

Review and Update of Findings from Economics of Simulation Study Groups

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ABSTRACT

This paper reviews findings from previous studies on the Economics of Modelling and Simulation (M&S), updates those findings, discusses related studies being planned or conducted, and highlights challenges in establishing metrics to evaluate contributions of M&S to future programs. This paper includes discussion of an ongoing study initiated at the Swedish Materiel Administration (FMV) for The Swedish Armed Forces; the questions, justifications, and answers to date will help identify the evidence needed to assist future decision makers faced with difficult choices for spending on M&S. Efforts to evaluate the effectiveness of M&S and its usefulness in assisting acquisition programs in North Atlantic Treaty Organization (NATO) countries such as the United Kingdom and Canada will be mentioned also.

Two international simulation organizations -- the Simulation Interoperability Standards Organization (SISO) and the Society for Computer Simulation (SCS) -- chartered groups in the late 1990's to build a better understanding of the Economics of M&S.

The SISO and SCS groups were formed to establish the general parameters of the topic, and, while the result was substantial, especially in data compilation, much of the original tasking remains. SISO may soon undertake a follow-on effort to define the Business Case for M&S. The data compiled by these two groups will be useful to establish a current understanding of the preceding work, filter out the substantive evidence, and establish a baseline for further work on the Effectiveness of M&S and also within the NATO M&S Task Group (MSG) 031 on The Cost Effectiveness of M&S. The findings and status of the SISO and SCS studies have been briefed to meetings of the International Test and Evaluation Association; the Interservice/Industry Training, Simulation, and Education Conference; and the SimSummit. This paper will recommend further steps to complete the actions recommended in both the SISO and SCS studies.

However, the existence of these SISO and SCS study groups and the products from these legacy efforts are not widely known throughout the community-of-practice in M&S. This paper will recommend ways to preserve and advertise the state of understanding from the previous efforts in order to foster explicit, conscious coordination among M&S stakeholders internationally. Use of a venue such as the international SimSummit organization and a convenient Effectiveness of M&S web portal to continue progress in understanding the effectiveness of M&S will be discussed. Within the Swedish study, the need for convincing evidence for the economical benefits of M&S is stressed. The challenge is to identify the most important expenditures for M&S to give the greatest return on investment and consequently increase the willingness among project managers to invest in M&S support. This section of the paper will present the progress in developing a Best Practice Guide for individual decision makers to know what to invest in M&S support for a specific task. With the growing importance of M&S, decision makers will ask necessary questions about why one should spend the next “dollar” on M&S. Both substantive and subjective answers to that question are important. Ultimately, there should be readily accessible information to answer questions such as “What do I gain in effectiveness, risk reduction, or cost savings if I fund this M&S task?”

1.0 INTRODUCTION

Since the first computer simulation game was introduced in the early 1960s and the first computer simulation for military training was introduced in the early 1970s [1], evidence on the effectiveness of M&S has been sought. Since those first uses, M&S has grown in importance, breadth of use cases, and integration into our daily lives. As distributed simulation grew in importance to the United States Department of Defense (DoD) in the late 1980s, leadership began asking questions about the effectiveness and the expense. The United States Congress held hearings on the effectiveness of simulation in the early 1990s, and at that time, testimony showed that M&S had already helped leaders look at alternative futures and combat forces train and rehearse missions and operations – Congress was presented with clear, substantive evidence that M&S had improved effectiveness in war for one specific battle [2]. Since those Congressional hearings, several attempts to quantify the effectiveness of M&S more broadly have been initiated, looking at topics such as impact assessment, simulation based acquisition, and benefits or economics of M&S. Each thrust into this topic raised awareness of the need for substantive evidence, gathered anecdotal evidence, generated reports, and, for the most part, disbanded. Some data from these previous efforts, momentum, and documentation in the interim was lost. This would be acceptable if the need to provide substantive evidence on the effectiveness of M&S did not persist. This paper proposes that attention on this very important topic must persist with a focus on a permanent study of this topic under an international organization chartered and funded to gather data, develop metrics, analyze data, and post knowledge gained on the web, preserving available legacy information already gathered, inviting new data, and monitoring test cases selected to build a substantive topic understanding.

1.1 Thesis

The Economics of M&S is being pursued with ever increasing interest and vigour, and, while significant results have been achieved, there is an opportunity nevertheless to (a) establish systematic collaboration on the Economics of M&S across the entire M&S community-of-practice, (b) act deliberately to establish consensus understanding of several facets of this topic, and (c) influence emerging M&S markets and business practices.

1.2 Interest in Economics of M&S

M&S has always had an economic aspect and provided, to some degree, a form of value in exchange for a cost paid. For a variety of reasons, however, the economic implications of M&S have been subsumed into the context in which it was used, and M&S costs and benefits have been difficult to discriminate from other aspects of the project at hand. Only in the last few decades has the perception of significant cost of assets and activities classified as M&S been perceived to be high enough to generate economic concern, while the benefit of simulation has been perceived to be great enough to warrant self-conscious investment, thus permitting the Economics of M&S to be accorded attention as a topic in its own right. In the discussion that follows, we address the emergent status and scope of interest in the Economics of M&S, introduce a conceptual framework for comprehensive investigation of the topic, identify and characterize the principle stakeholders and roles relevant to the subject, identify significant ongoing activities, and offer recommendations for consideration, decision, and action in pursuing a broad-based agenda for investigation and influence of the Economics of M&S.

1.3 Status of M&S as an Industry

M&S technology is: pervasive in its application, diverse in its implementation, versatile in its employment, powerful in its effect, valuable in its use, and (often) cost-effective. On the other hand...the case may be made that as a profession, an industry, and a marketplace, M&S is fundamentally immature. There are several “markers” of this immaturity that relate to the existence of a recognized technical discipline and profession, or industry. Failing to appreciate the body-of-knowledge, the development of efficient product and service markets is inhibited. Without any form of unambiguous identification of simulation professionals, the labour supply is indefinite, with an extremely insecure and inefficient labour market. Economies-of-scale are not achieved, and the mobility of technology and assets within the M&S industry and across application domains is reduced. Potential markets are unnecessarily fragmented; and the identification and provision of necessary products and services is duplicative. And, perhaps most significantly, financial investment both from within and outside the industry is deterred by the lack of perceptible market. Investment of intellectual effort into standards, technology, tools, and business practices is, therefore, discouraged. Like other industries before ours -- previous technology-enabled professions and enterprise domains -- we in M&S are experiencing the typical syndrome of an emerging market. Significantly, it is we in M&S who are wrestling with the inefficiencies pursuant to the immaturity of the M&S industry. Our understanding of the details of the Economics of M&S is a basis of our operating with relative competitive advantage in that marketplace and influencing the evolution of that market in the broader economic context.

2.0 BACKGROUND

Decision-makers in government, industry, and academia approve plans to acquire new systems, ensure the readiness of personnel to do their jobs, and look into the future to reduce risks and take advantage of opportunities. In each of these areas – acquisition, personnel readiness, and investigation of futures – there is a growing power of simulation to help. Yet, for some tasks, any use of simulation -- or authorizing more

simulation -- may not help, and the determination of right level and kinds of simulation to use are often complex balancing acts. It is both logical and appropriate for decision-makers to ask for ways to judge the value of simulation. Why spend another “dollar” on M&S? Indeed, what benefits have been realized from previous expenditures on M&S, and what will be the anticipated benefit of future expenditures? For many reasons, the answers to these questions are not easy to calculate. This paper will summarize the findings of previous studies to answer questions on the benefits of M&S, discuss ongoing studies in this area, and recommend future actions to continue progress toward answers.

In this paper, we report anecdotal findings about the “intelligent use” of simulation – which most often has a very positive reported return on investment. In the late 1990s, the Simulation Interoperability Standards Organization (SISO) established an Economics of Simulation Study Group and the Society for Computer Simulation (SCS) established a Technical Chapter on the Economics of M&S. The SISO and SCS groups were formed to establish the general parameters of the topic, develop a provisional market model, draft terminology and taxonomy of concepts, make a data call for readily available empirical evidence, document a business case, and identify best (most effective) practices relative to this topic. Much of the tasking remains unfinished; yet a significant amount of effort in framing the discussion, data compilation, and analysis of the data can be reported in this paper. The SISO and SCS activities engendered a growing interest in making progress in many of the investigation areas for the Economics of M&S – in fact a “Collegial Initiative on the Economics of M&S” has encouraged progress at meetings and conferences, including in conjunction with the SimSummit; Inter-service/Industry Training, Education, and Simulation Conferences; and SISO and SCS Conferences. Mr William “Bill” Waite, a co-author for this paper, is the driving force for establishment of the SCS and SISO Economics of Simulation groups, and he continues to lead the Collegial Initiative on the Economics of M&S and the SimSummit efforts.

Clearly, efforts to define the benefits of simulation continue. This paper will leverage available information from the NATO M&S Task Group (MSG) 031 concerning “The Cost Effectiveness of Modeling and Simulation (M&S)”, studying the exploitation of M&S by the defence community with the goal of saving time and money and increasing performance. MSG-031 included reviews of the United States’ Simulation Based Acquisition (SBA) initiatives and the Synthetic Environments-Based Acquisition (SeBA) efforts in the United Kingdom and Canada. The continuation of the Collegial Initiative on the Economics of M&S also has generated some new progress in this area, and a SISO Study Group for the Best Practices in M&S Business Case Explication may be chartered soon.

An update on an ongoing Swedish study on the benefits of using simulation will also be covered. Starting in late 2004, the Swedish Material Administration (FMV) for the Swedish Armed Forces initiated a study to help identify the evidence needed for decisions on M&S investments. One initial product of the FMV study will be a Best Practices Guide to assist leaders in making decisions about the optimal investments in M&S. Finally, this paper concludes with recommendations for future progress in this topic area, including a continued topic focus at regular SimSummit meetings, establishment and funding of a collaborative, informal web site to store documentation to date and illicit further submission of documentation and ideas concerning the Economics of M&S, and an effort to measure substantive evidence for the Economics of M&S.

