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Metrics for Modeling and Simulation (M&S) Investments

Scientific and Technical Report

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This report is submitted in fulfillment of:

CDRL A002: Study Report on Criteria and Metrics for the Assessment of (Return on Investment) ROI of M&S investments

CDRL A003: Study Report on a Decision Process for the Application of ROI Criteria and Metrics

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SYNOPSIS: METRICS FOR M&S INVESTMENT

The DoD M&S Steering Committee established tasking "to conduct a study to develop:

- a recommended, uniform set of measures to assess the effectiveness and benefits of (investment) actions implementing the DoD M&S Strategic Vision, and
- an appropriate methodology by which to utilize the metrics"

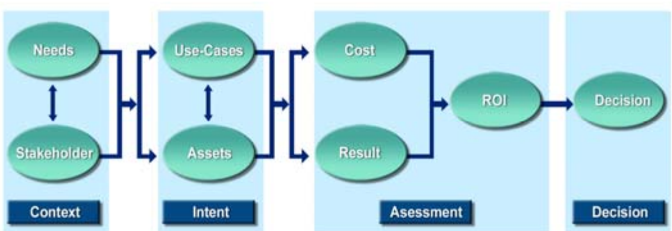
The study team developed a project execution strategy which addressed each of the elements of DoD's published "Strategic Vision for DoD Modeling and Simulation". From this strategy the team's research resulted in recommended best-practice for modeling and simulation investment that leverages successful business processes for use of metrics and systematic decision-making, while respecting the particular nature of the DoD mission, structure and business model.

Study findings were developed in each of the following areas:

Market Context and Business Practice	Cost Evaluation
Needs and Requirements Analysis	Results (benefits) Estimation
Stakeholder Community-of-Practice	ROI Evaluation
Use Cases	Decision Process
Asset Identification	Business Process

Metrics identified and qualified for use by DoD M&S investment agents include both traditional return-on-investment non-dimensional quantitative ratios and normalized qualitative factor valuations including risk. Guidance for metric value assignments is provided to facilitate the use of metrication and decision process execution at enterprise / corporate levels, domain or Service levels and at project / program levels of scope.

Careful analysis of the suitability of more than a dozen decision-process techniques resulted in the selection of a form of multi-criteria decision analysis designated MADM, for Multi Attribute Decision Method. This technique was embedded in a detailed, comprehensive business investment decision process:



Recommendations in 3 phases are provided whereby the algorithms, techniques, and business-process developed in this study may be deployed across the DoD in support of the DoD M&S Strategic Vision to leverage the power of modeling and simulation as a "national critical technology".

- Phase 1 includes socialization of report findings.
- Phase 2 includes refinement and establishment of practical viability of recommended investment decision process.
- Phase 3 includes deployment campaign for comprehensive employment of the recommended M&S investment decision process across the DoD.

Study Team Acknowledgments

The Study Team consisted of:

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The Team acknowledges the support and information tendered by many organizations during the conduct of this study, including particularly Department of Defense (DoD) Modeling and Simulation Coordination Office (MSCO).

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EXECUTIVE SUMMARY

INTRODUCTION - Chartered and funded by the Department of Defense (DoD) Modeling and Simulation Steering Committee, a diverse and experienced team, lead by The AEgis Technologies Group, Inc., undertook a study having the primary purpose of discovering, characterizing, and formulating recommended best practices to "…facilitate the cost-effective and efficient development and use of M&S systems and capabilities…"[1] within and across DoD's services, combatant commands, and agencies.

The study team developed a project execution strategy which addressed each of the elements of DoD's published "Strategic Vision for DoD Modeling and Simulation"; and resulted in recommended best-practice for modeling and simulation investment that leverages successful business processes for use of metrics and systematic decision-making, while respecting the particular nature of the DoD mission, structure and business model.

Description of the Team's efforts and constructive results includes consideration of: the need for the subject study and consequent investment guidance, circumstances attendant to the opportunity for addressing this challenge, the strategy of the study teams efforts, resulting determinations and findings, and recommendations for deployment and use of the proposed M&S investment best-practice.

STUDY NEED – Modeling and Simulation is a "national critical technology"[2] for the United States. M&S supports the economy of the country by enabling and sustaining our important industries. M&S contributes significantly to our national security and is vital to the missions of the Department of Defense. DoD invests heavily in M&S as parts of acquisition programs, and in training, analysis, testing, planning, and experimenting. All of the Services are also extensively involved in developing and executing M&S projects. Although difficult to quantify accurately, it has been estimated[3,4] that the DoD expends from more that one and a half billion to nearly ten billion dollars annually on M&S in its programs.

To produce the greatest impact from its investments, the DoD needs to manage its M&S programs utilizing an enterprise-type approach. This includes both identifying gaps in M&S capabilities that are common across the enterprise and providing seed moneys to fund projects that have widely-applicable payoffs, and conducting M&S investment across the Department in ways that are systematic and transparent. In particular, "Management processes for models, simulations, and data that … Facilitate the cost effective and efficient development of M&S systems and capabilities…." such as are cited in the vision statement require comprehensive Departmental M&S best-practice investment strategies and processes. M&S investment management requires metrics, both for quantifying the extent of potential investments and for identifying and understanding the full range of benefits resulting from these investments. There is at this time no consistent guidance for such practice.

STUDY OPPORTUNITY – The DoD has recently completed reorganizing its M&S management structure. This includes a new M&S management directive that established an "advisory body to the USD (AT&L)" to provide advice to the Undersecretary of Defense for Acquisition, Technology and Logistics (USD (AT&L)). Subsequently, the DoD M&S Steering Committee established a "Strategic Vision for DoD Modeling and Simulation". The DoD M&S strategic vision is to "…empower DoD with modeling and simulation capabilities that effectively and efficiently support the full spectrum of the Department's activities and operations." Enterprise-wide goals cited involve enhancements in standards, policies, management processes, tools, and people (the workforce). Each of these goals will require carefully managed investment in order cost-effectively to realize the M&S vision.

Consequently, the DoD M&S Steering Committee established the subject tasking to conduct a study to develop:

- a recommended, uniform set of measures to assess the effectiveness and benefits of (investment) actions implementing the DoD M&S Strategic Vision, and
- an appropriate methodology by which to utilize the metrics.

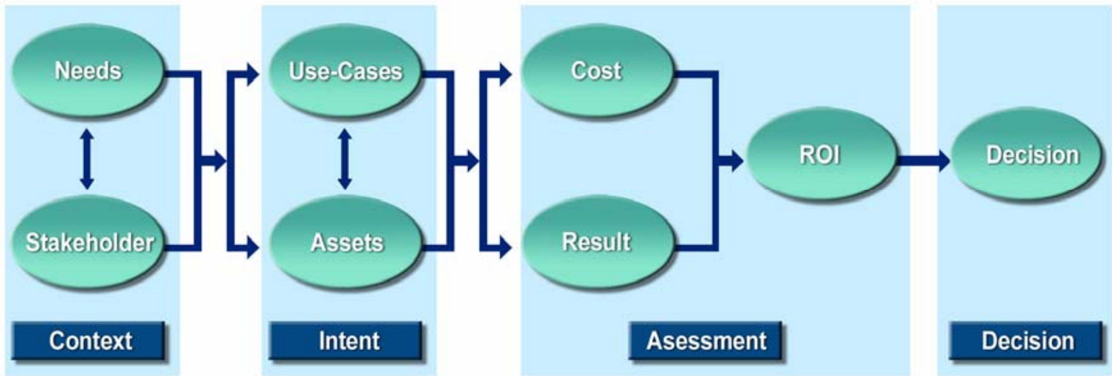
This report provides the results of that study.

STUDY EXECUTION – Study effort consisted of a systematic program of activity including tasks addressing: analysis, synthesis, evaluation, and conclusion.

A preliminary review of the study scope identified a full set of facets or factors whose analysis was considered to be critical to the study. These factors are:

- *Market Context and Business Practice* – discriminating DoD technology investment from commercial practice and leveraging commercial terminology and best practices suitably modified for the peculiarities of government executive business practice;
- *Needs and Requirements Analysis* – educing the sufficient conditions of M&S investment metrics and process to support the M&S DoD Vision;
- *Stakeholder "Community of Practice"* [5] Specification – recognizing how widely investment preferences vary across the DoD M&S communities and action-agent role players;
- *Use Case* – establishing use case specification and analysis as a basis for explication and evaluation of recommended process(es);
- Asset Identification – addressing the set of processes and product artifacts that are candidates for DoD M&S investment and identifying their cost and benefit dependencies;
- *Asset Cost Analysis* – identifying asset cost factors and their circumstantial dependencies;
- *Asset Benefit / Result Analysis* - identifying asset result factors and their circumstantial dependencies – particularly addressing government-sector indifference to commercial profit motivation and the presence of apparently intangible results;
- *ROI Algorithm Options* – analyzing commercial ROI methods and developing, adapting and tailoring ROI algorithms for DoD suitable for use in DoD best practice guidance; and
- *Investment Decision Process* – analyzing suitable alternative decision process candidates.

Synthesis effort entailed specifying recommended tailored ROI measures, and specifying recommended DoD M&S decision practice. The general M&S investment decision process recommended is illustrated in the eight-step control- and data-flow diagram below.



For each process activity, detailed definition is provided as indicated in the table that follows.

Process activity specification table

ACTIVITY CHARACTERISTIC	INFORMATION
Activity identity	• Activity Name and aliases
Activity description	• Activity Rationale / Need / Motivation
	• Activity Classification
Activity initiation	• Entrance criteria
Activity method	• Activity Procedure
Activity uses	• Previous uses
	• Prospective Applications
Inter activity relationships	• Activity sequence and control-flow
	• Activity information flow
Associated entities	• Tools
	• Actor-agents
	• Information pools
	• Product-object-artifacts
Problem (Risk) management	• Problem Identification
	• Problem Amelioration
Completion	• Exit Criteria

Several issues arise in considering ROI for government organizations in the face of characteristics that discriminate government from commercial business practices (e.g. lack of profit incentive, distribution of bill-payers and value recipients, and intangible value recovery over indefinite timeframes, such as are characteristic of government accounting). One method successfully used by the team to accommodate these circumstances is to rate each value metric on a scale from 1 to 10 and then take the sum of these evaluations. Then, evaluate the costs on a scale 1 to 10 based upon the maximum cost and use the (Value-Cost)/Cost formulation to attain a number for ROI

% Return = [(benefit) / (base)] * 100

Where: Benefit is the results (such as net income, revenue, yield, etc.) from a fixed Base of some type (total assets, total equity, total capital expenditure, etc.).

Multi Attribute Decision Methods (MADM) were deemed by the Team most likely appropriate for use in M&S investment decision contexts. MADM techniques were adopted and tailored to provide the basic algorithm for the "Decision" step in the recommended M&S investment decision process.

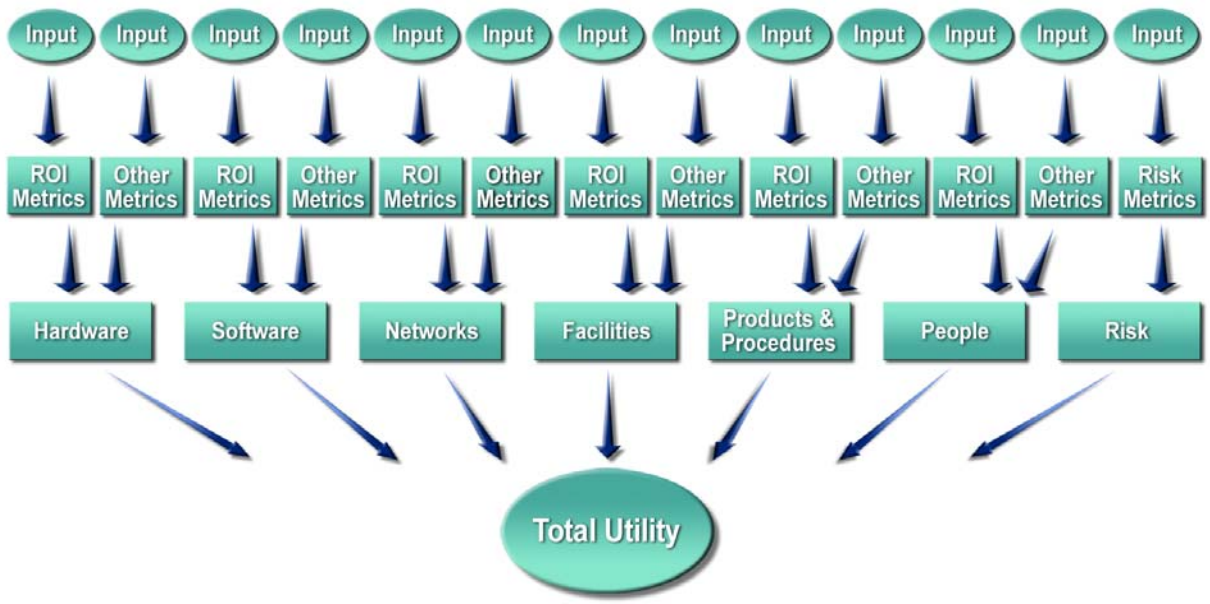


Diagram of MADM Process for DoD M&S Investment Organized by Asset Categories with Risk.

Evaluation effort was conducted through explication of three representative use cases selected for broad relevance to the interests of DoD investment executives. Three use cases that were analyzed in detail in order to evaluate the candidate investment decision process are:

- Use Case #1 (Alaska) Testing the Combat Benefit of a Position Determination System
- Use Case #2 Live Virtual Constructive Simulation Infrastructure Investment
- Use Case #3 - MDA Conceptual Modeling Investment

In each case, a virtual investment decision problem was 'solved' by the team in order to verify the candidate decision process and to generate additional determination s and findings.

STUDY DETERMINATIONS and FINDINGS – Determinations and findings were derived from preceding analysis, synthesis, and evaluation results. In the text that follows, summary findings (inferences) of the study are provided.

Market Context and Business Practice

F1: Adoption and adaptation of commercial practices based on differential characteristics of private and public sector business practices is necessary.

F2: Identification of complimentary, enabling business process re-engineering elements necessary and sufficient to: support execution of the subject recommended investment decision process; facilitate evaluation and improvement of the subject candidate process; and support to collection, storage, and retrieval of data associated with M&S investment decision calculations for use by the Department.

Needs and Requirements Analysis

F3: User needs and requirements discrimination is significant to dissociate stakeholder felt-needs from solution attribute criteria.

F4: Further needs and requirements analysis should follow based on stakeholder participation. Included should be particularly usability criteria and stakeholder specialization features.

Stakeholder Community of Practice Specification

F5: Thorough specification of stakeholder types is necessary and viable. Standard, persistent stakeholder role specifications, suitable for reference and appreciation across the DoD M&S enterprise environment are desired.

F6: Stakeholder perspectives influence on technical requirements should be explicitly identified and qualified.

Use Cases

F7: Use case analysis is practically imperative in 'hardening' draft processes, or in establishing the receptiveness of communities who may be asked to adopt the subject process.

F8: Whenever possible, execute stakeholder specification with cooperation of representative agents; or confirm use cases derived otherwise with representative agents.

F9: Selection and consistent use of (any) one well accepted use case specification schema throughout process design and deployment is likely to be effective.

Asset Identification

F10: Precise investment type identification is essential to concomitant concurrent cost and results (utility, benefits) identification and estimation.

F11: Consideration and accommodation in recommended practice of enterprise net assessment of desired asset investment is necessary. In particular, attention to free-rider dynamics and positive (or negative) externalities arising in association with any particular use case is prudent. [NOTE: this concern is inherited by cost and results determinations and findings as well, and introduces the fundamental question of how multi-scope collaborative decision-making can be optimally conducted.]

