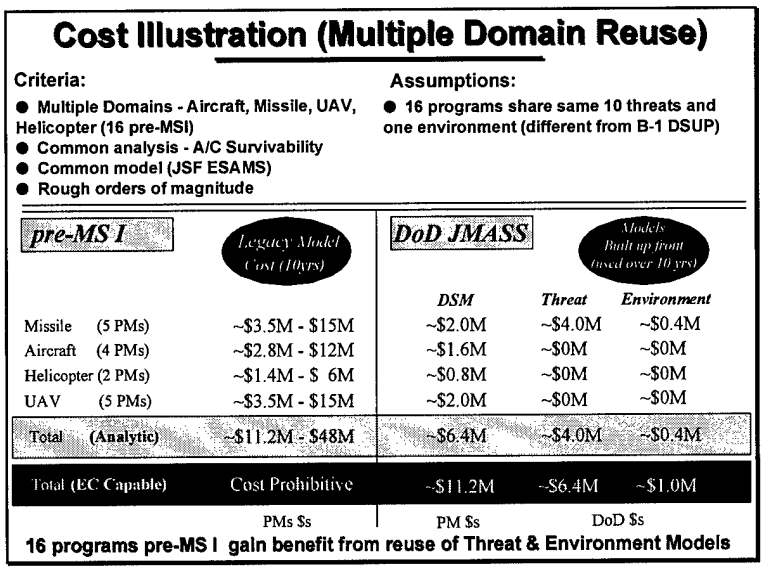

Figure 18. Cost Illustration, Multiple Domain Reuse (Legacy vs. JMASS)

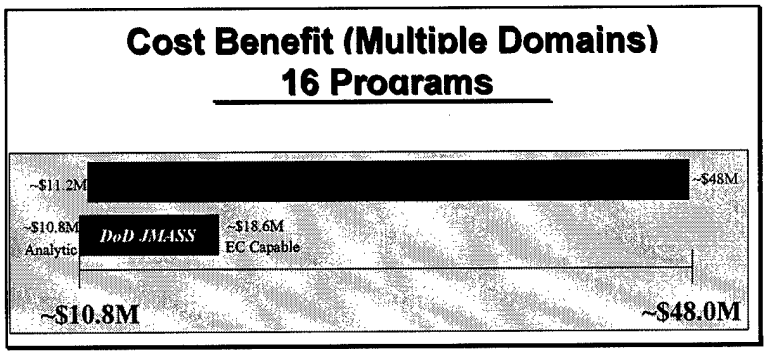

Figure 19. Cost Benefit

Analysis Summary Part 2. The range of JMASS cost, analytic to EC is at the low end range of ROM cost compared to legacy. Based on cost alone, the JMASS analytic capability is cheaper compared to legacy, ~$10.8M compared to ~$11.2M. To build JMASS at a robust EC capability, ~$18.6M, still is at the low end range of the legacy cost profile whereas an EC ESAMS is cost prohibitive. The PMs cost is lower when they only have to build the DSM. Although the front-end cost for the system may be high, JMASS demonstrates the additional benefits gained above cost: reuse of model components and models; elimination of the duplication of legacy use; and an overall better product with more capability than what is available in the legacy.

Assessment of Risk. When weighing the options, one must consider risk as a factor. The analysis revealed several criteria that are important to assessing risk. These criteria are presented with an assessment of risk for each. A scale is applied to each criteria in the form of: a minus sign (-), criteria containing risk; or, in the form of a plus sign (+), criteria containing no risk.

(-) User friendliness. Based on information from the pilot projects, the tools and services of the AF JMASS system still need improvement in order to gain acceptance from the analysis community.

(-) Timing. Based on information from the pilot projects, it is estimated the time it takes to develop models and deliver them to the model repository is ~2 ½ to ~5 years. Over this time period, the

acquisition programs identified at MS0 and MSI will be moving forward to MSI and MSII respectively. Interviews with various PMs revealed they become less receptive to new developments in their programs later in the acquisition cycle.

(-) Front-end Cost. The initial costs to build a suite of JMASS models to support a PM or group of PMs within a common domain is high. The whole suite of JMASS models must be available to the program at program start, the DSM, threat and environment, all capable of interoperating with each other.

(+) PMs Cost. The PM cost is low, as they now only have to pay for their DSM.

(+) More disciplined approach. JMASS provides a more disciplined approach, in common threats and common environment models. These common models provide a "level playing field" of analysis within and across multiple programs.

(+) Move to Object-Oriented. An object-oriented system provides some significant benefits: improved model development speed; easier M&S reuse; and common look and feel across simulations which reduces the learning curve for executing and using simulations.