3.0 TOPICS FROM PREVIOUS ACTIVITIES IN THE ECONOMICS OF M&S

The following areas were developed and presented in working groups for SISO and SCS, covered in articles on the topic, or are historical activities related to the topic; data compilation is covered in Section 4.0.

In addressing the Economics of M&S, we can hardly be more comprehensive than to cite the definition of economics as the study of how society manages its scarce resources [3]. Similarly, a Market is defined as a group of buyers and sellers of a particular good or service [3]. These definitions do beg discussion of several topics mentioned in this paper, including M&S scarce resources, M&S goods and services, M&S buyers and sellers, and trades and rates for M&S goods.

Five significant components of the Economics of M&S are: 1) M&S Cost-Benefit, 2) the Business Case for M&S, 3) the M&S Market, 4) the M&S Industry, and 5) M&S Stakeholders, with several facets discussed. Each of these components is introduced briefly to indicate the general status of the prevailing appreciation of the Economics of M&S and to suggest potential courses of action.

3.1 Cost-Benefit

To establish the cost or benefit (or cost-benefit) of a simulation entity or activity, the definitions suggest considerable latitude for interpretation. For instance, consider that the cost of simulation is frequently not only unaccounted, but fundamentally unaccountable, as a consequence of commonly confounding simulation development and use costs. Often, costs are classified as analysis, software development, infrastructure, or other more comprehensive systems engineering or enterprise efforts which simulation serves and, within which, simulation is contained. At a somewhat more abstract level, there is considerably less consensus for factors on which the cost of M&S depends, as compared to the circumstance in other disciplines [4]. Finally, costs as well as benefits are not fully intrinsic attributes of the simulation artefact or activity.

Simulation benefit suffers too from lack of accountability. The benefit of simulation is often difficult to differentiate from the benefit of the asset or capability that it inevitably supports. Its benefit may be distributed widely in time and place as simulation is used for alternative ends and re-used -- its benefits are propagated both laterally and longitudinally and its value is recovered across a disparate recipient population. Another difficulty with simulation benefit accounting is that much of the ascribed benefit is reasonably associated with foreclosure of pejorative futures – namely cost-avoidance or risk-avoidance. Such benefits are intrinsically difficult to track and value.

Finally, regarding both cost and benefit accounting, there is typically very little incentive to account for simulation investment and subsequent recovery during the timeframe when such documentation could be accomplished at reasonable effort – effectively reserving such analysis to after-action analysis of alternatives of M&S investments. There is simply no prescriptive best practice whereby cost or benefit of M&S may be accounted for in a timely way with any expectation of correctness, completeness, consistency, and auditable detail. The appetite exists, therefore, for means to identify, adopt, and reward at least “good practice” for M&S Cost-Benefit accounting.

3.2 Business Case

While cost and benefit (investment and recovery) are the vernacular of merit-function quantification, the expression of the Business Case is a somewhat higher order expression of the net value of M&S in its subject enterprise context. Accepting the definition of Business Case as a form of expression of the plausibility of alternative business practices, actions, or transactions [5], the successful Business Case requires the anticipated process or course-of-action be clearly appreciated by participating stakeholders. The Business Case then provides the basis for the commitment-to-act by stakeholders. Any given Business Case is dependent for its effectiveness on a variety of factors. The Business Case must be expressed in terms of business processes and practices which characterize the domain of application. Its elements must correlate to

the everyday behaviours, decisions, terms-of-reference, and values of the stakeholders. A Business Case must be cast to the stakeholders' various roles and "speak" to all in such a way as to provide adequate rationale for their respective adoption of good practices.

Appreciation of various sorts of costs and benefits must be reflected in an effective Business Case. Direct cost and cost-avoidance must be accounted. Quantitative benefits such as cost savings and qualitative benefits such as risk avoidance, product quality, and time-to-field must be accounted. Dependencies of cost and benefit upon extenuating circumstances must be identified. Visibility of cost and benefit metrics and aggregate merit functions will be required. Causal relationships between investment and recovery of investment must be evident especially across boundaries of stakeholder tenure or responsibility.

Finally, the context of expression and interpretation of the Business Case must be clearly established. The Business Case for M&S expressed now will certainly be different in future since the context of use will change. Business Cases may come to be established as valid for alternative levels of generality / abstraction, from generic to specific, depending on purpose and use. While the establishment of Cost-Benefit data generation practice would be welcome, we must understand that no amount of such data will serve the present need unless we can, with confidence and efficiency, communicate it via salient Business Case encapsulation.

3.3 Market

We naturally wonder what products, services, which buyers and sellers, and what interactive transactions mechanisms constitute the M&S Market. The answer certainly is that there is no such thing as an M&S Market, but instead many interlocking markets, loosely connected by the accident of overlap of tools, techniques, and advocates across relatively disjoint application domains. Because we must understand complex non-standard markets, analyze M&S-specific market structures and operations, influence market dynamics, and operate successfully in somewhat chaotic market environments; it is incumbent that we are proficient to understand and represent M&S Markets, and alternatively to design and implement such markets (or to influence existing ones) for the collective benefit [6].

Representing (or modelling) the M&S Market has been difficult, especially in light of the ostensible expertise of its community-of-practice. Certainly, there is the difficulty of identifying and characterizing the entities, relationships, and behaviours of a market that is known only narrowly to most stakeholders. In addition, there is the inhibition that social systems such as economic markets are not typical of the referents for the large majority of M&S practitioners. Finally, as all modelling efforts, representation of the M&S Market is part discovery and part invention; and is, in any case, extremely sensitive to the potential intended uses of the expected model. User needs, and consequently, requirements of M&S Market models, are hardly appreciated by consensus or well-documented. At best, we may find (or be able to construct) lumped parameter models that indicate the typical product commodity market: total market revenues current year, by supplier; total revenue per year all suppliers (direct sales, sales to distributors, distribution mark-up, total market); new licenses and total license renewals in year by supplier; percent revenue growth and dollar value revenue growth by supplier; and buyer demand in dollars, by buyer. Nevertheless, some specific market models are motivated by market design efforts introduced below; and the prospect of verified and validated M&S Market models may be nearer than is commonly assumed. In each such case, explicit representation of the concept of operation of the market itself, assuming the behaviours of market agents -- manipulating and exchanging products and services in accordance with expressible operational rules-of-engagement -- is necessary and is well within the capacity of the M&S community-of-practice.

3.4 Industry

The existence of an M&S Industry is an important topic. Especially since we consider M&S to be characterized as a group of “knowledge intensive business service firms” [7] in which M&S assets are capital as much as is software itself [8], and which emerge in accordance with generally recognized paradigms [9]. The M&S Industry is the superset of organizations, relationships, and cultures within which the M&S Market operates. For instance, establishment of industrial classification codes to uniquely identify the industry and members, and monitoring of general attributes and operational processes are typical industrial development functions. The recent emergence of organizations whose role is to purvey the entire industry and to influence those elements of its nature (technology, profession, market) on behalf of the common good is of special note. This testifies to the immature nature of the industry, yet suggests positive progress.

3.5 M&S Stakeholders

The existence of a variety of stakeholders with associated roles is particularly relevant for our look at the Economics of M&S, and there is value in identifying the stakeholder types and indicating their defining characteristics, their relative diversity, and their roles pertinent to the Economics of M&S.

3.5.1 Professional Societies

Professional societies are characterized by their emphasis on supporting practicing professionals, improving workforce quality by providing a variety of services and information, conducting meetings and technical conference events, and publishing both technical journals and news of interest to the practitioner community. The considerable diversity among societies relevant to the Economics of M&S is manifest in several forms. These include: fundamental focus and scope of the organizational field-of-regard, the facets of the topic that may particularly interest the organization, and the types of mechanisms whereby the Economics of M&S is manifest within their purview. SCS, for instance, is focused on M&S technology and has traditionally had an academic flavour to its membership and is, therefore, interested in the labour market and in influencing workforce development through educational design and delivery services. They address economic issues by means of a dedicated Technical Chapter, through hosting sessions with economic emphasis in its conference events, and by means of a column in its general interest magazine. SISO, on the other hand, focuses on simulation standards, and has a military and aerospace emphasis (although other domains such as manufacturing and medicine are becoming evident), and accommodates economic concerns in its conference meetings and workshop activities, having sustained a Study Group expressly devoted to the topic. The International Test and Evaluation Association (ITEA), while focused on physical testing and systems evaluation, and closely allied with the defence community, has considerable interest in M&S and has supported the exploration of the Economics of M&S in paper sessions, panels, and tutorials at its meeting events. The Military Operations Research Society (MORS) and the Institute for Operations Research and the Management Science (INFORMS) are peripherally involved and exhibit similar characteristics.