Cost Evaluation

F12: Cost estimation of potential investment must be systematic and clearly documented to facilitate follow-up reviews and analyses.

D13: F13: Standard practices such as cost-estimation to compute NPV and bundling of cost data with results, scoping for ratio measurement estimation, are prudent.

Results Estimation

F14: Audit traceability of results categories to mission and vision topics is essential; and results metrics must be commensurate with those whereby accomplishment of mission/ vision is to be accomplished.

F15: Evaluation of results via any recommended prescriptive process needs to be: a) well qualified with trisect to assumption of results elements and valuation included, and b) clearly and explicitly congruent to the stakeholder's perspective whose needs are intended to be met.

ROI Evaluation

F16: Attributes of ROI metrics should include a) non-dimensionality, b) time adjustment to net present value, c) weighted composability, d) derived across commensurate scope with respect to: stakeholder, transaction, asset, and organizational effect.

F17: ROI metrics must be generated from cost and results factors that are significant within the M&S mission and vision domain, using relevant cost and results factors.

Decision Process

F18: While several process specification schemas exist that would be suitable, a simple generic combination of tabular and graphic (activity-on-node, control-flow-on-arrow) notation is preferred.

F19: Multi Attribute Criteria Decision Process Making (MADPMCDM) style formulation meets all criteria and is preferred as a baseline decision approach.

STUDY RECOMMENDATIONS – Recommendations were compiled into three time-dependent periods or "phases".

Phase 1 recommendations address socialization of report findings and include:

- Brief report results to steering committee
- Compile comments and consequent requirements
- Amend recommended process accordingly

Phase 2 recommendations address refining and establishing practical viability of recommended investment decision process and include:

- Analytically re-evaluate and harden process
- Simulate recommended process
- Conduct proof-of-principle demonstrations of recommended practice with use cases selected specifically from the DoD M&S Vision goal categories.

Phase 3 recommendations address deployment campaign for comprehensive employment of the recommended M&S investment decision process within the DoD and include:

- Draft deployment and operational use plan
- Modify process and establish accoutrements in preparation for deployment
- Launch deployment with prototype employment

CONCLUSION – Use of modeling and simulation is widespread within the Department and across its Agencies, the Military Services and the defense industrial base. Cost effectiveness of M&S in this environment depends on continued successful investment in M&S assets and process competencies throughout the DoD enterprise. The current state of practice has inhibited efficient M&S investment, and has not been structured to support collective behaviors wherein economies of scale or common-practice may be leveraged. M&S investment has been neither explicit nor transparent in many programs and projects. Consequently, M&S investment have not typically been auditable or as controllable as befits enterprise investment in such a critical enabling technology. The M&S investment community *is,* within the defense establishment, as diverse as the use of modeling and simulation itself, and yet there have been no generally accepted practices whereby M&S investment may be considered systematically to both individual and collective advantage.

The DoD M&S Steering Committee understands that M&S assets and process improvement offer a significant opportunity to improve broad DoD mission performance. By conducting a 'return on (M&S) investment' (ROI) study, the Committee has taken advantage of the opportunity to allow the M&S Community of Practice to move from a state of casual, modestly informed, collaborative cooperation toward a state in which economic investment in support of the DoD mission may be transparent in its execution, intentional in its commitment, auditable in its effectiveness, and controllable in its consequences to:

"Empower DoD with modeling and simulation capabilities that effectively and efficiently support the full spectrum of the Department's activities and operations."

The M&S ROI study was conducted in such a way as to:

1) Be responsive to Congressional expectations and Departmental initiatives already underway;
2) Leverage, to the greatest extent possible, commercial investment practice, while recognizing and accommodating the particular requirements of DoD stakeholder communities, this report provides necessary and sufficient guidance for business process re-engineering for systematic DoD M&S investment; and,
3) Provide guidance for a systematic and transparent process for deciding and monitoring a wide range of potential investment alternatives that support the DoD vision.

The result is an initial capability for DoD M&S decision-makers to systematically monitor and inform future M&S investment under their authority, and to leverage future investments to best economic and practical advantage both within their own domain of operation and across the DoD mission enterprise. In particular, the ROI process described herein will help them understand the level and degree of success of M&S investment over time in order to facilitate efficient evolution of the most cost-effective M&S infrastructure and operations and will help DoD realize the value of M&S as a critical national technology and as an enabler of DoD's missions.

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1 INTRODUCTION

This report documents a Department of Defense (DoD) study to "*develop a recommended, uniform set of measures (metrics) to assess the effectiveness and benefits of actions from implementing the DoD Modeling and Simulation (M&S) Vision, as well as an appropriate methodology by which to utilize these metrics.*"[6]

1.1 Circumstance

The DoD M&S Steering Committee has noted that to date no effective processes or metrics have been established to routinely generate and describe Return on Investments (ROI) for DoD M&S. As a result, decisions are often made in a less formal and rigorous manner than desired. Decision-makers, such as the DoD M&S Steering Committee, need metrics which objectively and quantitatively describe the net value relative to the costs of DoD M&S investments. Guidance and information collection processes are also needed to routinely generate these ROI metrics.

This Study encompasses:

- √ ***Identification of the scope and type of M&S subject to ROI assessment;***
- √ ***Detailing M&S ROI investment criteria and metrics;***
- √ ***The rationale by which they may be objectively measured; and***
- √ ***A decision process for their application.***

This study encompassed: 1) the detailing of criteria and metrics for the assessment of the ROI of M&S investments; 2) their associated rationale and the means by which they may be objectively measured; 3) detailing a decision process for the application of the criteria and metrics; 4) identifying the scope and type of M&S that should be subject to ROI assessment, and 5) consideration of procedural guidance necessary and sufficient for the recommended practice to be as widely relevant to the diverse range of DoD M&S investment activities as possible.

1.2 Need

M&S Community leads, and other DoD decision-makers, need tools to systematically monitor and inform future M&S investment under their authority, and to leverage future investments to best economic and practical advantage both within their own domain of operation and across the DoD mission enterprise. In particular, they need metrics to help them understand the level and degree of success of M&S investment over time in order to facilitate efficient evolution of the most cost-effective M&S infrastructure and operations.

1.3 Opportunity

The DoD M&S Steering Committee understands that M&S assets and process improvement offer a significant opportunity to improve broad DoD mission performance. By funding efforts to investigate effective measures for quantifying 'return on (M&S) investment' (ROI), the Committee is taking advantage of the opportunity to allow the M&S Community of Practice to move from a state of casual, modestly informed, collaborative cooperation toward a state in which economic investment in support of the DoD mission may be transparent in its execution, intentional in its commitment, auditable in its effectiveness, and controllable in its consequences. The "Strategic Vision for DoD Modeling and Simulation"[7] statement to:

> *"Empower DoD with modeling and simulation capabilities that effectively and efficiently support the full spectrum of the Department's activities and operations."*

is the circumstance most indicative of the opportunity to address M&S return-on-investment systematically and with reasonable prospect of effectively employing the results.

1.4 Task Context and Background[8]

Use of modeling and simulation is widespread within the Department and across its Agencies, the Military Services and the defense industrial base. Cost effectiveness of M&S in this environment depends on continued successful investment in M&S assets and process competencies throughout the DoD enterprise. The current state of practice inhibits efficient M&S investment, and is not structured to support collective behaviors wherein economies of scale or common-practice may be leveraged. On the one hand, M&S investment is neither explicit nor transparent in many programs and projects. Consequently, M&S investment is typically neither as auditable nor as controllable as is needed to optimize enterprise investment in such a critical enabling technology. On the other hand, the M&S investment community *is,* within the defense establishment, as diverse as the use of modeling and simulation itself, and yet there are no generally accepted practices whereby M&S investment may be considered systematically and similarly by the DoD M&S community of practice, and managed to both individual and collective advantage.

M&S usage within the Department:

√ ***Depends on continued successful investment in M&S assets and processes.***

√ ***Requires improvements in the quality of M&S tools, data,, artifacts and practices.***

√ ***Is inhibited due to the absence of ant formal M&S ROI methodology.***

The "Metrics for M&S Investments" study is part of the Fiscal Year 2007 (FY07) M&S Project Plan of the DoD Modeling and Simulation Coordination Office (DoD M&S CO). The increasing interest and scrutiny of the Congress and the DoD Program Planning and Budgeting Process concerning the expanding use of M&S in the DoD make it imperative that the DoD M&S management process demonstrate convincing stewardship of increasingly valuable M&S investment resources. Other high visibility investment areas, such as the annual investment in Information Technology (IT), have addressed similar needs to demonstrate high return from their investment of the Department's Resources.

As illustrated in Figure 1.4-1, below, this report is focused on the analysis, synthesis and conceptual design of a value methodology and metrics for M&S that can be implemented Department-wide. Future activities, including detailed design, implementation and deployment planning and execution are envisioned as essential to demonstrate the utility of such a methodology and validate the efficacy of the study recommendations.

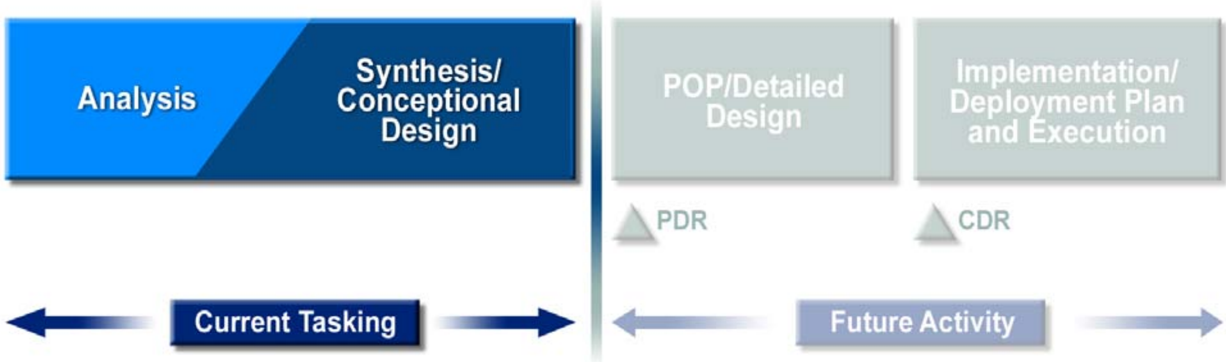

Figure 1.4-1. Developing Investment Practice for DoD's Enterprise M&S Strategy.

1.5 Task Challenges and Strategic Response

The fundamental need for successful investment in modeling and simulation within the Department of Defense is well documented and broadly recognized. In addition, more than a few efforts have been conducted to asses the then-current state, prevalent need, recognized gaps, business practices for M&S, and the deliberate management of M&S investment to achieve necessary and sufficient state of mission capability. Such efforts have included: North Atlantic Treaty Organization (NATO) M&S Conference[9] and Study Group[10] activity; DoD Business process re-engineering[11,12,13]; specific DoD standards-based business concepts for M&S interoperability and re-use[14]; military-service economic analyses and initiatives[15,16,17,18]; enterprise conceptualization by US Government agencies systematically to employ cost-effective M&S[19]; initiatives by other national defense establishments[20]; efforts by professional societies to analyze the mechanisms of M&S cost-effectiveness[21,22,23,24,25]; and academic research efforts[26] and specific determinations and recommendations reported as a results of a survey by *SimSummit* roundtable on "US DoD M&S Management / Leadership" executed for the US DoD Modeling and Simulation Steering Committee Tri-Chairs[27] , see Appendix D.

In anticipation of the present study, the AEgis Team identified several aspects of the problem whose treatment in previous efforts have been less than effective, resulting in less than influential results. Careful attention to previously unsuccessful attempts is considered necessary in order to specify a sound methodological approach likely to produce recommendations for a 'way forward' that are both: a) comprehensively relevant and acceptable to the diverse communities constituting the DoD M&S community of practice, and b) sufficiently concrete to be reduced to a reproducible process, hardened, and deployed broadly across the Department. In Table 1.5-1 and the comments that follow, a few of these challenges and intended mitigations are described.

Table 1.5-1. Inhibition To Comprehensive, Executable, Systematic Management of M&S Investment

ISSUE	MITIGATION
Aversion to systematic management control	Commitment via DoD M&S Vision
Habitual dependence on anecdotal evidence	Formal, systematic metrics and operational process
Stakeholder role parochialism	Nominal process with accommodative tailoring
Inhibition to valuation – aversion to intangibles	Requirements and guidance for intangible valuation
Ignorance of generally accepted accounting principles	Process designed to preserve GAAP
Unsystematic or non-existent business case exposition	Normative business case specification
Failure to appreciate difficulty of business process re-engineering	Anticipate complimentary BPR strategies or components

The fundamental aversion of elements of the Department to adopt and employ, consistently and with enforceable commitment, modeling and simulation practices is evident at several levels. At one level, the establishment of technical standards for M&S has proven to be problematic on both grounds of technical preference and economic implications. General efforts to establish enterprise wide resource collaboration across the Department has likewise been difficult. Certainly, the prospect of metrics-based collaborative investment is fraught with concerns of local sub-optimization, equity of influence, and free-rider risk. The single most useful basis for achieving desired collaboration (besides the generation, promulgation and use of ecumenical practice) is the commitment expressed in the DoD M&S Vision Statement[28], citing: *"A defense wide M&S management process encourages collaboration and facilitates the sharing of data across DoD components, while promoting interactions between DoD and other government agencies, international partners, industry, and academia."*

Basing M&S investment decisions upon anecdotal evidence has been chronic and endemic. Only the development and broad adoption of formal systematic metrics and processes for investment decisions will establish the grounds for audit traceability of the rationality of preference for decision alternatives and for the establishment of a legacy of well-documented investment success or failure.

Stakeholder parochialism, while inevitable, has influenced M&S investment in ways that are commonly masked by budgetary or programmatic considerations. While stakeholder needs and interests in M&S investment cannot and should not be disregarded; only a process in which those preferences are allowed, manifest procedurally, and documented explicitly is suitable.

Several matters relating to valuation and comparison of cost and benefit arise in consideration of rational investment processes. By far, the most disturbing to practitioners is the valuation of intangible benefits.[29,30] Of these matters, some level of uncertainty will always accompany M&S investment decisions. No process can be expected to succeed over the enormous range of DoD M&S investment decision alternatives that does not provide at least plausible guidance regarding qualified valuation of intangible cost and benefits. While there are some peculiarities in analyzing an economy in the government procurement context, the principles of investment accounting can and must be preserved.

The next factor relates to the failure in practice to express, document, communicate and act upon business case specifications that are comparable and intelligible. A Business Case is a form of expression of the plausibility of one or another business practice, action, or transaction… that provides the basis of expression and communication, of advocacy, of deliberation, of perception and judgment, and, last but not least, of the establishment of the *commitment-to-act* by [relevant] stakeholders, see Appendix E. The significance of consistent and transparent business case expression in supporting systematic management of M&S in general, and appreciation of investment in M&S in particular was made manifest in one meeting conducted by an M&S professional society[31] to address "enablement" of former departmental M&S business process re-engineering. In another case, "a panel was conceived and organized to explore the status of 'Business Case Expression' as a fundamental enabler of Simulation Based Acquisition (SBA)… in which offerings served both to accentuate the significance e of the Business Case in enabling SBA and to illustrate the 'way forward' whereby SBA business case(s) may be made sufficiently explicit." [32] Comprehensive and effective commitment to business case expression such as has been proposed by the Canadian defense establishment,[33] is necessary for broad based M&S business process engineering. In the present circumstance, ROI is considered to be an essential part of an effective business case expression, and so *de facto* will improve M&S management.