(+) Reduce Duplication of Effort. The object-oriented system reduces the duplication of simulation support elements and interfaces: input/output services, time management, distributed interfaces, common support tools (e.g. 3-D viewers, 2-D plots/strip charts, GUIs), and common support models (e.g. spatial, math, terrain).

General. This section is a compilation of insights from the study, including interviews, categorized into logical groupings. The insights are organized as follows:

1. **DoD JMASS System**
    - Requirements
    - Description
    - Costs
        - Up front
        - Overall
    - Benefits
2. **JIRD/JORD**

1. DoD JMASS System

Requirements

DoD JMASS is a notional acquisition system for the future, intended to save time and money. To be efficient and effective technically, its models and simulations must be:

- Reusable
- Interoperable
- Able to eliminate the legacy duplication of effort
- Cost effective
- A common model system and model set

From DoD management's perspective, this system cannot be so restrictive to the PM that it stifles initiative or good business practices (e.g. PMs leveraging Industry M&S successes to get the answers they need) which is a tenet of DoD Acquisition Reform. Top level industrial management had to move to M&S to maintain market share and remain part of the mainstream of manufacturing technology. Is there a requirement for a DoD M&S system? PMs, consumers of analysis, and the analysts of the M&S community who will use it are not asking for it, nor do they have the time or inclination to research a new way of doing business, but the need to find a better way is near term due to the shrinking Defense budget. Also, PMs are not waiting for a system to be built and fielded. They need answers, and need them today, so they are answering their performance questions wherever they can find the information. All the Services share the common goal of producing a better, cheaper and faster - "sooner in the hands of the warfighter" - product. The M&S system that can satisfy these common goals within each of the Services' specific warfighter domains will receive support.

AF JMASS, as all or part of DoD JMASS, once in its final form, must demonstrate its productivity so that PMs/analysts will want to use it. Cultural resistance will be high to changing the way DoD does business because it will be: 1) New; 2) No single system has been proven to fulfill all the requirements of all the Services; and 3) The understood inherent risk of technological obsolescence - hardware changes every 18 months, software every 5-6 years, and translators every 6 months.

DoD JMASS must hurdle technical and cultural obstacles, while at the same time minimizing the technological investment risk, to achieve DoD wide acceptance as the single acquisition M&S system.

System Description

The system should be a system of systems, made up of AF JMASS and others (yet to be determined). DoD's focus should be on interoperability and operational analysis, and Industry on manufacturing and design. AF JMASS does not fit all phases of acquisition, it only depicts engineering/engagement models, and it is not yet real time. The acquisition process requires much more than this, like costing, accounting, resourcing and high level analysis. AF JMASS has the potential to expand into more areas of acquisition than just T&E, but, at this point in time, it should be viewed as one of the blocks in the foundation that will lead to the fully robust DoD JMASS.

For a full description of DoD JMASS, data format, threats, standards, and environments will need to be completely defined so that reuse and commonality will be fostered across the process. The MSEAs that are to oversee and maintain the environments will be responsible for the libraries where the models and components will be stored are far from final resolution. Legacy models don't easily transition to the models of the future, object-oriented; in fact, based on Industry's experience, it is better to just scrap legacies and move to object-oriented formats.

System Costs

Up Front Costs. DoD PMs want low maintenance, low investment vehicles which will save them time and money. The risk and cost of new hardware and software are things they can ill afford and may be too high a price to pay. Using Industry as an example, Chrysler spent $100's millions and Boeing spent around $2 billion for the move from their old systems to CATIA, a single manufacturing and design M&S system. Leveraging AF JMASS could save $30 million, the sunk cost of the existing system, and 3 to 5 years. Couple this with a plan of DoD paying for the threat and environment models and PMs paying for the DSM; the M&S cost to the PM would be drastically reduced and a standard would be in place for Industry.

Overall Costs. In the long term, legacy models will be replaced by some form of object-oriented models. It is true that the first program that uses the new models will incur costs equal to or greater than present M&S systems (rough order of magnitude for AF JMASS threat models - analytical $450K, and EC $1M), but the follow-on programs that can reuse the models will get them free. The Air Force has studied 11 programs and estimated that the object-oriented EC capable models would cost $800M, but the reuse of AF JMASS model components and models reduces this cost to $350M. The Air Force is funding 8-12 analytical and 5 EC models, and the environment model for the B-1 DSUP program today.

System Benefits

The DoD JMASS system, by fulfilling its requirements, will support reuse, interoperability, and eliminate the duplication of effort. It certainly has the potential for substantial cost savings over time, while increasing capability at costs equal to or less than those being paid for legacy models. The legacy models used today do not promote interoperability. Programs tend to modify the model version they are using - duplicating effort, and normally require "sneaker net" operations to move data from model to model. The capability of more evaluations completed with less resources will certainly appeal to PMs, but the overarching embrace of object-oriented technology, and a standard to bridge/leverage Industry's M&S successes may be the most appealing benefit of all.