3.5.2 Academic Institutions

The academic community is generally focused on M&S technology invention and promulgation, with its own economic environment of tuition, grants, and R&D supported partly by student labour. Academia has varying stakes in the Economics of M&S insofar as they participate in the labour education market or in the technical services industry through their affiliated research centres and institutes. Several academic institutions are perceptibly active in the M&S field in the United States alone. For instance, the MOVES Institute¹ at the

¹ <http://www.movesinstitute.org/>

United States Naval Post Graduate School (NPG) was an early innovator in producing advanced degrees in M&S and emphasized technological innovation in communications and visualization. Two academic organizations with strong interdisciplinary emphasis in research and graduate education are the M&S Research and Education Center (MSREC)² at Georgia Tech, whose mission is to create and support cross-disciplinary research and development activities, and the Arizona Center for Integrative M&S (ACIMS)³ devoted to research and instruction to advance the use of M&S to provide coherent global solutions to multidisciplinary problems. Two other institutions focus on innovative technologies, namely: the Institute for Creative Technology (ICT) at the University of Southern California⁴, and the Institute for Simulation and Training (IST)⁵ at the University of Central Florida. The newly formed Center for Modeling, Simulation, and Analysis⁶ at the University of Alabama in Huntsville, and the Virginia Modeling, Analysis, and Simulation Center⁷, led by Old Dominion University, function as enterprise technology-maturation and promulgation fee-for-service centres. At an international level, the McLeod Institute of Simulation Sciences (MISS)⁸, a collective of university affiliates, coordinated through the SCS, has had relatively little substantive emphasis or impact on economic considerations, focusing more on curricular academic research collaboration. Overt activity by academic institutions in the Economics of M&S is limited to normal market participation as a specialized education and technology development and promulgation service agent. In future, leveraging the business and marketing expertise of academic institutions will help further the understanding of the Economics of M&S.

3.5.3 Government Departments and Agencies

Government organizations of interest include those in all departments but especially defence. Governments' military interests in M&S are perhaps seminal to the entire industry. Given the pervasiveness of government interest in M&S, it is not surprising that governments act in almost every conceivable M&S role. They are customer-users of simulation assets and services. They develop and deploy M&S assets (somewhat to the consternation of commercial developer-vendors). They subsidize technology and standards development and promulgation, and they invest overtly in the M&S workforce, establishing requirements, and offering training and establishing (local) certification qualifications. They have a considerable stake in cost efficient business practices for M&S life-cycle evolution and for use of M&S across the life-cycle of systems. Return-on-investment in M&S has become a matter of considerable government focus, and unfortunately, frustration.

It appears there are competing roles within government. On one hand, there is considerable correlation of appreciation and cohesion of intent across international defence establishments on the question of the Economics of M&S – what are the problems, opportunities, present circumstances, and future challenges? This correlation of interest is reflected to some degree in the breadth of activities undertaken by government agencies. On the other hand, every component of a given defence establishment has, by its nature, a specific perspective for which their view of the Economics of M&S is distinctively different. To appreciate this diversity, one needs only to consider, for instance, the view of a program manager being encouraged to leverage M&S technology, the departmental technology advocate, and the M&S support infrastructure agent.

2 <http://www.msrec.gatech.edu/>

3 <http://www.acims.arizona.edu/>

4 <http://www.ict.usc.edu/>

5 <http://www.ist.ucf.edu/>

6 <http://resadmin.uah.edu/research/Centers.html>

7 <http://www.vmasc.odu.edu/main.htm>

8 <http://www.simulationscience.org/>

Likely, the most significant and challenging perspective taken by governments with respect to M&S is that of establishing the role of M&S in business process re-engineering. Many government activities to study or participate in activities related to the Economics of M&S are referenced in Appendix One to this paper.

Government efforts are generally interesting and well-intended, but not always instrumented for success metrics and lessons-learned. Failure to capture M&S economic lessons-learned is chronic, influenced mostly by divisions in responsibility during product lifecycles. Auspicious counterexamples do exist^{9, 10}. There is motivation for economic instrumentation of new technologies, standards, business practices, and enterprise implementation programs¹¹.

Introduction of the HLA standard, for instance, whose adoption was known to have likely economic implications and whose successful acceptance was expected a priori to depend upon the perception by the M&S community-of-practice, was only casually monitored for economic impact. In that case, no effective pro-active campaign to anticipate and manage the (perceived) economic impact of introduction of the standard was executed; and adoption suffered consequently. Government activities are now generally sensitive to technology-investment and recovery. In addition, the considerable similarity of interest across national defence establishments in economic topics-of-interest is also significant and reassuring. It is, in fact, in this commonality of interest in the large scale impacts of M&S technology that constitutes the opportunity to “cooperate and graduate” in the study of the Economics of M&S. In fact, the NATO MSG-031, described briefly in this paper, is something of a pathfinder in such overt and clearly relevant cooperation.

3.5.4 Government Surveys

Two surveys conducted by government agencies deserve mention for their seminal effect in stimulating interest and establishing precedent. First, the United States Army Modeling and Simulation Office (AMSO) – now part of the Battle Command, Simulation & Experimentation Directorate¹² -- conducted a survey and analysis that set the tone for subsequent government surveys, and presaged Army interest in the subject, culminating in their SBA-like initiatives. The United States DoD conducted a survey and analysis for the initial justification of the SBA program; and both the United Kingdom and Canada have conducted extensive surveys and analyses in conjunction with the implementation of their SBA-like programs.

3.5.5 Government SBA Initiatives

The particular form of business practice that is denoted SBA in the United States^{13,14,15} and Synthetic Environments Based Acquisition (SeBA) in the United Kingdom^{16,17} is characterized by emphasis on shared

9 Training Capabilities Industry Strategy Game, Alternative #4 – ‘Microsystems’ Business Model, Sponsored by OUSD(R) and JFCOM, 11-13 February 2004,

10 “The Critical Under-utilization of Simulation-Based Test Beds”, Prepared by the Simulation Sub-panel of Systems SCORE, LA-UR-95-1011, Los Alamos, March 1995.

11 The Canadian DND Griffin Mothership program has as part of this contract tasking, collection and analysis of lessons-learned, intended to include those related to economics and prospective e-business practice.

12 <http://www.amso.army.mil/>

13 “A Roadmap for Simulation Based Acquisition – Report of the Joint Simulation Based Acquisition Task Force,” Acquisition Council Draft for Coordination, 4 December, 1998

14 “SBA Implementation Plan”, Acquisition Council draft of 14 June 1999.

15 “Simulation Based Acquisition: From Motivation to Implementation (01S-SIW-092)”, Konwin and Miller, SIW Spring 2000, SISO

representations of objective systems through simulation and data, physically distributed but operationally collaborative operations among disparate participating agents, and continuous evolution of objective systems. These eagerly awaited business practices have much in common. The vision is of an acquisition process in which Defense and industry are enabled by robust, collaborative use of simulation technology that is integrated across acquisition phases and programs. Similar sentiments are present in the United States Army's Simulation and Modeling for Analysis, Requirements, and Training (SMART)¹⁸ Program.

Not surprisingly, with concepts of such broad significance and potential influence, there is considerable debate about what precisely is intended for any particular implementation program, what degree of readiness exists in subject constituencies, and what forms of "enablement"¹⁹ are necessary and sufficient to introduce such practices to good individual and collective effect. SBA and SeBA -- taken as generic denotations for M&S business-process re-engineering -- are significant works-in-progress whose evolutions have been pursued deliberately by government and private sector teams for some time.

At least one activity²⁰, wherein the economic-domain enablement²⁰ of SBA was addressed, resulted in generic guidance for business case specification that, while no doubt instructive, has not been further invested.

3.5.6 Government Business Practice

Two activities relevant to the analysis and prototyping of business practice for M&S are currently underway and have significant promise and widespread potential benefit. These activities include: the Department of National Defence (DND) Canadian Advanced Synthetic Environment (CASE) and its associated Griffin Mothership proof-of-principle prototype, and NATO's MSG – 031 Study Group on "The Cost Effectiveness of Modeling and Simulation (M&S)".

Of several threads of the Canadian DND synthetic environment enterprise, the CASE initiative is one in which prototypical collaborative environments and business practices are being initialized in somewhat limited environments, with the expectation that future extension will follow for successful features and infrastructure. Including wideband communications and collaborative environment implementation, with the Griffin simulation-based training generic infrastructure ("Mothership") and instance ("Childship") nodes, the program will facilitate exploitation of synthetic environments.

The fundamental strategy for MSG – 031 is to compile and leverage national information into a single normative NATO analytical context and to establish, thereby, consensus appreciation of estimation, prediction, management, and cost-benefit of M&S. In this spirit, the suite of capabilities-management life-cycle processes used by the several national members is to be identified, characterized, and shared. Each of these national processes is to be represented in such form that the relevant needs, applicable types and uses, and consequent utility of M&S within that process is established. Thereafter, a single normative NATO capabilities management model with representative M&S applicability is to be agreed-upon. Within this context, the factors of cost and benefit for the manifold M&S elements of capabilities management support are

¹⁶UK Policy for SeBA at http://146.80.12.194/ams/ams/content/docs/seba/webpages/4supinfo/4_policy/frame_1.htm

¹⁷ Information on SeBA is provided at: <http://146.80.12.194/ams/ams/content/docs/seba/index.htm>

¹⁸ General information on the US Army's SMART Program is provided at: <http://www.amso.army.mil/smart/>

¹⁹ Hollenbach, James W., "Department of the Navy (DoN) Corporate Approach to Simulation Based Acquisition (SBA)", Fall Simulation Interoperability Workshop, 1999, SISO.

²⁰ NDIA SBA Conference Panel: The Bottom Line – (Enabler Class 9: Business Case Evidence), 17 May 2001, Chairman, W. Waite

to be deduced and documented. Finally, insofar as possible, M&S Cost-Benefit relations and M&S Business Case specification guidance for these canonical M&S investments and uses will be documented, and practical guidance for their expression and employment will be provided.

3.5.7 Government Market-Making

Similarly, there are two activities relevant to M&S market-making that are equally interesting. These activities include: the Joint Forces Command (JFCOM) “Macrosystems” Business Model, and DND/DRDC and DND/SECO efforts to establish permanent standing offers for simulation software COTS assets.