Finally, it is a matter of fact that for any organization with established culture, bureaucratic organization, and established business practice, change is difficult. The determinations and findings of this report and the pursuant recommendations do in fact constitute business process re-engineering process elements. As such, their implementation in context of deeply ingrained existing practices is likely to be challenging at best. For instance, while the recommended DoD M&S investment process that results from the subject analysis is relatively straight forward and algorithmically explicit; its practical implementation and execution will certainly depend on associated practices, equally logical, apparently appropriately, and firmly established. Unfortunately, modification of some of these practices (or establishment of same) are necessary conditions to the success of the M&S ROI management process. In particular, the management of data relating to corporate or enterprise investment decisions and consequences has proven difficult in previous, similar, circumstances (e.g. implementation of the HLA standard). The natural inference is that such ancillary or complimentary process elements, while formally outside the scope of the present analysis, will need to be addressed; and that provisions for graceful implementation of data generation, acquisition, retrieval, analysis and promulgation will need to be considered in order to improve the prospects of success of the recommended M&S investment process.

In all cases these strategic concerns and their mitigation are propagated through the methodology described in Chapter 2 and the analysis and synthesis documented in Chapters 3 and 4 respectively.

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METHODOLOGY / APPROACH

AEgis formed a multidisciplinary team of experts having a wealth of experience spanning the domain space demanding attention in this study. Study staff included individuals with degrees and extensive experience in business and operations research; experience in support of Service and Office of Secretary of Defense staff managing M&S policy generally and in particular domains as: analysis, acquisition, training, test and evaluation, etc.; and a legacy of leadership in participation in M&S community-of-practice interests in the economics of M&S.

As illustrated in Figure 2.0-1, and manifest in the acronyms of Appendix A, lexicon of Appendix B and bibliography of Appendix C this staff conducted literature searches, which led to a series of decisions regarding the overall study options. Closely coupled to identification of user needs and establishment of measurement criteria, several options for addressing M&S return on investment were pursued, resulting in selection of a decision process and metrics for recommended execution.

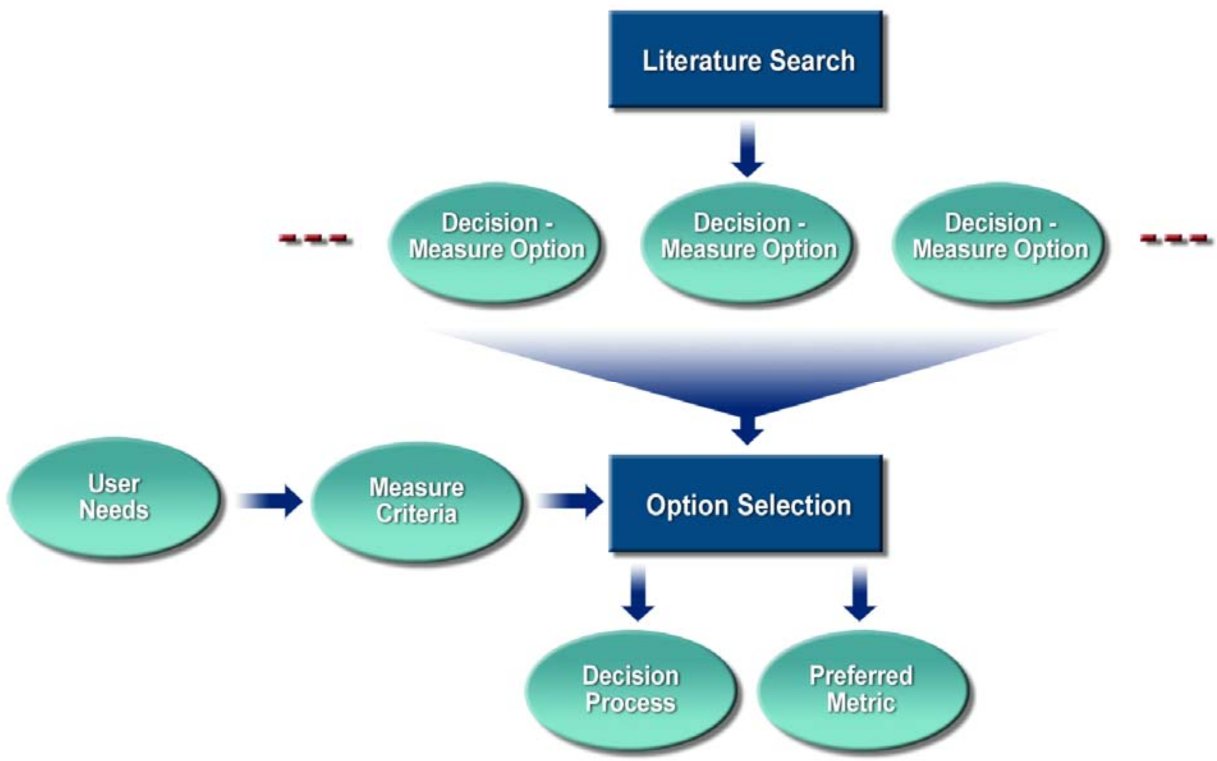

Figure 2.0-1. Methodology for Study of DoD M&S Investment Strategy.

Specific emphasis areas for the study were identified, and issue-topic and/or product-component leader responsibilities established early in the task. These are described in greater detail below. A detailed time-phased plan was developed to identify major study activities and associated milestone products (see Appendix F). A distributed collaborative environment was established to support and facilitate the team's efforts and the capture of study results. In addition, broader

DoD M&S Community input and participation was solicited as appropriate to inform study objectives to the maximum extent possible.

A phased approach was developed and used for execution of the study, which consisted of five overlapping activities, with emphasis on an evolving list of critical issues and fundamental perspectives. In the sections that follow, descriptions are provided for each component of this phased execution approach and for the set of critical issue topics whose appreciation and accommodation was judged by the team to be necessary to the successful completion of the study.

2.1 Primary Study Activities

Study effort was focused on:

√ ***Discovery of present state.***

√ ***Analysis of influence factors and alternatives.***

√ ***Synthesis of best practice specification.***

√ ***Evaluation of suggested solution.***

√ ***Presentation of report / briefing.***

The five-phased activity plan designed for the effort is outlined in the bullets below. In each case, the primary activity is indicated by the title phrase, and operational guidance or conditions and criteria for execution of the task phase are indicated in text.

- **Discovery of present state** – Using results of a bibliographic survey, team knowledge and interviews with stakeholders:
  - Identify stakeholders and their role-dependent sensitivities;
  - Discriminate market attributes (products services, buyers, sellers);
  - Identify and classify investment types and target assets;
  - Document M&S stakeholders needs / requirements; and
  - Establish study sufficiency (evaluation) criteria.
- **Analysis of influence factors and alternatives** – Identify / characterize alternative ROI techniques and implementation processes and methods. In doing so:
  - Evaluate alternatives in context of DoD needs and opportunities;
  - Capture relative attributes (pros-cons) of alternatives; and
  - Indicate potential implications of adoption / employment of each of the principal alternatives.
- **Synthesis of best practice specification** - Conceive and draft suggested best-practice. Reduce recommended practice processes to semi-formal specification, detailing associated algorithms intended for generation and comparison of quantitative metrics.
- **Evaluation of suggested solution** – Employ use-cases to evaluate recommended alternative practice(s) in terms of DoD stakeholder perspectives.

- **Presentation of Report/Briefing** – Draft and publish final technical report and associated briefing containing: report of task activity; results of task effort; and encapsulated best practice recommendation suitable for peer-review and evaluation.

2.2 Critical Topical Perspectives

Specific task requirements to establish ROI metrics for prospective investment in leveraging M&S technology throughout the Department considered challenges associated with the intrinsic complexity of the task subject matter and the sensitivity of stakeholders to the several contextual circumstances of capital investment required. An overall context and scope of study appropriate for task execution from an enterprise perspective was developed and is illustrated in the Figure 2.2-1.

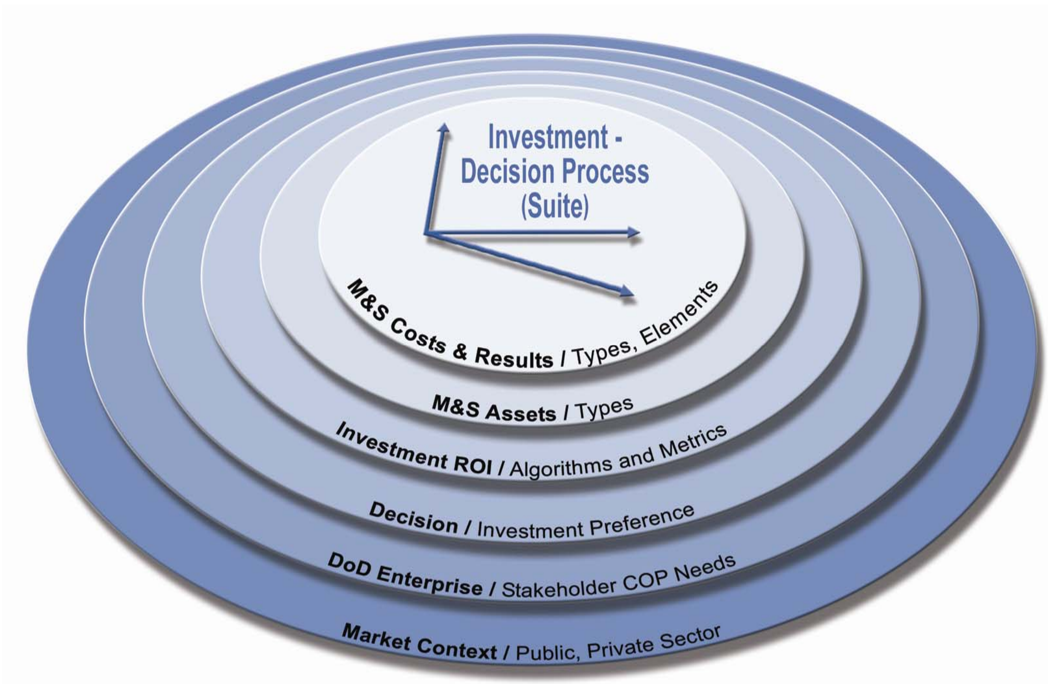

Figure 2.2-1. Task Context / Dimensionality.

Several topical perspectives that required investigation and understanding were identified by the team as necessary for successful study completion. These topics, and significant questions, concerns or implications arising from them, are detailed in the list that follows and to which specific attention will be addressed throughout this report:

- **Stakeholder / Community of Practice** – What stakeholders (roles) are there for whom M&S ROI metrics and processes are relevant? What attributes characterize / differentiate these stakeholder roles? What needs exist within the DoD M&S Community for ROI metrics and investment management processes? By what criteria can the sufficient conditions of such metrics and processes be demonstrated?

- **Use Cases** – What sample representative 'use-case' instances can effectively illustrate alternative investment processes and metrics, and can serve to support the definition, explication, and evaluation of process and metric alternatives?

- **Asset identification** - What specific assets (i.e., goods or services) can serve as the basis of investment in DoD M&S? How are those assets classified? related? and characterized?

- **Investment cost-element** – What are the elements that comprise the 'cost' of various DoD M&S investments? Upon what other circumstances are those costs contingent?

- **Investment results-element** - What are the elements that comprise the resulting 'benefit' or 'value' of various DoD M&S investments? Upon what other circumstances are those results assessments contingent?

- **ROI algorithms** – What alternatives exist whereby ROI metrics may be defined to support management of investment in the DoD M&S market? What are their assumptions? How should those algorithms be employed? Evaluated? Compared?

- **Investment-decision process** – What are the options among alternative process models whereby decisions for investment in DoD M&S may be made?

- **Documentation** – How should the subject analysis and its consequent results be captured to support research or deployment of recommended best practices? What lexical and bibliographic conventions should be established at the interface of M&S management and sound economic and budgeting practice?

- **Market context** – what are the market contexts in which DoD M&S investment occurs? Who are the buyers and sellers, what are the goods and services, and what business practices characterize the exchange of economic value in general, and investment in particular, in the DoD M&S market?

In executing the study, the AEgis Team intended to conceive and recommend, M&S ROI metrics and audit practices that can support the US DoD M&S investment process wherein it is self-conscious, explicit, documented, and poised to move to being "quantitatively managed". The conclusions and recommendations of this report achieved this intention via detailed study and analysis, structured by the nine topical perspectives just listed.

2.3 ROI Criteria & Metrics

Using the approach defined above and working through the nine perspectives defined above, the AEgis Team conducted studies to gain the necessary understanding for defining an initial set of criteria by which the ROI of an M&S investment could be determined. The chosen criteria, taken together, comprise a general methodology that will be able to be applied to all M&S

Any Valuation Methodology must include:

√ ***The identification of a metric, and***

√ ***A performance target.***

DoD projects. This methodology focused on the value created by, or received from, making any specific M&S investment:

- By analyzing the different costs – opportunity cost, human capital utilization, cash, etc. – involved in supporting a project, and adjusting for the risk-reward mix, time-value of money (net-present-value), and cost-of-capital, the Team created a general methodology by which the costs of a project can be quantified. The Team utilized managerial cost accounting (MCA) practices (as per the General Accounting Office's (GAO) recommendation) and Generally Accepted Accounting Principles (GAAP)[34], in performing calculations. By normalizing the measurement of cost, a comparison between different projects became possible and practical.

- Building on the work done in the private corporate sector to effectively evaluate investments, the Team adapted these techniques to the specialized DoD M&S environment. M&S projects can produce value in a variety of ways. This value can take the form of enhanced efficiency, greater scalability, increased effectiveness, as well as many others. Additionally, the reduction of costs – that is, the decrease of negative aspects such as time-to-develop, physical waste, or errors – can and should also be considered "value added."

- Given the complexity of the value proposition inherent in DoD M&S investment projects, a rigorous yet flexible system was found to be needed. The Team addressed this issue by utilizing a variety of best-practices such as Economic Value Added (EVA) methodologies and similar techniques used for investment analysis. Additionally, the Team explored the application of management techniques such as the Performance Prism, Intangible Assets Monitor (IAM), Balanced Scorecard, and other similar methodologies that can be employed to highlight value normally not recognized by more traditional cost accounting approaches.

For each criterion, the Team determined the applicable metric and the means by which it may be objectively measured. In doing so:

- Metrics and supporting information were developed to describe the total DoD investment in an M&S project, and to describe the net utility – that is, the difference between costs incurred and value received – derived from that investment.

- The metrics and supporting data together describe an approach that allows comparison between or among different candidate M&S investment projects.

2.4 Decision Process Using Defined ROI Criteria & Metrics

With the understanding obtained for defining an initial set of criteria and associated metrics by which the ROI of an M&S investment may be determined, the Team developed an initial recommended decision process for the application of those criteria and metrics. The Team developed an initial set of guidelines, processes and practices and then employed select Use Cases to evaluate those recommended alternative practice(s) in terms of stakeholder perspectives in representative domains. Use Case results were used to tune the initial recommended decision process.

2.5 Requirements of the Study and Its Results

Requirements for the establishment of a valuation method for investment in M&S programs are, in general, best driven from the top-down, while actual M&S program investment and execution is best built from the bottom-up. This chestnut of systems engineering is novel only insofar as its implementation is taken seriously. For the Study, the goal of the valuation activity was defined as establishing the best return on investment for a given M&S asset for a given purpose by a particular agency. It therefore made sense to start by identifying the basis for such a judgmental decision, inferring forms of evidence sufficient to support a positive outcome, and further deriving the means to generate and prepare for review and deliberation such evidence as is necessary and sufficient. The focus was not requirements compliance, but information gathering to support the government decision process and associated metrics to support program execution and oversight.