2. JIRD/JORD. The JIRD, as the only authoritative document for the development of DoD JMASS (the JORD is still being drafted), defines DoD JMASS as being capable of doing many things across the entire domain of the acquisition process. These capabilities are too broad in scope for an engineering/engagement model and simulation system. The pilot projects, which were designed to validate the capabilities of AF JMASS in relation to the JIRD, found that object-oriented is the right approach, cited improved model

speed and reuse, and reduced duplication of effort. The Army's portion of the pilot projects was only able to prove 16% of the JIRD requirements assigned, yet, the version of AF JMASS being used was an older version (3.1). The latest version (3.2), will potentially prove its capability as it is being employed by the B-1 DSUP program. Version (4.0), available in 1999, is estimated to meet 80% of the JIRD capabilities. The JORD, as it is finalized, must take into account what AF JMASS can accomplish and look at a system of systems approach to build the fully capable M&S system that the acquisition process requires.

Three Courses of Action. Upon review of the background analysis, cost benefit analysis, and insights, three courses of action are postulated. The three courses of action are presented along with the advantages and disadvantages of each. This information is followed by a presentation of recommendations in the next section.

- **Course of Action #1. Invest in Air Force JMASS.**

  Advantages: It is the most mature object-oriented system. Investments have been made in tools and services of system. Investments have been made in EC Threat and Environment Models (no extra cost to subsequent users). The system provides a more disciplined approach to analysis - use of common threats and environment models throughout the acquisition program.

  Disadvantages: There is an up-front cost to populate models for other than EC work. The system is not yet widely used by the analysis community. There is some risk in the robustness of the tools and services of the system.

- **Course of Action #2. Wait for Technology.**

  Advantages: In the future there may be a possible single system solution, a COTS solution, which may be cheaper.

  Disadvantages: Software technology is continuously moving and improving - how long do you wait?

- **Course of Action #3. Continue to use Legacies.**

  Advantages: No additional costs, analysts are comfortable using legacy models.

  Disadvantages: No apparent cost savings, continued duplication of effort, continued VV&A issues with the duplication of effort, lack of interoperability.

Invest in Air Force JMASS. The recommendation is to select Course of Action #1 - Invest in Air Force JMASS. Make a specific investment in air domains of aircraft, missile, helicopter, and UAV programs that share common interests by populating the model repository with threat and environment models common to these programs. Make the investment that meets the needs of the Service's requirements in common domains shared by the Services. Also, make an investment into the improvements of the tools and services of the system as recommended by the pilot projects so that engineers, programmers, and analysts will more readily use the system. Leverage the existing investment in threat and environment models from the B1-DSUP program to the other air domains so they will reap the cost benefit of reuse.

> *Rationale:* The Air Force has made, and continues to make, investments in this system. If DoD moved to something other than this system the cost could be ~$30M for a new start. The benefit of model reuse was proven in the cost illustration examples - the more expanded the domain, the greater the benefit.

Establish a Joint Program Office (JPO). Concurrent with the course of action, it is also recommended that a Joint Program Office as a management structure oversee the development of a system that meets the needs of DoD to support acquisition. There is a need to involve all stakeholders in both the acquisition and analysis communities.

> *Rationale:* A consistent thread of opinions throughout the study effort was the recommendation that a JPO be formed to support a tool structure for M&S in acquisition.

Recommend a Strategy for the Joint Program Office (JPO). The specific strategy for the Joint Program Office follows:

- Take an open-minded approach, be flexible, keep options open - a way to do business.
- Aggressively manage the timing of implementation of the system.
- Monitor technology advances in object oriented systems - maintain sensitivity to technological obsolescence.
- Monitor the successes of the B-1 DSUP use of Air Force JMASS - leverage successes into other large domains like munitions.
- Investigate areas of common interest in other DoD programs focusing on specific areas of analysis, sharing the benefits of the object oriented system.
- Take a building block, phased approach to the growth of the system in other domains.
- Continue pilot projects to refine requirements and prove benefits to the stakeholders.

> *Rationale:* The technological world is in constant change, especially in computer related technology. To avoid a situation of technological obsolescence, it is necessary to monitor carefully the ever changing software advances.

Summary. The investment in JMASS is technology for the future - the object-oriented approach meets many needs. It supports a model repository approach by fostering reuse of model components and models within and among acquisition programs that share common interests. The move to this system eliminates the existing duplication of effort found among the use of legacies. JMASS provides a disciplined approach to modeling, provides interoperability among engineering/engagement models and simulations, and

provides a standard for Industry. The JMASS system will initially address engineering/engagement models as described in the JIRD. The more robust acquisition needs will later need to be addressed.