In December 2002, the United States Office of the Secretary of Defense (Program Analysis and Evaluation) terminated the Joint Simulation System (JSIMS) program after the program fell more than 2 years behind schedule, was far short of performance goals, and expended close to \$1B. In conjunction with Joint Forces Command (JFCOM) and the Army Modeling and Simulation Office (AMSO), the DoD Deputy Under Secretary for Defense (DUSD) for Personnel and Readiness (P&R) conducted an “Industry Game” to simulate a fictitious acquisition of a replacement contract for the JSIMS program. The approach developed by the software services company, named “Macrosystems” stood out as a novel, pragmatic, and transformational approach to acquisition of large DoD simulation systems.²¹ Consisting of two interlocking processes for asset development and simulation system composable integration, operating in an open-market style and facilitated by “market-maker” agents, the business model has been selected as the basis of refinement and prototype implementation by JFCOM. Considering the genesis of this model and the potential implications of its demonstration, the Macrosystems business model is one of today’s critical efforts in the evolution of M&S business practice.

Meanwhile, elements within the Canadian SECO and DRDC, appreciating that convenient access to qualified simulation software assets is a significant enabler of broad-based M&S collaboration, have begun consideration of establishment of a ‘permanent standing offer’, whereby vendors can have their products listed and from which government users can select assets without extraordinary sole-source justification. Such a mechanism is expected to constitute in effect an “open-market” with very little transaction load, whereby buyers and sellers of M&S assets may exchange value most efficiently. Similar to the first loop of the JFCOM model, this market environment is expected to serve both buyers and sellers and provide at once the most efficient and open environment possible.

3.5.8 Private Industry

Private industry’s perspective is in some respects simple, but not universally attractive. Organizations are buyers or sellers of M&S assets or services (or more likely both) depending on their place in the value-chain. Often, in large organizations, M&S specialization produces internal markets. Their workforce requires investment, for which they buy (in-house or outsource) training and education. They operate in a market environment in which competition is highly inefficient as a consequence of the dominance of government procurement practices, the lack of apparent clarity of M&S product and service value offerings, and the artificial break-out of alternative application domains that inhibits lateral transfer of simulation technology and limits application-specific market headroom. Cooperation is both inconvenient and productive. For many commercial organizations, M&S is a free technology available through routine internal staffing and service relationship mechanisms, like mathematics or typing. For some, M&S is a specialized market in which they are seeking to occupy an identifiable and successful position. Notwithstanding the challenges of viable operations in an emerging market, private sector agents are perhaps most motivated to influence the industry

²¹ Novel Business Model Approach for Future JSIMS Acquisition, I/ITSEC 2004, Orlando, Katz, et. al., December 2004.

and its associated market, and therefore among the most motivated to understand the Economics of M&S and to operate more rationally and successfully with that knowledge.

3.5.9 Industrial Development Organizations

Consisting primarily of institutional member organizations, a variety of industrial development meta-organizations have emerged recently to assume advocacy roles for the industry and its occupants. For these industrial development organizations, the economics of one or another of several topics may be of primary interest. Two organizations are effectively regional in their scope of interest and advocacy domain. The National Center for Simulation (NCS)²², notwithstanding its name, started as a Florida state lobbying and advocacy group and is growing nationally slowly. Similarly, the Alabama Modeling and Simulation Council (AMSC)²³ serves a similar function, yet for the state of Alabama. At a national level, the National Training Systems Association (NTSA)²⁴ represents training system vendors including predominantly simulation-based training systems and conducts trade shows and technical meetings to promote their business interests in the market place. For small-business vendors, the newly formed National Modeling Analysis Simulation and Training Coalition (NMASTC)²⁵ provides lobbying and collaboration support to small-business technology innovators that are leading the charge in the M&S training world.

3.5.10 Overarching Organization – SimSummit

In an attempt to provide overarching communications and continuity of topical agenda, a meta organization -- SimSummit²⁶ -- was formed in 2002. SimSummit is an occasional forum -- kept relatively informal by mutual agreement -- of organizations with broad interest in M&S technology, professional development, industry, and market. Organizational membership includes Government, Commercial, Academic and Professional organizations. By way of protocol, meetings include one representative from each participating organization. Each meeting event has a particular focus and is structured in accordance with the wishes of the member organizations to produce the best possible collective effect. The role of the SimSummit organization member representative is to speak with authority on behalf of the participating organization respecting organizational needs, interests, initiative, and accomplishments in the evolution of the M&S community of practice. The particular virtue of the SimSummit forum is to find the very considerable degree of common interest that exists even among relatively disparate organizations. Elements of the SimSummit topical agenda related to the Economics of M&S are included in Appendix Two to this paper.

3.6 Other Activities

Given the general circumstances and actors identified above, there are, in fact, a relatively wide range of activities ongoing wherein the Economics of M&S occupies a prominent position. In order both to indicate what's afoot and to indicate what kinds of efforts can be generated at need, a few of these activities are described below. In each case, the subject activity arose out a felt-need within the M&S community-of-practice, consists of the cooperative efforts of one or another stakeholder constituency, and serves to produce some intentional product or effect. While it is certainly impossible to report exhaustively on such activities,

22 <http://www.simulationinformation.com/>

23 <http://www.amsc.to/>

24 <http://www.trainingsystems.org/>

25 <http://www.nmastc.com/index.php>

26 <http://www.sim-summit.org/>

we do provide an indication here of those efforts that seem particularly significant in influencing the cultivation of the M&S community-of-practice on economic matters and that, consequently, suggest the variety of such influential activities. From the point of view of the professional societies, there are three activities that are both influential and indicative of maturing interest in the Economics of M&S.

3.6.1 SCSC 1999

At a workshop conducted within the context of the SCS's Summer Computer Simulation Conference in 1999²⁷, the United States military Service M&S proponents reported their interests and accomplishments in understanding the Economics of M&S. This status was discussed together with the Director of the United States DoD Defense Modeling and Simulation Office, particularly respecting the potential implications of the implementation of the M&S Master Plan then underway and featuring development of the High Level Architecture (HLA). Pursuant to this meeting, it was agreed that the topic was sufficiently rich that an extended threaded debate, utilizing the auspices of various professional societies' events should be pursued. This commitment resulted ultimately in the "Collegial Initiative for the Economics of Modeling and Simulation".

3.6.2 Simulation Magazine

In the initial issue (Volume 1, Number 1) of its Simulation Magazine, the SCS provided an editorial column to serve as a mechanism for the prompt and effective exchange of ideas on topical issues which deserve continued, comprehensive, and systematic consideration. The topical scope of that column was: "The Economics of Modeling and Simulation" [10] taken to encompass: "consideration of the costs and benefits of M&S, the markets wherein buyers and sellers meet to exchange goods and services, and all the mechanisms whereby we make decisions about what to offer, what to purchase, at what price, and in anticipation of what the perceived value is." Subsequent features were equally welcome [11] and the opportunity to contribute to that column has been offered to the community at large.

3.6.3 SISO Study Group

Within the SISO concept of operations, a Study Group is a formal finite organization and activity intended to investigate topics in consideration of recommendations of their being pursued for publications of standards products. In 2001-2002, study group activity²⁸ was conducted with the topic: "The Economics of Simulation - Cost-Benefit and Return-on-Investment Analysis" and the activity was conducted with a view to generate work products including final report, lexicon of terminology, topical taxonomy for the economics of simulation, annotated bibliography of the subject information collected, market model specification, draft business-case specification guidance, and implications of standards and associated interoperability for the SISO mission.

Of these intended results, the data compilation and bibliography is discussed in detail in Section 4.0 of this paper. And, while the Study Group concluded that there was both appetite and opportunity for pursuit of other data products as well as "best practice" guidance, administration of volunteer participation available proved a bridge too far for the Study Group in the constrained time allowed.

²⁷ Society for Computer Simulation (SCS), Summer Computer Simulation Conference 99 (SCSC 99), Track: "The Economics of Modeling and Simulation", 26-29 January 1999.

²⁸ "Revised Terms of Reference (TOR) for the SISO Study Group on: The Economics of Simulation - Cost-Benefit and Return-on-Investment Analysis -", SISO, Orlando, 2 April 2001.

Nevertheless, discussion to reprise the topic and apply for SISO Product Development Group charter on the same agenda, contingent upon requisite constituency commitment, is underway.

3.6.4 Private Sector

Naturally the private sector is most interested in economic operations, and in fact the number of meta-activities in which Economics of M&S is being pursued is limited. The more typical venue for private sector agents to address the meta-issues of Economics of M&S is in the form of industrial development group activity as indicated in the following section.

3.6.5 Industrial Development Groups

One such locus is the United Kingdom's SeBA Forum. Comprised of a volunteer group of private and Government organizations, the forum seeks to facilitate the implementation, and continue the joint industry/MoD evolution of SeBA, share information concerning best practice, and promote the integrated use of systems engineering and M&S throughout the acquisition process. Among its functions are to encourage the effective adoption of synthetic environments practice and technologies; share information on guidance, best practice, lessons learned and current activities; and identify, agree, and adopt common metrics of cost effectiveness. Other industrial development venues are active, of course, and their efforts have resulted in at least two kinds of results. On the one hand, workforce and economic impact surveys have been generated that are of interest, and on the other, political bodies have been precipitated within the national legislative infrastructure whose potential impact upon the M&S economic environment is salient.

Both the NCS and the AMSC have commissioned surveys^{29,30} of the economic impact of M&S in their respective economic domains. These products are practically invaluable to establish the intrinsic significance of M&S as an industry within the respective geographic area, and to serve to establish its claim upon the interest of other significant players in the socio-economic sphere – typically (in the United States) Chambers of Commerce and State Economic Development Agencies.

Finally, industrial development groups actively manage trade shows wherein the economic vigor of the industry is exhibited in visible and reportable form. These events also illustrate, by the nature of their participants and the forms of value-offerings exhibited, some very significant trends in the industry -- recently, for instance, the increasing prevalence of distributed collaborative operations and use of low-cost modular Commercial-Off-The-Shelf (COTS) components in training simulation systems is readily evident at (I/ITSEC)³¹ managed by NTSA.