This system engineering process used for the Study is illustrated in Figure 2.5-1, in which M&S investment criteria and requirements flow downward. Particular steps in this ladder-down requirements process are discussed in greater detail in Section 4.

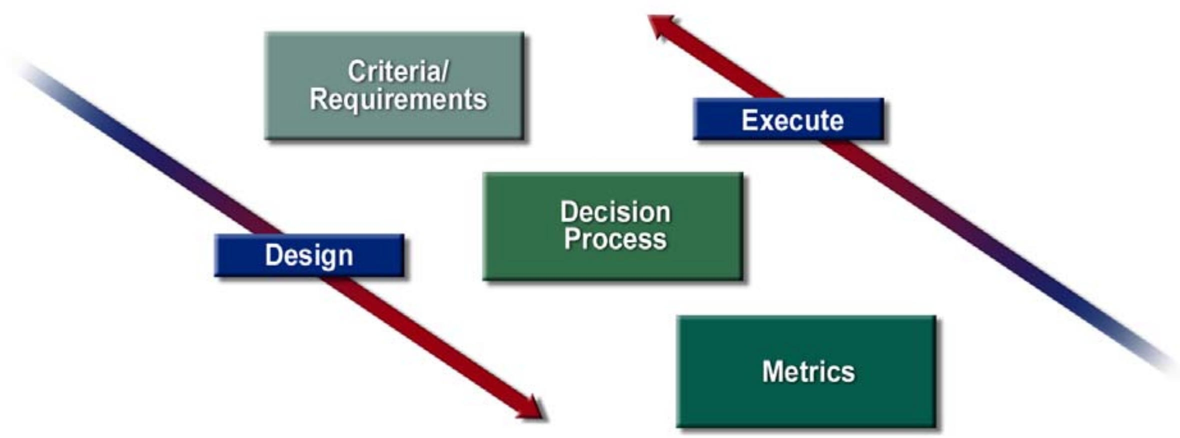

Figure 2.5-1. Integration of Requirements and Valuation.

Requirements for the subject study have been compiled from task guidance and Contracting Officers Representative COR instructions and documented in the tables of Appendix G and H. These requirements refer strictly to the completion of the study task and its documentary record. They are, in effect meta requirements, pertaining to the current task and not to the results of the task or the use of those results. Requirements relevant to the investment decision process guidance itself are introduced in Section 3.2.

3 ANALYSES

The following subsections of this report provide a summary of each study topic. The results of each were integrated to conceive and recommend for use, M&S decision process best-practice and ROI metrics and audit practices that can support the US DoD M&S investment process to capability maturity levels wherein it is self-conscious, explicit, documented, and poised to move to being "quantitatively managed".

3.1 Market Context & Business Practice

Enterprise M&S Investment requires structure, persistence and common valuation for consistent execution. The methodology proposed in this study, while based on current DoD acquisition practice, addresses also how DoD practice should be informed by theoretical aspects of economic capital structure, and considers the elements of such theory to guide its systematic investment in, and evaluation of, M&S resource initiatives. In this spirit, concepts of consumption and investment and capital asset management, assessment, and valuation must be considered in detail to conceive for DoD's adoption, adaption, and implementation of an M&S investment management approach that creates the largest possible value and flexibility while minimizing the costs of doing so.

Any consistent M&S management approach needs some concept as the underlying framework upon which to build a unified methodology. The DoD is a subset of one of the three main sectors of the U.S. economy – business firms, households and Government. In macroeconomic terms, this partition of the economy and interactions among components are indicated in Figure 3.1-1. This diagram is typical of macro-economic views of modern industrial societies. Insofar as individual households are not actors relevant to the subject analysis, they have been de-emphasized in the figure.

The problem of investment by DoD as an agent (or ensemble of agents) of the government acting as an investor in M&S, however, admits more nearly to micro-economic analysis. In Figure 3.1-2, a traditional micro-economic perspective is illustrated. Interactions between firms (acting in the usual role of households) and government (acting in the usual capacity of firms) are depicted. The relevant interactions involve exchanges of money (or its equivalent in liquid assets) for goods and services through markets that are venues for mediation of exchange of labor, materiel, and financial instruments. This second figure de-emphasizes purely financial services exchanges, as such purely financial transactions are beyond the scope of the subject analysis.

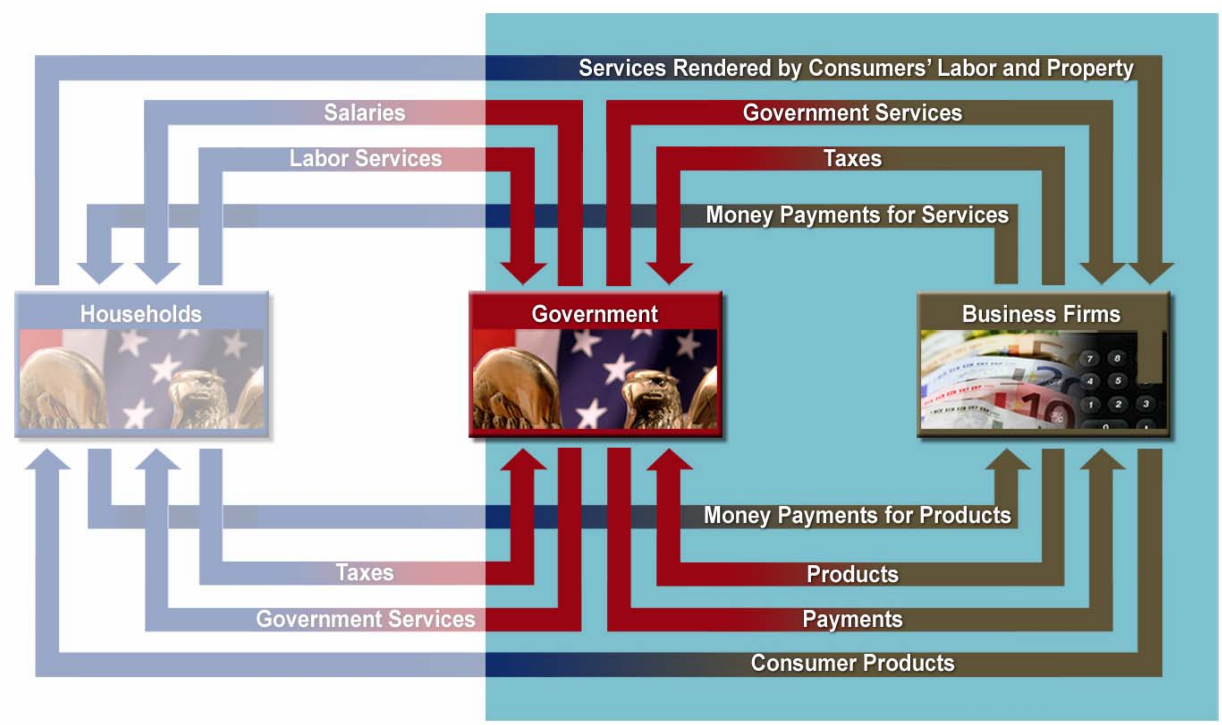

Figure 3.1-1. Macro-economic Schematic of Relationships Between Government and Firms.

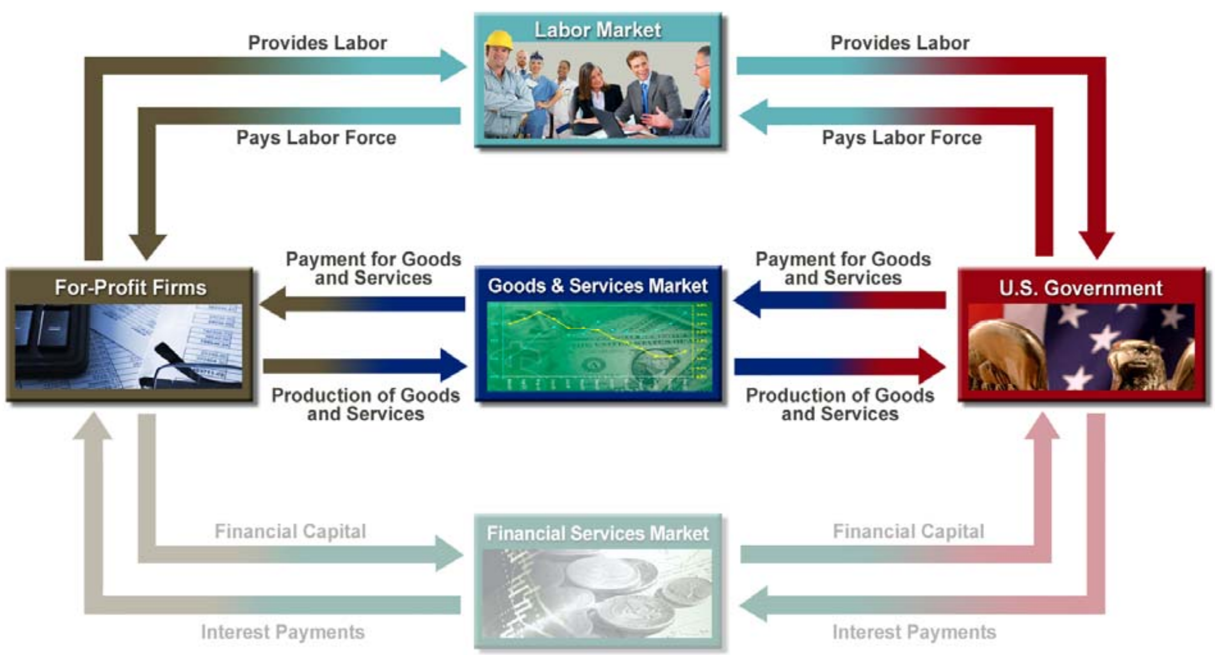

Figure 3.1-2. Micro-Economic Illustration of Relationship Between Firms As Sellers and Government as Buyers Participating in Markets for (M&S) Labor and for Goods and Services.

Analyzing M&S products and services, and labor markets as transactions between government (as buyer(s)) and business firms (as sellers) provides a basis, and a consistent underpinning, for the cost, benefit, and value analysis and assessment methodologies suggested in this report. DoD 'business' is contrasted with for-profit business as a way to illustrate the efficacy of the arguments presented. The concepts presented together make up a framework within which DoD can decide on the kinds and types of M&S to which ROI criteria must be formally applied. They also provide for decomposing aspects of M&S investment analysis into two major pieces – a quantitative piece, for which the following analysis provides details and Use Cases for how to implement, and a non-quantitative piece, for which important, but non-financial, metrics and criteria are likewise addressed.

3.1.1 Introduction and Background

Enterprise-level M&S investment requires structure, persistence and common valuation for consistent execution. The methodology proposed in this study, based on current DoD acquisition practice, addresses also how DoD practice should be informed by theoretical aspects of economic capital structure, and should consider the elements of such theory to guide its systematic investment in, and evaluation of, M&S resource investment initiatives.

> *"Stand-alone strategies don't work when your company's success depends on the collective health of the organizations that influence the creation and delivery of your product. Knowing what to do requires understanding the ecosystem and your organization's role in it*."[35]

This quote is the lead statement of an article published in the Harvard Business Review four years ago, addressing the fundamental premise that commercial businesses exist and thrive (or not) within the context of a business environment much larger than exists within the boundaries of an individual firm, and that to succeed, individual firms must learn to recognize and create value within 'the ecosystem' in which they exist. The article defined a 'business ecosystem' as that set of external organizations to which the success of your organization is closely tied, those for which critical dependencies exist. Translated to the domain of DoD M&S enterprise management, it would read something like this:

> *Stand-alone M&S strategies don't work when DoD's enterprise wide success depends on the collective value created across the organizations that influence the creation and delivery of value derived from investment in M&S. Knowing what to do requires understanding DoD's ecosystem and leadership's role in it.*

The organizations are many that influence the creation of value from M&S investment within DoD. The key to maximizing value on an enterprise level is, as is implied by an 'ecosystem' viewpoint, understanding who shoulders the costs, and who potentially derives value from the allocation of resources to M&S.

A fundamental assumption in this argument is that investment practice common to commercial industry is suggestive of but does not work "as-is" for the behaviors of DoD elements; and that translating long proven commercial methods to something useful to DoD for M&S governance requires a framework for translation of terms, methods, and processes into a methodology and 'best practice' of practical use to DoD leadership. This section lays the groundwork underlying that translation.

3.1.2 Current Circumstance and Context

Several factors distinguish the role-postures, motivations, and market transaction behaviors of government as a buyer-investor in M&S workforce, goods, and services from those typically assumed for business firms in that same posture in the microeconomic market environment. In the sections that follow, we identify several such factors, and educe their implications for measurement of ROI, for establishment of sufficiency metric criteria, and for M&S investment process practice.

In order to prepare for discussion of the practical realities of government departmental investment, we have to clarify with some precision the following:

- Intrinsic attributes of private-sector versus those of public-sector (or governmental) economic organizations
- Differential postures in relation to core economic concepts of private and public economic organizations.

For instance, it is clear *prime facie* that the fact that government is not a profit seeking organization will color its valuation of financial return on investment. In order to proceed with the detailed analysis and synthesis of DoD M&S ROI, it is prudent to make such distinctions explicit and to call attention to their implications.

Having cited rationale and intention to survey and differentiate private- and public-sector postures with respect to fundamental economic concepts, there is a challenge to systematic explication of this field – this is the typical conundrum of scanning a three dimensional manifold. In order to expedite our own story-telling, we will proceed as follows:

1. Consider the *general attributes of organizations*; and cite in turn the similarities and differences that characterizes private- and public-sector organizations
2. Similarly, *consider essential core economic contexts*; and cite in turn the similarities and difficulties that characterize private- and public-sector organizations.

This process will be illustrated in the form of a pair of tables in which organizational attributes and economic concepts are rows and are reviewed in turn in comparison to the differential characterization of private and public sector organizations. These simple indicia are supported by textual amplification and illustration. This preliminary analysis is considered necessary in order to execute our strategy of logically and creditably employing private-sector economic behaviors (particularly investment) in public-sector (particularly DoD) contexts.

3.1.2.1 Private- and Public-sector Relevant Characteristics

Clearly private- and public-sector organizations are different in ways that are likely to influence their postures with respect to economic concepts attitudes and operations. In this section, we strive to identify those discriminates, to make explicit some of their attributes and to suggest (in summary form) why these distinctions are going to matter in considering M&S ROI.

Table 3.1.2.1-1 indicates, for several basic organizational attributes, the specific relevant characteristics or values of those attributes that do (or do not) discriminate private- and public-sector organizations. Attribute values are selected intending to relate to government organizations generally yet reflect realities of DoD.

Table 3.1.2.1-1. Comparison of Relevant Attributes of Private- And Public-Sector Organizations.

ATTRIBUTE	PRIVATE-SECTOR	PUBLIC-SECTOR
Mission		
Mission commitment and devolution	Highly desirable, typical	Highly desirable, typical
Mission scope	Enterprise wide, private good	Society wide, public good
Mission partition	Clearly partitioned by market sector	Clearly partitioned by societal need, and within DoD by law
Mission accomplishment	Survival, growth, profitability	Service accomplishment, societal welfare
Accountability	Fundamentally economic, evaluated at unit and enterprise by accretion	Political-societal, evaluated at enterprise independent from evaluation at component units – former are political societal, operating units are budget and function valuation
Stakeholders		
Types	Stockholders Board(s) of directors Executives Employees Indirect staff Direct staff Suppliers and Customers	Citizens Congressional (and Judiciary) oversight Executives Employees General and administrative staff Operational staff Suppliers and public and private customers
Role Functions	Vision, mission, policy determination and advocacy Leadership Decision Command and control Acquisition of operating capital / Investment Service delivery / Production Marketing, sales and distribution	Vision, mission, policy determination and advocacy Leadership Decision Command and control Acquisition of operational capability / Investment Service Operations Missionary and budgetary negotiation or direction
Structure		
Identity, holism, coherence	Necessary	Necessary
Partition	Flexible, contingent	Relatively static, traditional
taxonomy	Process or product oriented	Socio-political sensitivity oriented
Financial responsibility	Profit/cost centers	Budgetary units
Process		
Management Style	Diverse, largely hierarchical, but modified by matrix, team, product family encapsulations	Bureaucracy

Table 3.1.2.1-1. Comparison of Relevant Attributes of Private- And Public-Sector Organizations.

ATTRIBUTE	PRIVATE-SECTOR	PUBLIC-SECTOR
Competition	Overt in markets versus competitors	Budgetary and political prestige
Cooperation	Common control authority Client-server relationships Suppliers Customers Market- (or industry-) member relationships Explicit internal markets based on normal economic processes Private to public sector relationships (lobbying, etc.)	Common control authority Client-server relationships Suppliers Users Mission-function relationships (e.g. across departments for homeland security, between military services, etc.) Lack of systematic internal markets – ameliorated by joint acquisition and operational guidance Relation to private sector, limited for DoD to acquisition, multiuse technology, and congressional interface.

As part of the federal government, the DoD operates within the context of the U.S economy, in general, yet has special needs and requirements related to its unique role and mission. A few of these implications – suggested by the attributes table above – include the following:

- Government as mission driven on behalf of their stakeholders (citizens) versus firms as mission driven on behalf of their own stakeholders (stockholders) does not discriminate prime facie between government and firms' investment motives.
- The existence and degree of fractionation or internal competition or the complexity of internal markets do not inherently discriminate between private- and public-sector organizations. On the other hand, the particularities of these partitioning relationships do in fact have implications for business practice. For instance, the legal and persistent partition of the missions of military services, their functional overlap and the consequent redundancy in acquisition, deployment and use of common functions seem to characterize DoD economic behaviors. Similarly, the persistent functional decomposition of the Office of the Secretary of Defense (OSD) organizational units that are fundamentally uncorrelated to M&S practice or investment requires extraordinary ameliorative accommodations.
- This being a capitalist society where firms are profit motivated and where government operates on budgetary allocations pro bono does so discriminate.

Table 3.1.2.1-2 indicates, for several basic economic concepts, the specific relevant characteristics or attributes, whose values do (or do not) discriminate private- and public-sector economic postures and behaviors. Attribute values are selected intending to relate to government organizations generally yet reflect realities of DoD's economic posture.

Table 3.1.2.1-2. Comparison of Economic Postures of Private- And Public-Sector Organizations.

ECONOMIC CONCEPT	PRIVATE-SECTOR	PUBLIC-SECTOR
Market posture	Typical market postures as sellers of goods and services include: • Commodity vendors • Monopolist • Oligopolist	Typical market postures as buyers of goods and services include: • Commanded and solicited product-service buyers • Oligopolist
Business practice	Diversity of business practice is considerable, and continually emerging, elements of which include: • Capital markets are diverse (stock purchase, leveraged agglomeration, angel investors, etc.) • Types of business unit and partnerships are diverse (e.g. large and small businesses; internal and external markets; product and service encapsulation; market evolution) • Standing of products, services, and intellectual property is diverse (e.g. open source, patent and other forms of protection,	Business practice is seriously stylized: • Acquisition of assets for consumption or investment alike is limited to government (DoD) procurement from private sector by means of highly regulated processes and rules-of-engagement. • Government intellectual property is seldom managed as a corporate or enterprise asset, from which investment recovery is expected or managed
Consumption	Consumption expenditures are out-of-scope for investment return analysis	Consumption expenditures are out-of-scope for investment return analysis
Investment	Investment entails expectation of deferred gratification and consequent recovery of relatively greater future benefit	Investment entails expectation of deferred gratification and consequent recovery of relatively greater future benefit
	Investment 'bill payer' scope-of-interest is usually congruent with 'ROI recipient' scope	Investment 'bill payer' scope-of-interest is often incongruent with 'ROI recipient' scope
	Assets available for investment in M&S are relatively independent of private sector context or usage	Assets available for investment in M&S are relatively independent of public sector context or usage… however, some forms of asset investment are peculiar to DoD mission interests
	Costs necessary for investment in M&S are relatively independent of private sector context or usage	Costs necessary for investment in M&S are relatively independent of private sector context or usage
	Benefits of M&S investment, when considered at all are typically evaluated and reported in terms of 'monetized' results	Benefits of M&S investment, when considered at all considered to be significantly intangible (represented more

Table 3.1.2.1-2. Comparison of Economic Postures of Private- And Public-Sector Organizations.

ECONOMIC CONCEPT	PRIVATE-SECTOR	PUBLIC-SECTOR
		likely on capability and mission accomplishment than in financial terms)
Capital	Capital is explicitly accumulated from stockholders and other investors and are intentionally designated for investment	Capital is extracted from unit(s) operating budget and is expended in transactions in which operations and investment may be significantly conflated
	Capital management (differentiation, acquisition, deployment, etc.) is explicit and important	Capital management is practically unrecognized
Return-on-Investment	Fundamental metric for missionary success	Capability accomplishment and budgetary compliance are fundamental metrics of institutional success
	Normally includes consideration of only concrete financial returns (goodwill being handled 'off the books')	Is inhibited by need for assessment of intangible consequential results (goodwill is still 'off the books')
	Best practice includes at least: • ROI is a ratio-scale (non-dimensional) variable • Calculation entails normalization to commensurable values (e.g. adjustment via net present value computation)	Best practice *should* include at least: • ROI is a ratio-scale (non-dimensional) variable • Calculation entails normalization to commensurable values (e.g. adjustment via net present value computation)

In view of the differential posture of private- and public-sector organizations in relation to relevant fundamental economic concepts indicated in the table above government postures have at least the following implications:

- Government (DoD) being the (only) buyer in many parts of its M&S market *does* discriminate it from private sector M&S investment … notwithstanding considerable fractionation of investment interest with in the Department.
- Conflation of producer-user exists in DoD without the compensating mechanisms of internal market mediation
- OSD collegial cooperation via the M&S Steering Committee is essential pursuant the fragmentation of M&S use and need for oversight and corporate investment. This particular decision-making administrative mechanism does constitute constraint to viable investment process alternatives
- Government is faced *with accounting of intangible benefits as contrasted to monetized benefits or simple revenue.*
- Free-rider issues are not wholly the provenance of government, but where, as in government, revenues and expenditure are disjoined by the artificialities of politically influenced budget allocation, and where as in DoD, the special intuitional operational units such as exist within the OSD, and between OSD and the Title X military services,

free-rider concerns are particularly chronic and apparent. It must be recognized that, unlike a commercial practice (e.g., firm or company based), when DoD invests, there is often a misalignment of the ‘cost bearer’ (the resource sponsor) and the “benefit accruer” (the organization or organizations that benefit from the investment), especially when the investment creates and returns value to DoD components beyond those expected to make use of the original investment. This situation is typically framed in terms of the free rider problem, the situation in which some benefit from an investment without having paid a fair share of the cost. This may not seem to be a problem, but in assessing candidate investment for which resources are not sufficient, there does not exist in present DoD practice a methodology to capture and characterize the future and extended value accruing to users beyond the primary intended users of the investment. Having a methodology to capture such extended benefit could change the outcome of an investment decision from ‘not possible’ to ‘approved’, and additionally provide a mechanism for assessing all beneficiaries for their share of the costs of the investment.

Figure 3.1.2.1-1. DoD M&S Investment Straddles Private and Public Sector Enterprise Operation and Business Practices

3.1.2.2 Consumption vs. Investment

Consumption is the process of using products in order to satisfy needs & desires (self-generated or imposed; real or imagined). In doing so, the products are used up, transformed, or deteriorated in such a manner as not to be either reusable or recognizable in their original form. The term, in the general economic sense, excludes the use of intermediate products in the production of other goods (such as purchase of buildings, machinery, or software). For instance, viewed from this perspective, most expenditure for software or simulation products cannot be viewed as consumption – because software is not consumed by its use. It instead retains its original form, function, and capacity to provide value - a characteristic of a capital good, much as a building or bridge is a capital asset. When consideration of value is undertaken, the value of 'consumption' of a product, service, or process necessarily includes some element of basically subjective judgment, with organizational or individual utility, or satisfaction, being some significant subset of the total valuation ascribed by the consumer to the product, service, or process consumed.

In the same sense that a new intelligence center building, a new network infrastructure, or a new satellite system are all additions to existing capital owned/operated by DoD all are a form of asset, having enduring value accruing to its owners.

Appendix I indicates in detail how software in particular and simulation products in general constitute capital assets, embodying knowledge and persistent value. As such, software in many cases should be subject to the investment management processes provided in the following sections of this report.

3.1.2.3 The Specialized DoD M&S Environment

In addressing a complex subject such as under consideration here, a fundamental question is, "what is the present state of practice within DoD?"

The DoD M&S Vision addresses standards, architectures, networks, and environments, stating a need to provide sharing of tools, data, and information. It further addresses policies intended to promote interoperability, reuse, and leveraging of M&S investment. These are functions which would be applauded by proponents of an 'ecosystem' view of M&S governance. DoD explicit recognition of M&S assets as digital capital – fixed and working – in evolving its ideas of frameworks and architectures, is offered as a viable and workable path for progress towards both of these objectives.

Across DoD, present practice is to base investment in M&S on a number of methods, but at an enterprise level, it is neither systematic nor consistent. Writing in Acquisition Review Quarterly, C. David Brown, Director for Test and Technology for the Army Developmental Test Command wrote in a 2000 study, "Most program managers justified their M&S investment based on one or more of the following:

- reducing design cycle time;
- augmenting or replacing physical tests;
- helping resolve limitations of funds, assets or schedules; or
- providing insight into issues that were impossible or impracticable to examine in other ways."[36]

He further stated, "Many program managers argue that the entire acquisition system is focused on getting a project into production, through performance trials, and permanently into the military's inventories. Seldom are they given sufficient funds, staff, or time to investigate the potential benefits of tools or technologies such as M&S. Importantly, leadership provides little incentive to capture data, build expensive models, or conduct additional analyses to transfer M&S results to other projects.

Simply put, program managers are under intense pressure to complete their programs on or under budget and within timelines. Existing programs lack enticement to develop new models or simulation tools that may have wider application to other programs, or that will be much cheaper to operate and sustain."[37]

3.1.2.4 Towards Achievement of Economies of Scale and/or Common-Practice

To effectively and efficiently meet its operational and support objectives, DoD has committed to development of robust use of M&S to help meet the full spectrum of its activities. DoD practice needs to evolve beyond the largely program manager centric paradigm that makes up the majority of M&S investment. For best efficiency and effectiveness, DoD should build and sustain close management of acquired M&S infrastructure as assets (not as 'tools', not as 'consumables'.) And with this, these assets (both traditional and digital capital) and their interoperation must be actively managed. Present DoD practice is to manage M&S investment on a project by project basis, as described above, in what some would describe as a 'project-centric' approach to managing a M&S asset portfolio. This approach misses opportunities to take advantage of *economies of scope*, by which is meant generating increased value or cost savings by actively managing a portfolio to intentionally develop groups of assets of similar kind. (Within the Navy, a good example of this is current effort to look at standardization of Anti-Submarine Warfare (ASW) components and systems across ship and aircraft classes –sonar detection equipment, analysis gear, and environmental data collection and processing.) For DoD M&S investment, adopting economies of scope as part of criteria for valuation of investment would drive analysis of opportunity for use of modularity, flexibility, and simulation interface standards as part of investment value calculations.[38] The metrics for assessing economies of scope tend to be macro level, and different from, metrics devised to serve a project culture. The methodology recommended in this report provides means to address and quantify both micro and macro aspects of M&S investment analysis, enabling assessment of candidate projects in terms of contributing to economies of scope.

3.1.2.5 Towards Systematic Consideration of M&S Investment

In commercial business economics, there are various different views (indeed definitions) of "capital", "investment", "consumption", "costs", "benefits", "revenue", "value", "producer", and "vendor", and "customer", and *they are different* in many cases than the views that exist within and across DoD. In the commercial domain, what most enterprises do is choose some set of definitions and meanings for terms in use, and also the metrics, criteria, and computational methods by which investment decisions will be made. Key elements of that practice are defining and understanding the enterprise's suppliers, customers, teaming partners, and sources of revenue. 'Producers' are separate from customers, thus the determination of "costs" and "value" are independent. Essentially, a customer does not care what a producer's costs are; only the value (objectively or qualitatively determined) of the product is of importance, and market pricing mechanisms drive much of the valuation process.

In contrast, for DoD investment, in many cases a) the producer of investment funding is also the consumer for the M&S product, b) market pricing mechanisms do not exist or are too 'thin' to be relied upon, and c) in most cases, there is no 'revenue' derived from an investment – only value which accrues to the Users of DoD's investment.

3.1.2.6 Finding, Recognizing, and Highlighting the Value of M&S Investment

The disconnect from commercial best practice, which has to be addressed by DoD is that in many cases DoD M&S investment cannot be monetized in a manner analogous to commercial business. There is a hard distinction between investments which can be monetized vs. those which cannot. By "monetized" is meant the ability to reduce or translate all elements of value to a number expressible in dollars and cents. A primary difference between DoD "investment" and that of commercial industry is that in many cases the monetization of value elements cannot be achieved in a consistent manner. DoD's characterization of value must often be in qualitative terms, terms which are difficult to compare. This means, essentially, that the decision space in which DoD operates is different than that of commercial industry. Figure 3.1.3.5-1 illustrates this difference.

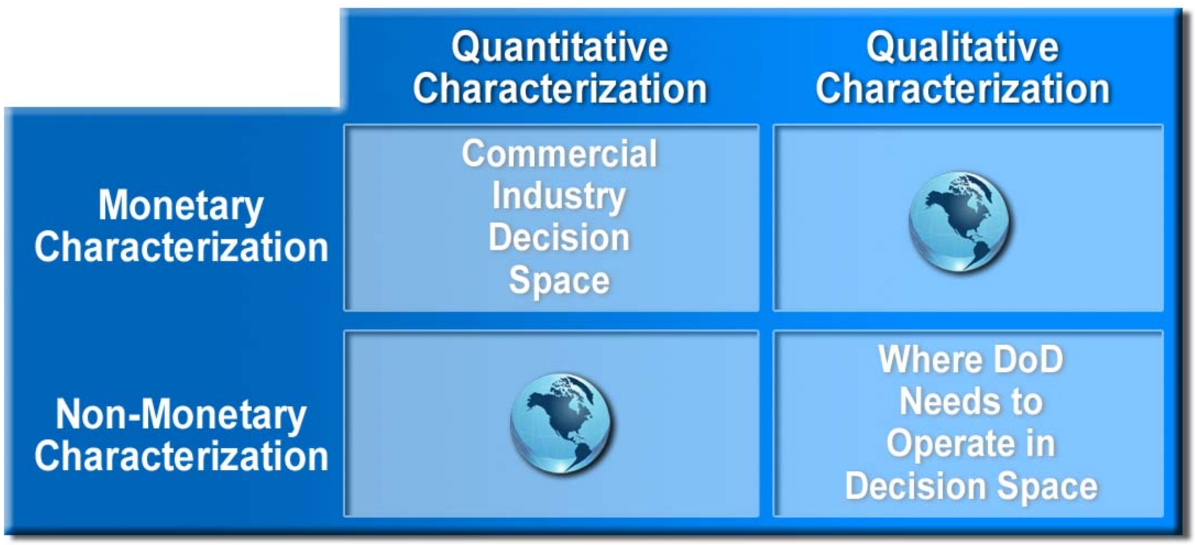

Figure 3.1.3.5-1. DoD Investment Decision Space Options.