3.6.6 Public Collaboration

Motivated by the widespread expressions of interest first evidenced at the SCSC 99, an ad hoc collaborative program was initiated in the Fall of 1999 and has continued intermittently since. The program, designated the "Collegial Initiative on the Economics of Modeling and Simulation", was conceived to be an opportunistic, collaborative exploratory of the nature of the economic aspects of M&S. It includes as its domain of interest

29 2004 Alabama Modeling & Simulation Industry Survey, Bernard J. Schroer and John Regner, Alabama Modeling & Simulation Council, October 2004.

30 [http://www.simulationinformation.com/Impact of Florida's Modeling Simulation and Training Industry](http://www.simulationinformation.com/Impact%20of%20Florida's%20Modeling%20Simulation%20and%20Training%20Industry), National Center for Simulation, Orlando, Fall

31 <http://www.iitsec.org/>

anything having to do with the Economics of M&S, including, identification and explication of markets, market mechanisms, metrics of cost and value, and economic issues of potential significance to the M&S community. The program is intended to be a grass-roots discovery process of the subject across the widest appropriate domain-of-interest at a suitable abstract level so as to be both accessible and useful to the entire M&S community. As a largely un-funded pro bono publico enterprise, leveraging the auspices of established Government, Educational, Commercial, and Professional institutions, it seemed prudent and has shown some success particularly in the conduct of initiative working meetings as adjuncts to SIW, SCSC, ITEA, and I/TSEC meetings already established. In conducting this exploratory, we have intended to crystallize our current understanding of the state of the Economics of M&S; to generate products capturing current wisdom, lessons-learned, and prospective action; and to derive value in understanding the economics of M&S and being better able to operate as “rational” players in the M&S Market. The degree to which the program has been successful in its own right is debatable, but the effect it has had upon socializing the topic of the Economics of M&S and spawning other more concrete efforts such as the SimSummit and NATO MSG-031 is evident to more than two hundred actively subscribed participants.

4.0 DATA COMPILATION FROM PREVIOUS ECONOMICS OF M&S STUDIES

In the late 1990’s, the topic of the “Economics of M&S” was undertaken by several groups. The United States Air Force headquarters staff (“Air Staff”) had reorganized, and the General Officer in charge of M&S on the Air Staff had asked for proof that he would get value for an additional “dollar” he devoted to funding M&S programs. Virtually the same week, Mr Bill Waite sent out a notice of an upcoming meeting of the newly chartered SISO Economics of Simulation Study Group focused on defining the benefits of the “next marginal dollar” for M&S. Within a few months, SCS established a Technical Chapter on the Economics of M&S, under the leadership of Mr Bill Waite also.

The first task undertaken for both the SISO and SCS groups was data compilation. Most of the compiled evidence is anecdotal, yet fairly consistent, because substantive evidence on the economics of simulation -- absent pre-planning for it -- is very difficult to gather. One of the first tasks undertaken by the data compilation group was to decide how to categorize the areas of M&S and the ways that M&S can provide cost savings, cost avoidance, or increases in effectiveness.

In reporting the benefits of simulation, the data compilation group partitioned the use cases of M&S into several categories: wargaming, experimentation, assessment, acquisition, evaluation, training, and decision support for combat operations. This was a subjective decision, and more general categories can be used. For this paper, we will discuss the economic benefits of simulation in terms of acquisition of systems, training for readiness to perform, and evaluating alternative futures. These categories correspond roughly with the use cases in current United States Air Force M&S planning documents. The impact (benefit) of M&S varies by -- or within -- a use case, and this will be further discussed in this paper. The power of simulation is increasingly being realized, and M&S from one use case is often used in other use cases. The demarcation between acquisition and readiness training or acquisition and evaluation of alternative futures is rapidly blurring. The crossover -- the blurring of M&S use across previously distinct tasks -- is yet one more indication of the value of M&S.

For the data compilation efforts, documentation gathered by the SBA Task Force in the United States and referenced in numerous SBA reports formed the core of the data gathered. Once the data compilation effort and ongoing results were advertised, numerous additional data sources were gathered -- word of the effort “primed the pump” and generated additional interest and input, sometimes from unexpected sources.

Unfortunately, maintaining that level of interest in the community of practice for M&S was difficult absent continued attention and a persistent, consistent web site for reference. This is probably a good lesson for current and future research efforts concerning the Effectiveness of M&S.

M&S is used to support many activities, and it has been found to be valuable for several reasons. M&S provides risk reduction by providing training where mistakes are not fatal, minimizing environmental impact, allowing covert rehearsal, and ensuring information security. M&S is efficient because it reduces the cost to assemble the training team, reduces stress on high-value assets, provides a standard instructional environment, and reduces the use of expendables. M&S is effective because it accelerates creation of scenarios, allows rapid changes in combat arenas, provides a test-bed for concepts and strategies, increases availability and portability, and reduces personnel and operational tempos. Some measure of economic benefit or cost avoidance due to the use of simulation is often sought. A metric of Return on Investment (ROI) is used in this paper, and it is calculated as $(\text{Benefit} - \text{Cost of M\&S Use}) / (\text{Cost of M\&S Use})$ or $(\text{Cost Avoided} - \text{Cost of M\&S Use}) / (\text{Cost of M\&S Use})$. Additional formulation and estimates of M&S value are proposed in other studies [14].

4.1 Data Compiled for Benefits to Acquisition

One can evaluate the Economics of simulation where it supports our ability to develop, build, and test new weapon systems. Here, historically derived returns on investment, cost avoidance, cycle time reductions, and lifecycle cost savings are documented and may warrant further investigation. M&S use in acquisition of new or improved systems is one area of M&S use where economic benefit is a most natural computation, yet the information provided is almost exclusively anecdotal because metrics have not been drafted or accepted and monitoring of acquisition programs for economics or effectiveness of M&S has not been undertaken.

It appears that this is also the area of greatest financial pay-off for M&S use. Of the total budget controlled by defense-related acquisition program managers in the United States, it is estimated that 3% to 15% of the budget is being spent on M&S; with over 200 defense programs between \$1M and \$50B in size, the investment in M&S and the potential pay-off is high [15].

Estimates derived from industry and government acquisition programs in the United States indicate that the intelligent use of M&S can reduce design cycle time by 50% on average [16]. The use of appropriate M&S starting at program initiation potentially saves 2% in system life cycle costs—easily \$Bs in savings across the United States Department of Defense (DoD). Furthermore, for small acquisition programs with no more than \$20M invested in simulation, M&S has an estimated return on investment of approximately 25-to-1 when used intelligently [17].

Other examples of the value of simulation exist throughout industry. For instance, between 1993 and 1995, DuPont has estimated a savings of almost \$1B by using M&S to increase yield, reduce downtime, and lower maintenance costs with increased process understanding and control [18]. Work at AT&T Bell Laboratories with semiconductor simulations has produced a direct benefit to AT&T estimated in the \$10M to \$15M per year range, with designs made available 1.5 years earlier than with previous methods [18].

The most convincing testimonials to the power of M&S are in comparisons of concurrent or nearly concurrent programs that can be used to illustrate acquisition with or without the use of M&S [16]. For instance, the Boeing Corporation invested heavily in M&S for design and development of the 777 aircraft. Results from the 777 model acquisition compare very favorably to the design and development of the earlier 747 aircraft for which M&S use was limited. The 747 model required 10,000 shims for ill-fitting parts, while the 777 aircraft

required just 50 shims per aircraft. Scrap was reduced by 30% on the 777 aircraft. Rework of parts was reduced from 30% for the 747 aircraft to 3% for the 777 aircraft.

Other comparisons for military procurements help explain the value of simulation [16]. In one example using the F-15E aircraft, virtual manufacturing assistance using M&S (in 1997) was contrasted to traditional methods (from the early 1990s). The use of M&S to support the manufacturing process led to a 33% reduction in design release time, 27% reduction in design cost, 19% reduction in manufacturing cycle time, 20% reduction in factory floor space, 24% reduction in parts count, and a 78% reduction in fasteners required for assembly. For a United States Defense Advanced Research Projects Agency initiative for concurrent engineering, a radar warning system was redesigned using traditional versus concurrent M&S-supported design techniques. The traditional approach required 96 man-months, while the M&S supported concurrent design approach required 46 man-months for completion.

The aggressive use of M&S in test and evaluation saves (or at least cost avoids) huge amounts of funding each year—over \$100M per year across the United States DoD Services [16]. Intelligent use of M&S to support evaluation reduces live testing, destruction of valuable assets, use of over-tasked test ranges and equipment, and decisions based on sparse data. For instance, the testing of the Advanced Medium Range Air-to-Air Missile would cost \$3M for each supported test launch; yet M&S allowed up to 300 runs for the same price as one live test. Such cost trade-offs allow more complete evaluation of the launch envelope and less uncertainty in the operation of the weapon. As another example detailed at the 2000 Air Armament Summit at Eglin Air Force Base in the United States, 8500 M&S runs for the AGM-65 Maverick missile pinpointed areas in the launch envelope where live testing was beneficial and preceded 12 perfect flight tests. The use of M&S for test and evaluation can also pinpoint where live testing can be focused, or it can be used to terminate unworthy programs early before too many resources have been expended in live evaluation and fielding.

Further work to capture the true economics of M&S use in a variety of acquisition programs will be of great value for decision-makers. The use of M&S can assist DoD in determining that systems will meet critical performance requirements. Weapons systems that are moved into production prematurely often result in flaws that require time-consuming and expensive changes [19]. Definition of terms, business cases, and market models for the use of M&S will assist in the accurate analysis of the economics of M&S from program inception through logistical support.