The decision spaces in which DoD current practice tends to occur are indicated by the icons, with the square peg and round whole analogy a relevant one for the many instances for which investment decisions must be made without adequate tools for comparison of either cost or value/benefit accruing to the government.

When considering allocation of resources to DoD M&S, the essential elements of value are an important issue. There are costs, of course, and explicitly definable benefits, but more importantly, at the enterprise level, *there are values which must be assigned by leadership* to complete the process of estimating ROI and other measures of value with respect to M&S assets. It is suggested, following from the arguments presented here, that DoD M&S management processes can be served well by adopting the methodology recommended by this report.

3.1.2.7 Investment Measures, Commercial and Government Practices

Typical measures used to assess investment success in commercial industry are discussed in Section 3.9, 'ROI algorithms'. Methods include calculations of Net Present Value (NPV), Internal Rate of Return (IRR), and Yield. The objective of these methods is to produce a value, in dollars, for management assessment and comparison of options, choices, and alternatives. For each of these methods, an enterprise must apply judgment and expertise in estimating a number of metrics values used in the analysis, typically including estimates of discount rates, market risk, tax rates, and sales volumes. Such techniques reduce to manageable proportions the process of making investment decisions. Such normally employed techniques serve industry well, yet it must be recognized that all such investment measures have quantitative errors (bad guesses with respect to interest rate trends, for example), and that in most decision processes, there are non-monetary factors which bias "yes" or "no" decisions in ways not entirely reflected in calculations-based metrics, 'standard' financial equations, or cost estimates. Once made, decision feedback is market driven, in terms of revenue received (or not), or costs reduced (or not) as a result of investment made. These methods, supported by long standing practice, financial accounting rules and standards, and 'common' industry practice, allow all participants in the investment business to arrive at some estimation of discounted Present Value (PV), a term which represents an investment in dollar terms as the current value of an expected future revenue stream, and, similarly, at an estimation of NPV, the present value of an investment's future cash flow less the initial cost of making that investment. When using this analysis approach, the 'yes' or 'no' decision is simple. If NPV of a contemplated investment is positive, the decision should be "yes"; if negative, "no". In simple equation terms,

$$NPV = PV - I$$

Where I = cost of the investment, and both NPV and PV depend on assumptions of future revenue streams and of future interest rates.

Again, to emphasize, a "yes" decision is warranted if NPV > 0.

Unfortunately, DoD investment in M&S does not generate 'revenue' in the sense used in commercial valuations – PV and NPV cannot be calculated. So, some other approach must be used. An approach based on value to the government, as described above, is an essential recommendation of this study.

3.1.2.8 DoD M&S Investment as an Enterprise Activity

What is needed, of course, is an assessment methodology which addresses all of the considerations discussed to this point. Using the concepts of capital as embodied knowledge, digital capital, capital structure and maintenance, and applying methods for comparing alternatives on both quantitative and qualitative bases, an assessment and decision methodology has been developed to serve DoD's interests. It enables and makes explicit comparison of alternatives for each of three basic decision alternatives:

I. Investment A vs. Investment B
II. Investment A vs. "do nothing"
III. Investment A (or B) vs. non M&S Investment

for which both 'A' and 'B' are specific M&S investment candidates, and both I and III can be extended to include more alternatives.

Subsequent sections of this report provide explication and justification for implementation of the methodology, which enables consistent application of metrics, measures, and criteria to decision alternatives of these three categories. Using the methodology enables prioritization of considerations both monetary and non-monetary, and both quantitative and non-qualitative. A significant feature of the methodology is the provision of means (via value estimations and ROI calculations) to justify other than the low cost option among specific M&S investment candidates.

Key to effectiveness of the methodology is an understanding of the conditions underlying the market context and business practice presented above. Appendix H describes in some detail concepts of capital, capital structure, and capital maintenance, and concepts addressing specifically consideration of software as a form of knowledge embodied in code and made available via hardware. Together, these concepts form the underlying framework alluded to in Section 3.1 and 3.1.1 as the theoretical and consistent underpinning of the analysis provided in this report. It is worth emphasizing the relationships among the concepts: **"**Certain conclusions rise on these foundations: If capital is knowledge and knowledge is initially dispersed, then new capital development must be a social learning process in which initially dispersed knowledge gets built into the new capital goods. If complementarity is of the essence, then knowledge of the relevant complementarities, of how to fit a new capital good into the existing capital structure, is an important kind of knowledge that must get built into new capital. As for systemic evolution, because the capital structure is a web of overlapping relationships, introduction of a new capital combination in one area will create entrepreneurial opportunities for changes in other areas. Hence the overall evolution of the capital structure is a co-evolutionary process in which one development leads to another."[39] DoD M&S investment, as presented here, is a process of building new capital in combination with existing assets, one that includes explicitly how both software and hardware fit into the mix of investment made by DoD to extend and expand DoD M&S capability on an enterprise basis.

3.1.2.9 Business Process Re-Engineering

In the beginning of the subject analysis, the study team focused on the details of investment and return-on-investment metrics. Consideration of such metrics is introduced in the text above; and detailed analysis of specification, calculation and employment of such metrics are described in terms of practical investment management decisions educed in text that follows. Further pursuit of the topic made clear that the use of any such metrics needed to be considered in context of an investment process model that could be deployed and used widely across the DoD. Such a context was found to be different in several ways from current practice. On the one hand, recommended investment processes were developed with the intent to bring DoD investment decision practices more nearly into line with commercial investment practices. On the other, the sheer diversity (and generally unsystematic) existing M&S investment process is seen to be in sharp contrast tot eh canonical recommended process developed by the study team and reported in Appendix M. Consequences of the study team analysis and the effective content of recommended practice derived thereby constitute one element of business-process re-engineering for the Department. Such a change in business process is significant for its own sake given the difficulties attendant to changing business practice in any organization, let alone the Department of Defense. Another issue arises, however in consideration of these relatively straightforward recommended changes.[40] In particular, the recommended change in process developed and documented below is likely to require concomitant changes in processes whereby investment decision agents evaluate and report their decision rationale. Use of web-based and service-from-the-cloud computing applications seem likely necessary in order to guarantee that the subject process is implemented correctly and that data relevant to that rationale be made persistently available to the Department for future investment process improvement and effectiveness evaluation.

Use Cases are provided in subsequent sections to illustrate implementation of the concepts and processes described in the paragraphs above.

3.2 Needs and Requirements Analyses

Every technical activity is predicated on stakeholder needs and the consequent technical requirements devolved from those needs. The necessity of explicit requirements to serve as guidance for the completion of the technical effort and to serve as a basis for its satisfactory completion applies to any substantive effort, including analysis, system or software development, test, evaluation, etc. The objective of this study is to produce as its 'resulting product' a process specification sufficient to be used as guidance for M&S decision-making within the contest for the US DoD. Insofar as that process is our product, requirements constraints upon its acceptable attributes are likewise required.

In order to establish *a priori*, such requirements, we have taken the point of view of the process-product user and identified all such attribute desiderata. The result of this analysis is reflected in the tables of Appendix I. These characteristics – compiled without the benefit of a concrete proof-of-principle application of the process, but with a nominative set of seminal use cases and anticipated stakeholders in mind – are intended to cover comprehensively the 'ilities' of the subject process.

Having established this set of requirements, the Team subsequently reviewed the resulting process-product in light of there being evaluation criteria for the results of the study effort. While compliance with practically all these requirements was found to be demonstrable, and while the recommended M&S investment decision process is considered sound to that degree; the Team will nevertheless recommend proof-of-principle trials for the recommended process wherein the technical requirements proposed and others that may be educed hereafter to serve as a basis of re-visiting compliance of the process with the then-extant requirements.

3.3 Stakeholder & Community of Practice Specification

> √ ***Key to determining metrics for M&S ROI is an understanding of the stakeholders and their role-dependent sensitivities***
>
> √ ***Preliminary definition of the categories of stakeholders and their particular perspectives provides a useful two-dimensional slice into the multi-dimensional M&S stakeholder market space***

Understanding the stakeholders and their role-dependent sensitivities within the M&S community of practice is a key step to developing an effective process for determining the metrics for M&S. This section presents and utilizes a description of the M&S *market* to produce a framework for analyzing the stakeholders, and also compares DoD and commercial market terminology. After identifying and characterizing stakeholders, this section then provides examples of important concerns for them, concerns which lead naturally toward the identification of M&S investment metrics and the development of initial sets of use cases with associated stakeholder needs and requirements. The goal of this part of the overall analysis is to provide a consistent and complete set of stakeholder descriptions for use in developing metrics for M&S investments.

The development of stakeholder agent roles continues by defining the *categories* of market shareholders that correspond directly to the market elements. This first characterization is followed by a second defining the *perspectives* of the market stakeholders. These two attributes, selected from many possibilities for characterizing stakeholders, produce a useful two-dimensional slice into the true multi-dimensional space of M&S stakeholders.

After these initial characterizations, the approach presents examples of stakeholders' *offices*, organized by stakeholder perspective. This is followed by examples of stakeholders' *concerns*, organized by stakeholder category. These examples indicate the usefulness of the chosen two-dimensional slice of stakeholder space for characterizing M&S stakeholders.

Finally, a graphical depiction of the two-dimensional slice of the M&S stakeholder space is presented. This serves as an aid in the development of viable use cases later in the analysis.

3.3.1 Stakeholder Characterization in Terms of the M&S Market

DoD stakeholders operate within the context of a broad M&S market. Here, we use the concept of "market" to mean the full economic landscape over which modeling and simulation products and services have impact. Figure 3.3.1-1 illustrates the context within which the DoD stakeholder "community of practice" (COP) operates within the full M&S market.

Figure 3.3.1-1. M&S Stakeholder Context.

The COP consists of stakeholders having seven significant roles, as indicated in Figure 3.3.1-2. These are the consumers/users, the buyers, the sellers, the investors, the approvers/raters, the reviewers, and the promoters/advocates. Each is heavily involved in the M&S market, and each plays a different role. Table 3.3.1-1 provides definitions of these stakeholders.

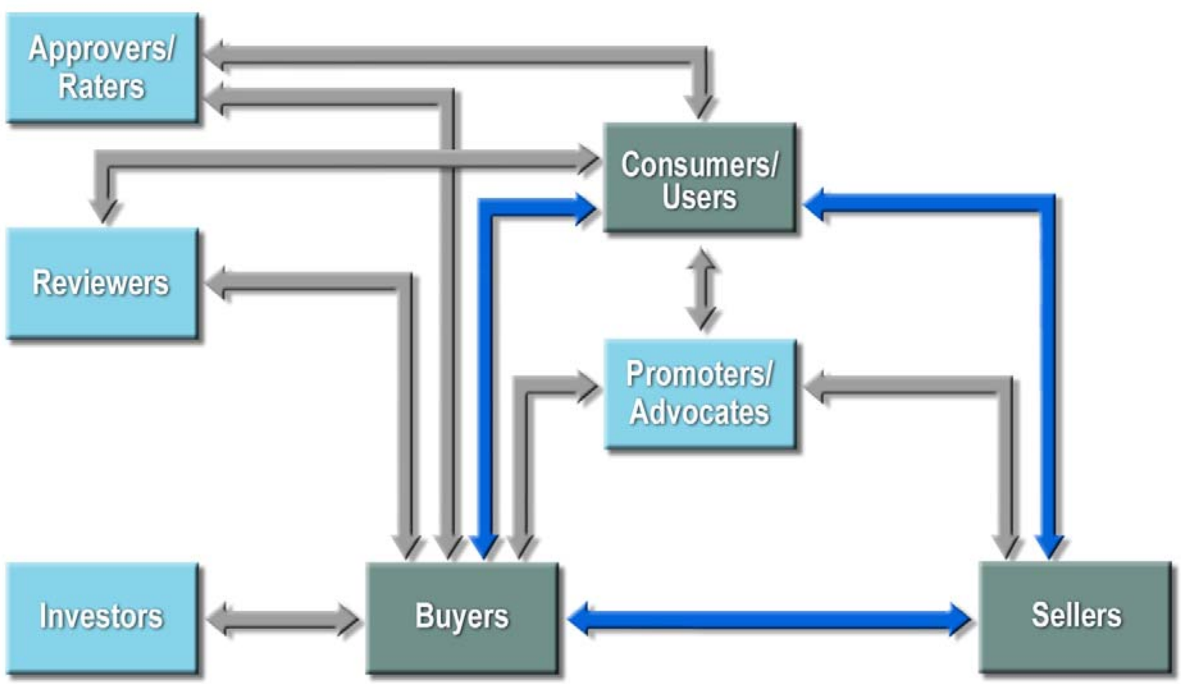

Figure 3.3.1-2. Stakeholder Roles in M&S Market.

Table 3.3.1-1. M&S Stakeholder Role Definitions.

Stakeholder Category / Market Segment	Stakeholder Category Definition
Consumers / Users	End users of M&S-powered analyses, studies, or systems, or of M&S tools, data, or services
Buyers	Expenders of funds for M&S-powered analyses, studies, or systems, or of M&S tools, data, or services
Sellers	Providers of M&S tools, data, or services
Investors	Providers/appropriators/deciders on expenditures of funds for M&S-powered analyses, studies, or systems, or of M&S tools, data, or services
Approvers / Raters	Providers of a "seal of approval" for M&S tools, data, or services
Reviewers	Providers of "advise and consent" on M&S issues including M&S-powered analyses, studies, or systems, or of M&S tools, data, or services
Promoters / Advocates	Independent providers of "encouragement" to the development of the M&S market for M&S-powered analyses, studies, or systems, or of M&S tools, data, or services

A comparison between the terminology used in this analysis to describe roles found in the DoD M&S market and the terminology more commonly employed to describe the commercial world's market roles is provided in Table 3.3.1-2.

Table 3.3.1-2. DoD and Commercial Market Terminology.

DoD	Commercial
Consumers / Users	Consumers
Buyers	Agents
Sellers	Sellers
Investors	Custodians
Approvers / Raters	Raters / Influencers
Reviewers	Reviewers
Promoters / Advocates	Promoters / Advocates

3.3.2 M&S Stakeholder Categories

The seven stakeholder "roles" reflected in Figure 3.3.1-2 and defined in Table 3.3.1-1 are fundamental to this analysis. Each is heavily involved in the M&S market, and each plays a different role. Consequently, the first "cut" (or dimension) for characterizing M&S stakeholders is to define each of these role types as a *category*.

Table 3.3.2-1 provides examples of the specific types of people (or offices and industries) that populate these categories.

Table 3.3.2-1. M&S Stakeholder Category Examples.

Stakeholder Category / Market Segment	Stakeholder Category Examples
Consumers / Users	Individual program level users/specifiers Other federal government Other government Foreign governments Organizations Academia Industries
Buyers	Individual program level program managers/specifiers Other federal government Other government Foreign governments Organizations Academia Industries
Sellers	Individual program level developers providers and developers of enterprise tools/data/services Other federal government Other government Foreign governments Organizations Academia Industries
Investors	Program managers Planners, SC, Integrated Product Team (IPT), M&S CO HASC/SAC members
Approvers / Raters	Accreditation agents Policy managers (senior OSD decision-makers (political appointees, SES), senior OSD staffers (GS-15))
Reviewers	Leaders of M&S-enabled communities
Promoters / Advocates	Service office directors, leaders, champions for Service M&S Individual congressmen and staffers, M&S Caucus

3.3.3. M&S Stakeholder Perspectives

Each of these stakeholder categories comes to the M&S market with a role-dependent perspective. This concept of stakeholder *perspective* for M&S is a second dimension useful in characterizing DoD stakeholders and their needs.

As shown in Table 3.3.3-1, the market involves five different “echelons” or perspectives. These are the program perspective, the community perspective, the enterprise perspective, the federal perspective, and the society perspective. For DoD M&S investment, the lower three perspectives − program, community, enterprise − are considered to be internal to the DoD. The top two perspectives in the hierarchy − federal and society − are considered to be external to the DoD. Stakeholders from each of the five perspectives are heavily involved in the M&S market, and they all play different roles.

Table 3.3.3-1 summarizes these stakeholder perspectives and provides examples of the specific types of people (as categories plus offices and industries) who populate these perspectives.

Table 3.3.3-1. M&S Stakeholder Perspectives.
(perspectives listed from narrowest to broadest)

Perspective	Category	Examples
Program		
	Consumers/Users	Users/specifiers
	Buyers	Program managers/specifiers of M&S investments
	Sellers	Developers
	Investors	Program managers
	Approvers/Raters	Accreditation agents
Community		
	Sellers	Providers and developers of enterprise tools/data/services
	Investors	Planners, SC, IPT, M&S CO
	Approvers/Raters	Policy managers (senior OSD decision-makers (political appointees, SES), senior OSD staffers (GS-15))
	Reviewers	Leaders of M&S-enabled communities (currently: acquisition, analysis, experimentation, planning, testing, training)
	Promoters/ Advocates	Service office directors, leaders, champions for Service M&S
Enterprise		
	Sellers	Providers and developers of enterprise tools/data/services
	Investors	Planners, SC, IPT, M&S CO
	Approvers/Raters	Policy managers (senior OSD decision-makers (political appointees, SES), senior OSD staffers (GS-15))
	Reviewers	Leaders of M&S-enabled communities (currently: acquisition, analysis, experimentation, planning, testing, training)
	Promoters/ Advocates	Service office directors, leaders, champions for Service M&S
Federal		
	Investors	HASC/SAC members
	Promoters/ Advocates	Individual congressmen and staffers, M&S Caucus
	Buyers	Other Federal agencies (NASA, DOE, DHS, …)
	Sellers	Other Federal agencies NASA, DOE, DHS, …)
Society		
	Consumers/Users	Other government (state, local, regional), foreign governments, organizations (Simulation Interoperability Standards Organization (SISO), SimSummit, SCSI, IEEE), academia, industries (medicine, manufacturing, …)
	Buyers	Other government (state, local, regional), foreign governments, organizations (SISO, SimSummit, SCSI, IEEE), academia, industries (medicine, manufacturing, …)
	Sellers	Other government (state, local, regional), foreign governments, organizations (SISO, SimSummit, SCSI, IEEE), academia, industries (medicine, manufacturing, …)

There is a correlation between stakeholders' perspectives and the "timelines" of stakeholders' decision/return processes (including the time to wait to evaluate results). For example, Program perspective stakeholders tend to have shorter timelines, often measured in months. Community and Enterprise perspective stakeholders tend to operate along longer timelines, often measured in years. Stakeholders having either Federal or Society perspectives also tend to have longer timelines, depending on the types of issues involved with their M&S-related programs.

Most of the subsequent analyses in this report involve the Program, Community, and Enterprise perspectives as these are the perspectives most immediately involved with metrics for M&S investments.

We note that, at some fundamental level, all of these perspectives deal with "enterprises", as even the program manager for a single program usually has multiple efforts underway supporting the program and these need to be managed as an enterprise.

3.3.4 Stakeholder Offices

In analyzing the roles and interests of stakeholders, it is also useful to characterize M&S investment stakeholders (people) in terms of the offices they hold. Stakeholders, of whatever category and perspective, execute their duties from within assigned billets or job codes. The mission, vision, and objectives of these individual offices will effect the execution of M&S investment strategy by the assigned stakeholders. In Table 3.3.4-1, stakeholders (arranged by perspective) are shown to be involved in a wide variety of offices. Specific examples are provided in the table for the three DoD-internal perspectives (program, community, enterprise); more general ones are provided for the two DoD-external perspectives (federal and society).

Table 3.3.4-1. M&S Stakeholder Offices – by Perspectives.

Stakeholder Perspective	Office Types	Office Examples
Program		
	ACAT 1 programs	FCS, JSF, DD-21, …
	Specific simulation programs (tools, data, services)	JAS, …
Community		
	M&S-enabled Communities	Analysis – PA&E, Joint Staff Acquisition – AT&L / AMSWG Experimentation – JFCOM Planning – Joint Staff, Policy Testing – DOT&E, AT&L Training – P&R
Enterprise		
	OSD	OSD AT&L/DDR&E, PA&E, P&R, OT&E, TRMC, …
	COCOMS	JFCOM
	Service M&S Management	AMSO, AFAMS, NMSO, MCMSMO
	DoD Agencies	DARPA
	DoD M&S Management	M&S Planners, M&S SC, M&S IPT, M&S CO
	Non-Profits, FFRDCs	IDA, CAN, MITRE, RAND
Federal		
	Congress	HASC/SAC, M&S Caucus, Congressional Staffers
	Federal Agencies	NASA, DOE, DHS, …

Table 3.3.4-1. M&S Stakeholder Offices – by Perspectives.

Stakeholder Perspective	Office Types	Office Examples
Society	State, local, regional governments	Other government (state, local, regional), foreign governments, organizations (SISO, SimSummit, SCSI, IEEE), academia, industries (medicine, manufacturing, …)
	Foreign governments	Other government (state, local, regional), foreign governments, organizations (SISO, SimSummit, SCSI, IEEE), academia, industries (medicine, manufacturing, …)
	Sellers	Other government (state, local, regional), foreign governments, organizations (SISO, SimSummit, SCSI, IEEE), academia, industries (medicine, manufacturing, …)

3.3.5 Stakeholder Concerns

This subsection continues the analysis of stakeholders for M&S investment metrics by presenting examples of stakeholder concerns. These concerns, presented in Table 3.3.5-1, are segregated by stakeholder category (consumer, buyer, etc.) to provide some comparability with the concerns of stakeholders in more commercial markets.

Table 3.3.5-1. M&S Stakeholder Concerns.

Stakeholder Category	Selected Concerns
Consumers / Users	Effectiveness, availability, validity, usability, maintainability, applicability, re-usability, interoperability
Buyers	Cost, risk, schedule, ability to meet user requirements, defendability
Sellers	Sales cost, production/development cost, schedule, risk, re-usability, protectibility of intellectual property
Funders	Cost-effectiveness, utility, defendability
Approvers / Raters	Cost-effectiveness, utility, interoperability, alternatives
Reviewers	Cost-effectiveness, alternatives, utility
Promoters / Advocates	Effectiveness, cost, utility, ROI

Stakeholders' concerns can also be analyzed from the view of the stakeholders' perspectives. Concentrating on the three DoD-internal perspectives, Program, Community, and Enterprise:

- Enterprise stakeholders' concerns focus on M&S capabilities that apply across diverse activities of the services, combatant commands, and DoD agencies. Consequently the enterprise stakeholders' concerns are broad and encompassing. They include standards, policies, management, tools, and people. Other concerns are collaboration, interactiveness, and sharing of assets in a defense-wide manner.
- Community stakeholders' concerns focus on managing M&S within specific areas such as acquisition, analysis, planning, testing, training, and experimentation, and are oriented towards indicators of success or failure.
- Program stakeholders' concerns focus on applicability, availability, and affordability; credibility, analytic soundness, user friendliness, and entertainment ability; and modularity, interoperability, and portability.

Details of stakeholders' concerns by perspective are provided in section 3.5.

Many of the concerns are common across the stakeholder categories. Cost, cost-effectiveness, risk, and utility occur in multiple places. Similarly, the "ilities" are major concerns for many stakeholders. These concerns lead naturally toward the identification of relevant M&S investment metrics later in the analysis.

3.3.6 The M&S Stakeholder Space

With the presentation of DoD stakeholders by category, perspective, and concern, we are ready to offer a summarization of the characterization of M&S stakeholders. The objective of the analysis was to identify a consistent way for the DoD to understand the roles and impacts of stakeholders on the assessment and evaluation of specific M&S investments. Of importance to the study was identifying which stakeholders should participate in consideration of investment, and which should, by process, perhaps not be involved. Approaching this by framing M&S investment consideration in terms of the two dimensions of *category* and *perspective*, as presented above, was found to be most promising. Table 3.3.6-1 summarizes the two-dimensional slice of the full, multi-dimensional stakeholder space that appears to provide the most insight and understanding, and Figure 3.3.6-1 presents the slice graphically. This figure will be utilized repeatedly for use case development to describe and indicate the different types of stakeholders involved in evaluation of candidate M&S investment projects.

Table 3.3.6-1. M&S Stakeholder Categories and Perspectives.

Stakeholder Category	Stakeholder Perspective
Consumers / Users	Program
Buyers	Community
Sellers	Enterprise
Investors	Federal
Approvers / Raters	Society
Reviewers	Society
Promoters / Advocates	Society

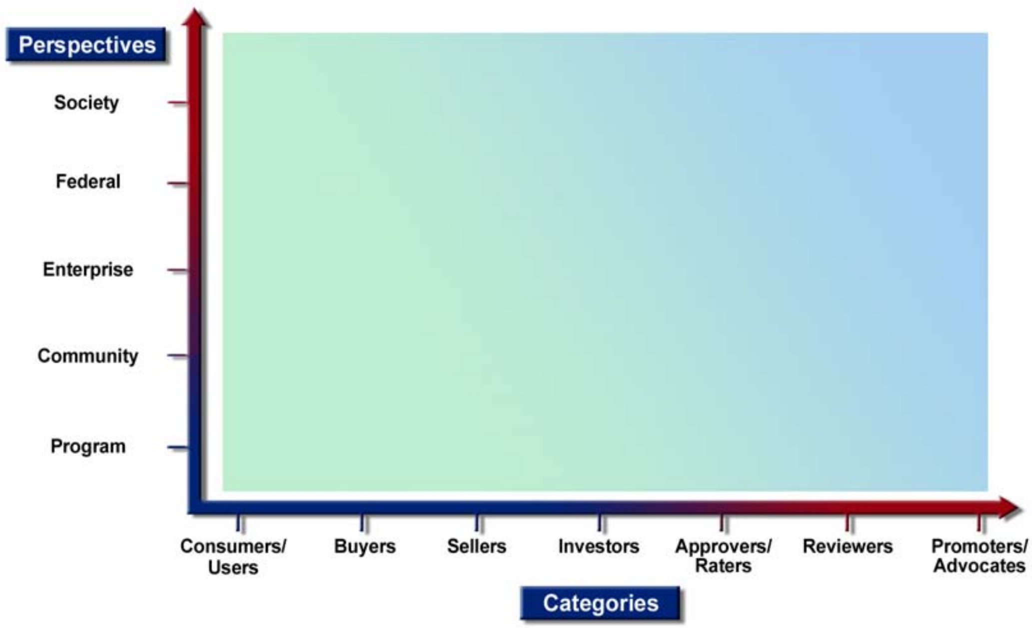

Figure 3.3.6-1. A Two-Dimensional M&S Stakeholder Space.

- √ ***Two important dimensions of M&S Stakeholder characterization are categories and perspectives.***
- √ ***Categories correspond to the element of the M&S market.***
- √ ***Perspectives correspond to the echelons of the stakeholders.***

3.3.7 Summary

A framework for the analysis of M&S stakeholders was developed and differences among the stakeholders' roles described. This characterization of stakeholders can be applied to support and guide viable use case development and analysis.

The characterization of M&S stakeholders as summarized in Figure 3.3.6-1 and the presentation of stakeholder concerns in Table 3.3.5-1 together provide a consistent method for determining which stakeholders should be considered for specific candidate M&S investment assessments. The two important dimensions are *categories* and *perspectives.* The categories correspond to the elements of the M&S market. The perspectives correspond to the echelons of the stakeholders.

Although this description of the M&S market and its elements could differ from that developed or to be developed by other analysts, and these characterizations of the M&S stakeholders could also differ from those envisioned by other analysts, the ultimate "proof of principle" in this stakeholder analysis is supporting the development of viable use cases.

3.4 Use Case

Developing and understanding use cases including stakeholder needs and requirements is an important step in determining, refining, and evaluating the process for investment metrics for M&S. For example, use cases illustrate stakeholder issues and role-dependent sensitivities together with investment decision processes. Use cases also serve to support and guide the definition, explanation, and evaluation of process and metric alternatives.

This section provides a framework that encompasses a consistent and complete set of use case descriptions for use in the analysis of M&S investment metrics. The framework will be used to produce specific use case examples for evaluating and tuning recommended practices in decisions.

The approach presented for developing this framework starts by reviewing the corresponding framework for M&S stakeholders (presented previously) derived from the description for the M&S market. The review includes stakeholder characterization (categories and perspectives), stakeholder concerns, and the description of the stakeholder space.

The framework is defined by seven parameters - *what/where*, *who*, *why*, *when*, *how*, *so what*, and *data support*. The development continues with detailed discussions of the *what/where*, *why*, *when*, and *data support* parameters; discussions of the others are presented elsewhere in this report. The framework is also depicted graphically as a "use case space."

The section concludes with the presentation of a five-step method for developing "useful" use cases together with a generic example describing several use cases for M&S investment metrics involving testing. These examples indicate the breadth of demands and opportunities for utilizing this project's efforts.

- √ ***Developing and understanding Use Cases is an important step in determining, refining, and evaluating M&S investment metrics.***
- √ ***Use Cases illustrate stakeholder issues and role-dependent sensitivities in context of investment decision processes.***

3.4.1 Introduction

The development of the use case framework is based on the stakeholder analysis summarized in Table 3.3.6-1 above. The graphical version of this (Figure 3.3.6-1) serves later to clarify some of the issues involved in use cases.

3.4.2 Use Case Structure

The key concept for this section is that of the use case framework for M&S investment metrics. This is a top-level characterization of use cases and indicates the fundamental issues for their development. As shown in Table 3.4.2-1, the analysis examines seven separate parameters. These are the classic *what/where*, *who*, *why*, *when*, *how*, and *so what* combined with a parameter concerning *data support* and availability. Selected values for these seven parameters are provided in the Table.

Table 3.4.2-1. M&S Use Case Framework.

Parameter	Selected Values
What/Where	Investment situation, investment goal, investment timeline, asset types, asset numbers, other asset information, geographical constraints, …
Who	Stakeholder market category, stakeholder perspective, stakeholder office, …
Why	Concerns, issues, forcers, drivers, constraints …
When	Near-term investments, mid-term investments, long-term investments, schedule constraints
How	Costs (near term, mid term, long term)
So What	Result, benefit, utility, cost savings
Data Support	Sources, pedigree, availability, timeliness …

These parameters underlie the entire development of use cases. The *who* parameter has been discussed extensively in the stakeholder section. The *how* and *so what* parameters are discussed in separate sections of this report concerned with delineating costs and results, respectively. The *what, where*, *why*, *when*, and *data support* parameters are detailed below.