4.2 Data Compiled for Benefits to Readiness/Training

The cost avoidance attributed to M&S for training is considerable. Across the United States DoD, success in M&S training has outpaced M&S success in other areas. For battlestaff training exercises, Joint Task Forces and/or Component staffs are trained to plan and execute a Joint or Coalition campaign. Simulation has grown in importance for these exercises due to resource savings and improved training quality.

In the early 1980's, the scenario control staff typically scripted the entire exercise with weeks of pre-exercise meetings to script all inputs. A ratio of 1-to-1 for support staff to trainees was needed because every engagement was decided by dice roll and manual input. Real-world systems were seldom used to input exercise events, and "training like we intend to fight" was not fully possible. POSITIVE LEAP 1980 was the first Rapid Deployment Task Force Exercise, and 2800 controllers were needed to drive the exercise for a 2800-person training audience. Since the early 1980s, M&S has increasingly been relied on to support battlestaff training exercises. With minimal M&S support, REFORGER 1988 trained 35 maneuver headquarters and used 97,000 soldiers, 7,000 tracked vehicles, and 1,080 tanks throughout Europe as training aids at a cost of \$53.9M plus \$20M maneuver damage. Using more robust M&S, REFORGER 1992 trained

35 maneuver headquarters using 20,000 soldiers and 135 tracked vehicles as training aids in Europe and the United States at a cost of \$19.5M with no maneuver damage. Currently, the ratio of training audience to control force is 3-to-1 in a typical battlestaff training exercise, saving 500 or more personnel per exercise. This cost avoidance attributed to M&S amounts to at least \$9.0M per year for the United States Air Force key exercises versus a cost of approximately \$4.0M for M&S maintenance. Distributed M&S for battlestaff training is improving the quality of training by linking the training audience to the scenario, using real-world systems, providing repeatable standards for training, while saving personnel tempo and expenses.

For battlestaff training exercises, the economics of simulation can be further documented by estimating the cost avoided by using simulation vice live forces as training aids for the battlestaffs. If about one-half of the sorties in a typical Blue Flag battlestaff training exercise were live sorties, the added cost would be over \$7.3M per day. For a typical annual United States Air Force battlestaff training exercise schedule, the cost of live flying about one-half of the exercise sorties would be over \$500M per year. M&S helps the United States Air Force realize a cost avoidance return on investment of approximately 100-to-1 in battlestaff training exercises driven by M&S. Of course, training needs, personnel tempo, operational tempo, safety, and resource limitations make M&S-supported training the logical choice today and in the future.

For mission-level training, M&S is growing in use. For instance, each Service in the United States now has a mission training system for weapons system-level training in immersive, multi-player synthetic environments. These systems will provide improved individual and team training in environments and scenarios that would be impossible to create in live training outside of combat. They are an improved adjunct to live training and also save resources. Simulator operating costs are one-tenth to one-third the cost of operating the actual weapons system. The cost of purchasing an entire mission training system, such as the Close Combat Tactical Trainer, based at several United States Army posts, is approximately equivalent to the cost of three new tanks and some operations tempo trade-offs.

Probably the first use of M&S for support to operations (and readiness) was for mission rehearsal in the special operations and tactical aircraft mission areas. The importance of M&S has grown through technology improvements and better understanding of its capabilities, in fact, M&S now increasingly facilitates battlestaff rehearsal and decision support to operations. M&S allows warfighters to visualize how to change aspects of the campaign. Lessons learned from military operations point to the need for improved decision support tools, including predictive M&S tools that can screen courses of action and predict enemy actions. M&S will be used to accelerate contingency planning and response and improve execution of campaigns; yet the value of this asset to operations will be difficult to quantify.

M&S is proving to be a valuable training tool in many other fields, including medicine. New systems with interactive “dummies” train soldiers and physicians to treat wounds on the battlefield and conduct patient care in hospitals. New virtual reality systems allow trainee surgeons to feel and see their knife-work. They can see high-resolution three-dimensional images of the human body and feel the pressure of the instrument as it “cuts” through tissue [20]. The growing field of Advanced Distributed Learning will also, to some extent, provide training to deployed forces and may include M&S tools. One measure of the value of simulation is in its spread through many disciplines, from medicine to security force training, to improve readiness in widely disparate specialties. This popularity proves the value of M&S and further justifies the need for investigation of the effectiveness or economics of simulation.

4.3 Data Compiled for Benefits to Investigation of Alternative Futures

Wargames often focus 15 to 20 years or more in the future, and these venues are used to evaluate future doctrine, strategy, or concepts, using a mixture of current and hypothesized weapons systems, against anticipated enemy forces in presumed future scenarios. Wargames, or future studies, historically used role players and control staffs to generate future scenarios and responses; however, M&S use in wargames is growing as increased fidelity, immersive scenarios, and reduction in numbers of support personnel are desired.

For most wargames, M&S has become the only acceptable means to generate the immersive future battlespaces. The M&S used in wargames usually does not require human-in-the-loop or links to real-world systems. The M&S often is closed-loop with multiple complete runs of the scenario used to determine an average outcome. In order to further the understanding of the economics of M&S, cost trade-off analyses should be conducted for wargames in the United States such as Army After Next, Navy Global, or Global Engagement to compare the cost savings and benefits of using M&S vice using alternatives to M&S, such as additional role players and support staff.

Experiments generally look within the timeframe of the current or the next five-year funding plan and are focused on evaluating innovations in operational concepts, procedures, or weapon systems. Experiments such as United States Joint Expeditionary Force Experiment (JEFX) look at new ways to use current equipment (perhaps with minor modifications) in scenarios using anticipated near-term adversary forces. M&S is used extensively in experiments; yet, the M&S systems have not been developed exclusively for experimentation, which ideally calls for the ability to use multiple paths with both fast-forward and rewind of the simulation [10]. In JEFX 99, nearly 100 simulations were used to drive the experiment. For JEFX 99, M&S generated an immersive environment of 2500 intelligence messages and 2100 mission updates per day through the Theatre Battle Management Control System and over 12,000 intelligence updates every 10 minutes through other real-world systems [21]. Role players and support staff could not have generated such a torrent of real-world message traffic; without the use of M&S, realism and effectiveness would have declined, and costs in terms of staff tempo and TDY funding would have increased markedly. Preliminary evaluations of the cost avoided by using M&S vice actual military forces, added role players, and message runners in experimentation has shown an ROI of approximately 60-to-1. For instance, in a recent training experiment at 11th Air Force, Elmendorf Air Force Base, Alaska, a simulation cost of \$34K provided continued simulation support to 11th Air Force and cost avoided over \$1.2M in live-fly sorties. Simulation also provided exceptional realism for this experiment when simulated entities were substituted on the common operational picture for live sorties that had been weather/maintenance canceled, and the battlestaff members did not realize the entities were not live. It is recommended that further analyses be conducted to evaluate the resource savings and increased realism generated through M&S use in experimentation.

Historically, one of the first uses of M&S was for force structure analyses to evaluate future force structure needs of individual Military Services in the United States. For instance, force structure studies that evaluate the required mix of air superiority, ground attack, and mixed-use platforms now rely on M&S. Studies like the Deep Attack Weapon Mix Study or the Quadrennial Defense Review use several M&S systems to estimate the required size of each Service to meet the challenge of presumed future conflict scenarios and tasking. For many types of analyses, there is simply no alternative to M&S tools; therefore, there has been little need to justify investment in them. The cost-benefit analysis for M&S use here should include not only the use of role players in lengthy analyses, but also the quality of the analyses that would result if M&S were not used. An undersized or poorly equipped future force might be very costly to the Coalition.

Of course, non-military examples should be mentioned, for instance, systematic toxicity analysis of chemical mixtures in the environment or the workplace is highly impractical without the use of M&S. For instance, a chemical mixture of 25 component chemicals has over 33 million combinations required for analysis at a \$3T estimated cost [22]. The time, expense, and number of live test subjects required to do full testing necessitates alternative methods. To have a reasonable chance of successfully dealing with the issues of toxicology of chemical mixtures, M&S is integrated into the assessment process to produce a model-directed focused experiment on a reduced number of test points using live test subjects.

Other types of assessments are focused on improvement in procedures or processes. For instance, an analysis of the weapons storage area at Nellis Air Force Base (AFB) in Las Vegas, Nevada, using legacy M&S resulted in recommended system upgrades and improved security effectiveness. The approach devised via M&S saved \$7M at Nellis AFB alone and resulted in double the security effectiveness of the previously planned approach [23]. Similar cost savings are anticipated at other weapons storage sites.

4.4 Final Thoughts on Data Compilation for Economics of M&S

Some of the documents gathered in the SISO and SCS efforts are posted to the United States Defense Modeling and Simulation Office (DMSO) Impact Assessment/Economics of Simulation web page (<http://www.msiac.dmsomil/ia/default.asp> under the "Documents" category and under the subcategory for the SISO "Economics of M&S Task Force". Other documents may be found at the DMSO special interest page under SBA (<http://www.msiac.dmsomil/ia/links.asp>) or in searching the DMSO M&S Resource Repository (<http://www.msrr.dmsomil/>). The University of Central Florida (UCF) in Orlando, Florida has leveraged the approximately 100 useful documents gathered in the SISO and SCS Economics of M&S efforts for their degree programs in M&S, and graduate students from UCF have developed an annotated bibliography of all the documents and are developing a UCF graduate studies web site for the documents.

A central, consistently available, complete web portal for the Effectiveness or Economics of M&S could accelerate progress in all related studies. Future researchers and decision makers will desire a web location to locate documentation, read previous and ongoing studies, identify current research, review ideas for metrics, upload new information, and offer innovative ideas. Such a portal does not exist, but could easily and quickly be developed, leveraging all the work by UCF, DMSO, and others. This central web location for the Economics of M&S would increase awareness and rejuvenate the flow of information on the topic. It would also generate new ideas on how to measure the benefits of M&S and how to develop substantive vice anecdotal evidence. An international organization, such as SimSummit, with the addition of some external funding, may be a logical proprietor for the Economics of M&S portal.

5.0 THE SWEDISH STUDY ON THE ECONOMICAL BENEFITS OF M&S

The Swedish study, Economical Benefits of M&S, is being conducted by Ericsson AB at the request of Swedish Materiel Administration (FMV) for The Swedish Armed Forces. The purpose of this effort is to make those individuals (that are in a position to make decisions about investments in M&S support during the early phases of the acquisition process) aware of the benefits that are associated with the use of M&S.

5.1 Motivation for the FMV Study

The importance of an economic perspective on the use of M&S becomes very obvious when M&S is about to enter a new domain. It is quite simple to prove that the use of M&S for training is cheaper than training with

real equipment and a complete opposing force. The qualitative benefits associated with the use of M&S for training is not an argument for the first investment but a part of the result, which will lead to further investment in, and an increasing use of, M&S. This positive helix needs to be started for every phase of the product lifecycle, which is the purpose of the Swedish study, *Economical Benefits of M&S*.

The Swedish Armed Forces, as many others, is undertaking a transformation, and, at the horizon, Net Centric Warfare (NCW) is looming. In 2008, Sweden is obliged to put up resources for the European Union Battlegroups, which means that we need to be compliant with our allies. It is recognized by the stakeholders of the Swedish Armed Forces that this new situation calls for a renewal of methods, materiel, and doctrines, at a minimum. In the Swedish defense decisions from 2004, the government stated that M&S should be used in order to support the Swedish Armed Forces in the struggle to reach the NCW-vision and, when there, carrying it out in the most efficient way. The purpose of the study, *Economical Benefits of M&S*, is to build confidence in M&S support by providing Project Managers with a tool, in the form of a Best Practice Guide, to use when deciding whether to invest in M&S or not. The study is limited to address the earlier phases in the acquisition process, for instance, the concept phase. The reason for this is that the effect of decisions in this phase is most significant to the cost and outcome of an acquisition program.

The need for a reliable demonstration of the economical benefits of M&S is not unique for Sweden, and since the resources of the study are limited, it is logical to investigate results from other efforts and collaborate with those who have been involved in similar work. The efforts mentioned in this section were undertaken in order to get the picture of the body of knowledge for the *Economics of M&S*. A series of interviews with Program Managers (PMs) from different levels within FMV has also been carried out in order to verify that the Swedish PM struggles with the same problem as PMs in other countries.

5.2 Questions, Justifications, and Answers to Date for the FMV Study

The main question for the FMV study is "Which factors are critical for making decisions concerning investments in M&S support with respect to cost-effectiveness?". In order to answer this question, the following sub-questions need to be addressed:

- (1) WHY use M&S as support? What are the arguments? What results have come out from previous efforts? The reason for using M&S is obvious: In this FMV study, well known projects like the Boeing 777 versus Boeing 747 comparison have been reviewed together with a couple of other successful projects in order to give the target group of the study information that illustrates the differences that M&S makes.
- (2) WHAT implies M&S-support? What was used within previous efforts? It is useful to know what is behind the figures, therefore the M&S-tools and environments from the presented success stories are briefly analyzed.
- (3) WHEN is it cost-effective to use M&S as a support? When is it not cost-effective? Is it possible to identify criteria that are valid for every project regardless of its nature and context? It would be convenient if it was possible to identify exact limits for a number of parameters that are valid for every project in every context. So far there is little or no evidence that this is the case: M&S is a powerful tool for handling issues in a constantly changing context, which implies that every project and every situation is more or less unique. The answer to the "When" question is to provide the decision-makers with a Best Practice Guide that is based on lessons learned from other projects. The decision is left to the decision-maker, but with the support of a solid foundation composed of experiences from similar projects/situations.

- (4) WHERE is M&S support most cost-effective? Where in the timeline from concept discussions to the identification of the solution does the M&S support make the biggest difference? A success story may also be a story that ends before it starts, which is the case for some of the projects that were reviewed during this study. The benefit from making a decision to terminate a project early might be huge. It is important to build the artefact right but it is much more important to build the right artefact.
- (5) WHO can benefit from using M&S-support? From the available success stories, is it possible to identify which project that can benefit the most from using M&S support? So far, it is safe to say that almost everyone can benefit from using M&S, but everyone does not realize it. Within software engineering, architecture/constructing, interior decoration, etc it is widely recognized that in order to reach the goal, it is necessary to build models (of paper, on paper, pictures, animations, test programs etc), it is also necessary to observe these models in a context (geographical, hardware/software, over time, etc) in order to be able to decide whether the suggested solution contributes to the goal.

5.3 Ideally, What Would PMs Want to Have Available in Explaining the Economics of M&S?

Ideally, a PM would like to write down an abstract description of his/her project together with the available resources (economic, personnel, time, etc) and push the button: The answer on whether to invest in M&S or not appears “by magic” together with a plan. There is a danger in considering M&S as a substitute for methodologies, decision-making, judgements, etc: M&S is a tool that strengthens the organization’s ability to make good decision about artefacts, missions, etc. However it is important that a PM is able to present the benefits from M&S use in both quantitative and qualitative terms. He or she needs to point to the figures of fewer personnel, less project time, etc but also show that the result was more in accordance with the customer/user intentions.

Increasing the use of M&S or finding new ways to use M&S requires a change mechanism. The nature of changing must be considered because it does not matter if something is good with respect to finance if PMs feel “there is nothing in it for me personally”. To incorporate a new paradigm, which is what M&S implies, it is necessary to find the triggers for change. Every individual in the decision-making needs to feel that there is a reward if he or she should be interested in using M&S.

The result of the study, Economical Benefits of M&S, will be a first version of a Best Practice Guide (BPG) that shall guide the PM when making decisions about investments in M&S. This BPG will help the user find his or her way in order to get answers to the 5 questions:



5.4 Future Direction of the FMV Study

A possible future direction for the study, Economical Benefits of M&S, would be to continue with the work with the BPG in order to get a more complete guide. It is important that a PM is able to present the benefits from M&S use in both quantitative and qualitative terms. He or she needs to point to the figures of fewer personnel, less project time, etc, but also show that the result was more in accordance with the customer/users intentions. The need for data is urgent, which requires that there be a way to systematically collect information about projects that allows a comparison of results.

Another part would be to attach a planning guide to the BPG. Although one has to keep in mind that there is a danger in considering M&S as a substitute for methodologies, decision-making, judgements, etc: M&S is a tool that strengthens the organization's ability to make good decisions about artefacts, mission, etc. M&S is not a tool that makes decisions on its own.

6.0 ASSOCIATED ONGOING EFFORTS

In the M&S business, two things are true: (1) M&S will be increasing important and (2) questions about the economics of M&S will continue. For the United States DoD, the Joint National Training Capability (JNTC) is a robust, growing program based on an integrated live, virtual, and constructive (LVC) simulation environment available globally, linked to operational command and control systems, and available continuously [25]. JNTC is a key part of the DoD Training Transformation Program. Similarly, new programs in United States DoD test and evaluation will leverage distributed communications networks and a mixture of LVC simulation environments to test in a Joint system of systems approach [26]. Yet, questions about the economics of M&S will continue, and current studies [27] include sections on the "Benefits and Costs of Modeling and Simulation" because in government and industry there are still questions about how to spend that next marginal "dollar" on M&S or otherwise.

6.1 Collegial Initiative in the Economics of M&S

This initiative is an opportunistic, exploratory of the nature of the economic aspects of M&S, initiated in the Fall of 1999. It includes as its domain of interest anything to do with the Economics of M&S, and it is ongoing, searching for opportunistic venues and interested new participants along with the faithful core.

6.2 Future Related Initiatives in SISO: Definition of the Business Case for M&S

SISO recognizes that advances in low-cost, high-power computer, graphics, networking and telecommunications are just some of the key technologies that enable use of distributed simulations in new and exciting ways. Yet, questions about how M&S can yield value will persist. Chartering of a SISO group for the "Best Practices in the M&S Business Case Explication" is being planned. This effort will extend the results of the previous SISO Economics of Simulation Study Group to the Business Case for M&S.

6.3 SimSummit

SimSummit³² is an occasional forum -- kept relatively informal by mutual agreement -- of organizations with broad interest in M&S technology, professional development, industry and market. Organizational membership includes Government, Commercial, Academic, and Professional organizations and members are expected to conform to established membership criteria. Membership is initiated by an official expression of interest by the applicant organization indicating its role in the M&S community-of-practice and its interest in participating in the SimSummit forum. SimSummit meetings will continue to include Economics of M&S topical sessions as the members desire or circumstances dictate.

6.4 Synthetic Environment-Based Acquisition Research in Canada and the United Kingdom

The motivation and logic of SeBA was first briefed at the European Simulation Interoperability Workshop in June 2001. SeBA is an acquisition process in which government and industry are enabled by robust,

³² <http://www.sim-summit.org/>

collaborative use of simulation technology that is integrated across acquisition phases and programs. SeBA is characterized by collaborative processes, semantic consistency, interoperability of representation, and ubiquity of presence of M&S across constituencies, place, time, and activity. SeBA is defined as the consistent and coherent application of modeling, simulation, and synthetic environment (SE) technology within, and across, both acquisition phases and programs to facilitate the attainment of smart acquisition. SE is the linkage of models, simulations, people (real or simulated), and equipment (real or simulated) into a common representation of the world. In the United Kingdom, the SeBA Forum was created to facilitate the implementation of SeBA and continue the joint industry/Ministry of Defense evolution of SeBA, share information concerning best practices, and promote the integrated use of SE and M&S throughout the acquisition process. In Canada, SE enables stakeholders to simulate complex interactions or environments by providing technology processes which enable models, simulations, people, and equipment to interact in a virtual world. Increasingly, a tailored SE is being used as a very effective and powerful enabling technology that becomes a single “concept-to-fielding” methodology, offering the opportunity to achieve a better system design, a faster acquisition time, or cheaper overall costs. These efforts will continue.

6.5 NATO MSG-031 on the Cost Effectiveness of M&S

The economic implications of M&S have been a matter of interest and concern for some time. Discussion in context of SBA initiatives in the United States and SeBA in the United Kingdom and Canada and lately in context of Capabilities Lifecycle Management in all countries has brought to the fore considerations of a need to know: (a) empirical history of cost and benefit of M&S, (b) how to estimate M&S Cost-Benefit for prospective applications, (c) how to specify the M&S Business Case in terms of the perspectives of the several stakeholder constituencies, and (d) the broader appreciation of M&S as an emerging profession.

The use of M&S has grown rapidly, but continued growth will depend on M&S being seen as cost effective and adding value. Programs generally make a specific business case for M&S outlays and there is a need for generic business case guidance. By identifying non cost effective application areas, the barriers preventing the proliferation of M&S will be identified, providing an indication of future research priorities. This activity will produce a report discussing the cost effectiveness associated with the exploitation of M&S by defence applications. The report will be populated with case studies from national and NATO activities and across the identified defense application domains.

Once the application areas have been defined, case studies concerning the cost effectiveness of M&S within these domains will be identified. Cost effectiveness evidence, both empirical and subjective, will be sought and documented. A balanced view needs to be maintained and this should include a review of circumstances where M&S have been used but subsequently were not deemed to be cost effective. The report will conclude with a generic M&S Business Case and a statement on the technology areas that need to be developed further to improve the economics behind M&S. The intended program of work will include: (1) the objective to report M&S cost-effectiveness in context of normative acquisition systems engineering process; (2) use cases particularized with respect to defense application domains, types of simulation assets, types of uses of simulation assets, and location in the capabilities management systems engineering life cycle; (3) metrics and related measures of merit whereby cost and benefit might be quantified ; and sensitivity or appreciation of the study group to the “vector valued” nature of M&S Business Case in context of alternative stakeholders.

6.6 The Swedish Study on the Economical Benefits of M&S

The purpose of this study is to build confidence in M&S support by providing Project Managers with a tool, in the form of a Best Practice Guide, to use when deciding whether to invest in M&S or not. The study is limited

to address the earlier phases in the acquisition process, for instance, the concept phase. The reason for this is that the effect of decisions in this phase is most significant to the cost and outcome of an acquisition program. Development of the Best Practice Guide continues.

7.0 FUTURE RECOMMENDATIONS RELATED TO THESE EFFORTS

Where do we go from here? We know M&S will continue to grow in importance, and we know there will continue to be questions about the effectiveness/economics/benefits/value of M&S. Ideally, the data compilation effort for the SISO and SCS Economics of M&S groups should not have stopped, and a persistent venue for advertising what had been gathered -- inviting future input -- should have been established. Researchers wanting to use the data compiled by these groups have increasingly found that several pertinent reports are no longer available electronically. We offer a few recommendations:

- Task and fund an international M&S body, such as SimSummit, and designate government agencies, such as DMSO, to keep the attention on this topic. Constant attention on the topic and regular tasking to report progress is essential. A short period of attention every few years and the use of volunteers will not get the right job done. You'll get what you pay for.
- Preserve the data compiled by the SISO and SCS groups on a readily accessible, persistent web portal that encourages continued input of data and ideas
- Solicit submission of current reports on the Effectiveness/Economics of M&S...look for positive and negative reports
- Define the necessary products and actions to establish a baseline understanding of the Economics of M&S: develop a provisional market model, draft the terminology and taxonomy of the concept, continue the data call, document the business case, and identify best business practices
- Charter the SISO Group for Best Practices in the M&S Business Case Explication
- Continue the Collegial Initiative for the Economics of Simulation and take the message to an ever expanding group of conferences and venues internationally and across industries and academia
- Develop metrics that can be used to judge the value of M&S. Very thoughtful work in this area [3, 17] has advocated new initiatives to determine the value/utility/payoff of M&S – claimed by many but substantiated by very few. More rigor in computing the economics of M&S should be instituted; however, exact calculations based on subjective, anecdotal data will still be anecdotal.
- Identify pilot programs to track expenditures and identify decision points where M&S choices were made. An FMV pilot program could be instituted at this point in time to gain understanding of the economics of M&S. Ideally, pilot projects in various areas such as acquisition, readiness training, and investigation of futures could be undertaken in several countries and reported regularly at SimSummit meetings.

8.0 CONCLUSION

This paper proposes that attention on this very important topic must persist with a focus on a permanent study of this topic under an international organization chartered and funded to gather data, develop metrics, analyze the data, and post the knowledge gained on the web, preserving available legacy information already gathered, inviting new data, and monitoring test cases selected to build a substantive understanding of the topic. In this paper, we report anecdotal findings about the “intelligent use” of simulation. SISO and SCS studies are

referenced, and the data gathered is summarized. An update of an ongoing Swedish study on the benefits of using simulation was also covered. The SISO and SCS activities engendered a growing interest in making progress in many of the investigation areas for the economics of M&S, and follow-on activities such as the Collegial Initiative on the Economics of M&S and the SimSummit were also discussed. This paper leveraged available information from the NATO MSG-031 on “The Cost Effectiveness of Modeling and Simulation (M&S)” and mentioned that the MSWG included reviews of the United States’ Simulation Based Acquisition (SBA) initiatives and the Synthetic Environments-Based Acquisition efforts in the United Kingdom and Canada. The continuation of the Collegial Initiative on the Economics of M&S also has generated some new progress in this area, and a SISO Study Group for the Best Practices in M&S Business Case Explication may be chartered soon. Finally, this paper concluded with recommendations for future progress in this topic area, including a continued focus on the topic at regular SimSummit meetings, the establishment and funding of a collaborative web portal to store documentation to date and illicit further submission of documentation and ideas concerning the Economics of M&S, and an effort to measure substantive evidence for the Economics of M&S.

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10. APPENDIX ONE: GOVERNMENT ACTIVITIES FOR ECONOMICS OF M&S

This listing highlights several government activities to study or participate in Economics of M&S activities:

- CapDEM³³ Technologies Demonstration Program, Canada
- Department of National Defence (DND), Canada, Synthetic Environments Coordination Office (SECO) Office³⁴
- DND Canadian Advanced Synthetic Environment (CASE)
- DND Defence Research and Development Canada (DRDC)³⁵ and Griffin Mothership
- DND, Canada, Joint Simulation & Modeling for Acquisition, Requirements, Training & Support (JSMARTS)³⁶
- FMV SMART Lab³⁷
- United Kingdom (UK), Directorate of Analysis, Experimentation & Simulation (DAES)³⁸
- UK Defence Sciences Technology Laboratory (DSTL)³⁹
- UK Synthetic Environment Based Acquisition (SeBA)⁴⁰ and UK SeBA Forum⁴¹
- UK Towers of Excellence, Synthetic Environments Priority Area^{42,43}
- United States (US), Air Force Agency for Modelling and Simulation (AFAMS)⁴⁴
- US Army Simulation and Modeling for Acquisition, Requirements and Training (SMART)^{45,46}
- US Navy Modeling and Simulation Office (NMSO)⁴⁷
- US DoD SBA⁴⁸

33 http://www.capdem.forces.gc.ca/po_e.html

34 http://www.drdc.dnd.ca/seco/index_e.html

35 <http://www.drdc-rddc.gc.ca/>

36 <http://admmatapp.dnd.ca/cosmat/dmasp/downloads/ModellingSimulation/>

37 <http://www.smart-lab.se/>

38 <http://www.mod.uk/issues/simulation/daes.htm>

39 <http://www.dstl.gov.uk/>

40 <http://www.mod.uk/issues/simulation/seba.htm>

41 http://www.semb.co.uk/organisations/seba_forum.htm

42 <http://www.mod.uk/toe/index.html>

43 http://www.mod.uk/linked_files/toe.pdf

44 <http://www.afams.af.mil/index.cfm>

45 <http://www.amso.army.mil/smart/>

46 http://asc.army.mil/docs/briefings/slc_2004/Treppel_FRONT_ONLY_SMARTSrLeader_ver13_06_Aug_04.ppt

47 http://nmsso.navy.mil/nd_contents.cfm

48 <http://www.msiac.dmsomil/sba/>

11. APPENDIX TWO: SIMSUMMIT ECONOMICS OF M&S AGENDA ITEMS

The objective of the SimSummit forum is no less than to significantly advance the evolution of the M&S profession, industry, and market. The declared agenda of SimSummit includes the elements relevant to Economics of M&S depicted in Table 1.

Table 1: SimSummit Topics Relevant to the Economics of M&S

| Topics | Discussion Points |
|---|--|
| Economics of M&S | What are the economics of M&S? What is the allocation of scarce resources? |
| M&S Market Description | What products, services, buyers and sellers populate the M&S market? How do transactions occur? |
| M&S-Based Enterprise | How can M&S support enterprise operations, for instance procurement and operations? |
| Business Case Specification | How does one explain the cost-effectiveness of M&S to decision-makers? |
| Acquisition/Procurement Application | How can/should M&S be used most economically in capabilities and materiel acquisition management? |
| M&S Investment in Technology, Assets, and Applications; and ROI | How can/should investment in M&S be made and recovered? |
| Reuse of M&S Assets | How can M&S assets be re-used cost-effectively? |
| Cost of M&S Asset Development and Use | What is the cost of M&S asset investment and asset employment? What cost estimating relationships apply? |
| Value of M&S Asset Development and Use | What is the value of M&S asset investment and use? What are the metrics of M&S benefit? |