3.4.3 Use Case Parameter What/Where

This "dual" parameter provides basic information concerning the use case situation. For example, this parameter details the situation, goal, and timeline involved with the investment. It also describes the assets involved including their types, numbers, and any other clarifying information. In addition the parameter describes geographical constraints involved with the situation.

3.4.4 Use Case Parameter Why

This parameter provides details about the concerns, issues, forcers, drivers, and constraints involved with the situation. The concerns are those for M&S stakeholders previously described in the stakeholder analysis section and displayed in Table 3.4.4-1 segregated by stakeholder category (consumer, buyer, etc.). (Also see section 3.5.4.) Many of these concerns are common to several stakeholder categories. For example, cost, cost-effectiveness, risk, and utility occur in multiple places and the "ilities" are major concerns for many stakeholders.

Table 3.4.4-1. M&S Use Case Stakeholder Concerns.

Stakeholder Category	Selected Concerns
Consumers / Users	Cost, effectiveness, availability, validity, usability, maintainability, applicability, re-usability, interoperability
Buyers	Cost, risk, schedule, ability to meet user requirements, defendability
Sellers	Sales cost, production/development cost, schedule, risk, re-usability, protectibility of intellectual property
Funders	Cost-effectiveness, utility, defendability
Approvers / Raters	Cost-effectiveness, utility, interoperability, alternatives
Reviewers	Cost-effectiveness, alternatives, utility
Promoters / Advocates	Effectiveness, cost, utility, ROI

This parameter also provides information on *forcers* (external influences that mandate or accelerate certain decisions), *drivers* (important considerations that have large effects on the results of decisions), and *constraints* (external considerations that restrict and bound choices).

3.4.5 Use Case Parameter When

This parameter provides information on the timelines associated with the use case investment. The common values for this parameter are “near term”, “mid term”, and “long term”. This parameter also describes any schedule constraints pertaining to the investment. As noted before, stakeholders’ timelines are correlated with the stakeholders’ perspectives, with enterprise perspective stakeholders usually having longer timelines than those of program perspective stakeholders.

3.4.6 Use Case Parameter Data Support

This parameter provides additional information clarifying data issues involving metrics for the use case. Important attributes include the sources for metric data, the pedigree (including Verification, Validation and Accreditation (VV&A) status) of this data, the availability of data, and the timeliness with which the data can be collected.

3.4.7 M&S Use Case Space

This subsection summarizes the framework of use cases for M&S investment metrics. The parameters presented above (Table 3.4.2-1) form the seven dimensions of our M&S use case space. Since there are many other possible parameters for use cases, this space should be considered as a seven-dimensional slice of an even more highly-dimensioned full use case space.

This use case space is represented graphically in Figure 3.4.7-1 below. This figure will be utilized repeatedly in the use case analysis to describe and indicate the different types of parameters that need to be considered in use case development.

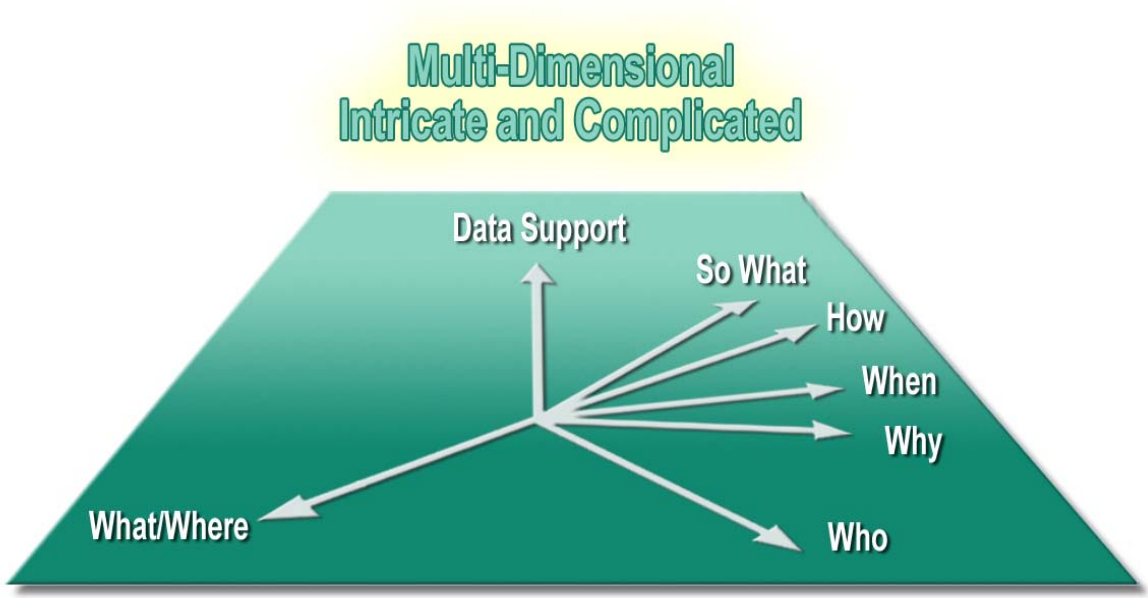

Figure 3.4.7-1. The M&S Use Case Space.

3.4.8 "Useful" Use Case Development

This section provides suggestions on an approach for developing use cases that can be applied practically and beneficially to the process of determining, refining, and evaluating metrics for M&S investment.

The steps for this approach are summarized graphically in Figure 3.4.8-1.

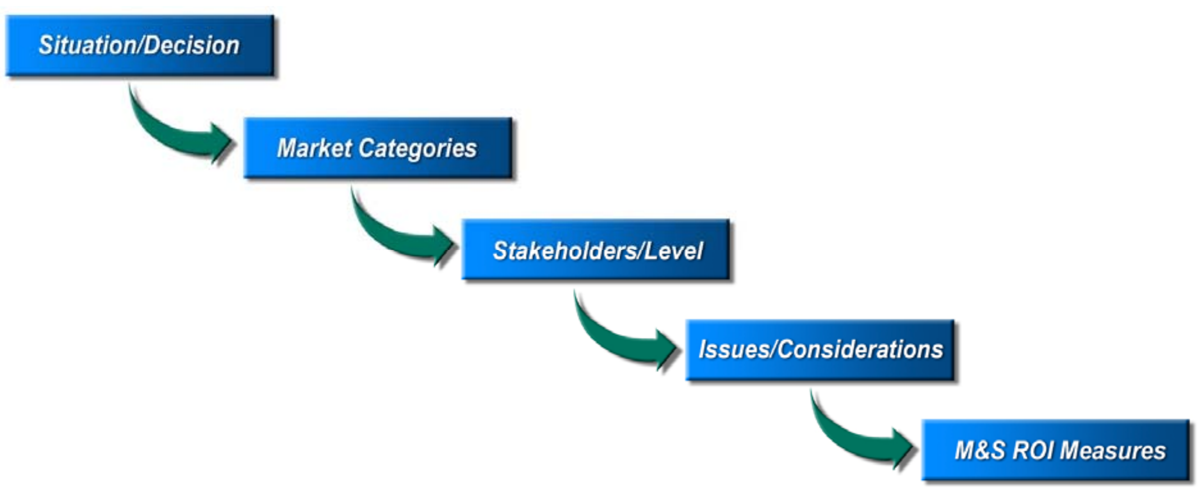

Figure 3.4.8-1. "Useful" Use Case Development.

Step 1 postulates a generic situation/decision involving an investment in M&S. This "sets the stage" for developing the parameters in the use case framework.

The next three steps specify as much as possible about realistic parameters in the above framework, namely the *what/where*, *who*, *why*, *when*, *how*, and *so what*. This includes:

- Step 2: determining the primary M&S market *categories* involved with the situation/decision (these should be restricted to the primary categories since many might be involved),
- Step 3: identifying the specific (generic) stakeholders in the primary market *categories* and their *perspectives* (placing them in the stakeholder space) for the situation/decision, and
- Step 4: delineating the generic issues or concerns of these stakeholders for the situation/decision.

Step 5 specifies the types of M&S investment metrics that are available and applicable for the situation/decision, and elucidates the *data support* issues involved with these metrics. For example, if the data needed for an investment metric is very difficult, expensive, or time consuming to develop for the postulated situation/decision, then that metric is not useful and should be discarded for another (for that situation/decision).

3.4.9 Example "Useful" Use Case Development

This final subsection provides an example of developing a "useful" use case.
Step 1: The generic situation/decision involves the possibility of enhancing test ranges with the adoption of new or improved M&S toolsets. Some possibilities for investment include:

- New standards for interfaces between M&S on distributed ranges
- New tools for testing autonomous systems
- Additional V&V on tools

Step 2: The primary market categories for this use case include:

- User category (program manager located at a test range)
- Investor category (manager located at a DoD testing office)

Step 3: The stakeholder perspectives for this use case include:

- Program perspective (program manager located at a test range)
- Community perspective (manager located at a DoD testing office)

Step 4a: Specific issues for the program manager located at a test range include:

- Effectiveness, availability, validity, usability, maintainability, re-usability, interoperability
- Cost, risk, schedule, ability to meet user requirements, defendability

Step 4b: Specific issues for the manager located at a DoD testing office include:

- Effectiveness, availability, validity, usability, maintainability, applicability, re-usability, interoperability
- Cost, risk, schedule, ability to meet user requirements, defendability
- Cost-effectiveness, utility, interoperability, alternatives

Step 5: The M&S investment metrics are selected from those presented elsewhere in this report and data support issues are investigated as appropriate.

For this example, the placements of the stakeholders in the stakeholder space are shown in Figure 3.4.9-1. Appendix J provides three examples of application of the Use Case framework and process described above. The examples were chosen to illustrate use of the process in addressing three different kinds of candidate M&S investment. Each should be reviewed while keeping in mind the Use Case development process presented here.

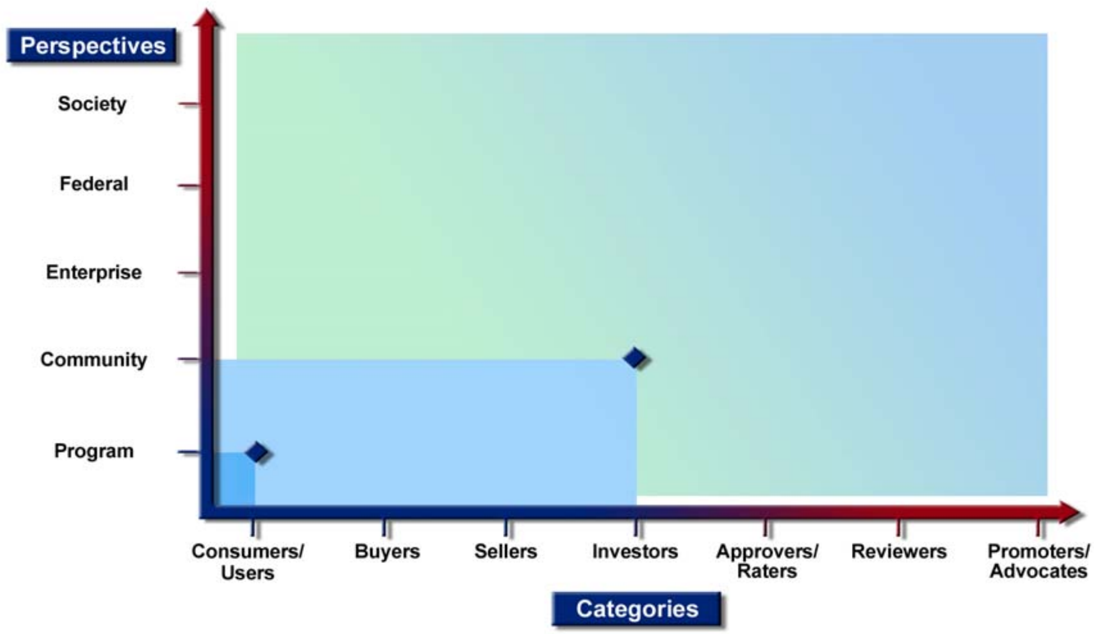

Figure 3.4.9-1. Example Stakeholders.

3.4.10 Summary

There are many possible use cases for testing the development of M&S investment metrics. This section has presented a framework for describing use cases together with a method for developing viable use cases applicable to testing M&S investment metrics. The issues involved with the stakeholders for M&S investment metrics are complex, but can be structured to support the analysis.

3.5 Asset Identification

3.5.1 Introduction and Background

> √ ***Fully understanding the concept of ROI for DoD M&S requires differentiating between investments and consumables and categorizing the assets in which the DoD invests.***
>
> √ ***Delineating the types of assets under consideration enables the development of metrics needed to calculate ROI and an investment decision process.***

To fully understand the concept of ROI for DoD M&S investments, we have to know what kinds of things the DoD buys in the M&S space. This requires differentiating between investments and consumables and then breaking out the things in which the DoD invests (which we will define as assets) into categories and sub-categories. Furthermore, it is useful to view this list of types of assets from the standpoint of the DoD M&S Vision statement, as well as through the eyes of the M&S "communities" as listed in the DoD M&S Management Structure diagram. It is important to delineate the types of assets under consideration, as it enables development of metrics needed to calculate ROI and a process to determine which M&S investments are the most advantageous to the DoD.

3.5.2 Current Circumstance and Context

In accounting terms, an asset is defined to be

"something that has future economic benefit and is available to be converted into cash if necessary (or is cash) to meet liabilities."

From a more general business sense an asset can be defined as:

"Something of monetary value that is owned by a firm or an individual. Assets are listed on a firm's balance sheet and include tangible items such as inventories, equipment, and real estate as well as intangible items such as property rights or goodwill." [41]

From a DoD perspective the first part of the second definition is clearly applicable; however, the concept of *future economic benefit* is also important for distinguishing an asset from a consumable item. For our purposes we define an asset as

"Something of monetary value, owned by DoD, that has future benefit."

'Future' in this sense is typically thought of as more than 12 months from the current time. Examples of DoD M&S assets include: F-16 simulators, the Distributed Mission Operations Center at Kirtland AFB, the Battlestation 21 simulator at Great Lakes Naval Station (to include the building), and the video game, 'America's Army.'

A consumable, on the other hand, is defined differently - from the dictionary: 'Capable of being consumed; that may be destroyed, dissipated, wasted, or spent.'[42] Accountants view consumables as those items that will be used up or depleted within a 12 month time period. For the purposes of this report both of these views are appropriate. Examples of DoD consumables are: paper, pencils, jet fuel, ink for printers, and removable computer disks.

3.5.3 Approach

Our approach to identifying assets was to look at the DoD M&S Vision Statement and the DoD communities (Acquisition, Analysis, Planning, Training, Experimentation, and Testing) defined as the vertical "surfboards" in Figure 3.5.3-1, and then to list every known type of item that each area/organization might procure. After compiling this list a literature search revealed nothing that was not on the list.

Once the types of assets were agreed upon, we felt that categorizing, sub-categorizing, and cross-referencing the assets to the DoD M&S Vision Statement and the DoD Communities might reveal some interesting relationships. We categorized the assets using the five categories from the DoD M&S Vision Statement (Infrastructure, Policies, Management, Tools, and People), which we refer to as the "Enterprise" view, and also categorized them by DoD M&S Community. Additionally, to gain further insight, we broke each view down into smaller sub-categories and mapped assets to each of these. With the DoD M&S community view we chose to look at subcategories from a mission standpoint and also from an organizational standpoint, realizing that each view yields slightly different subcategories and mappings.

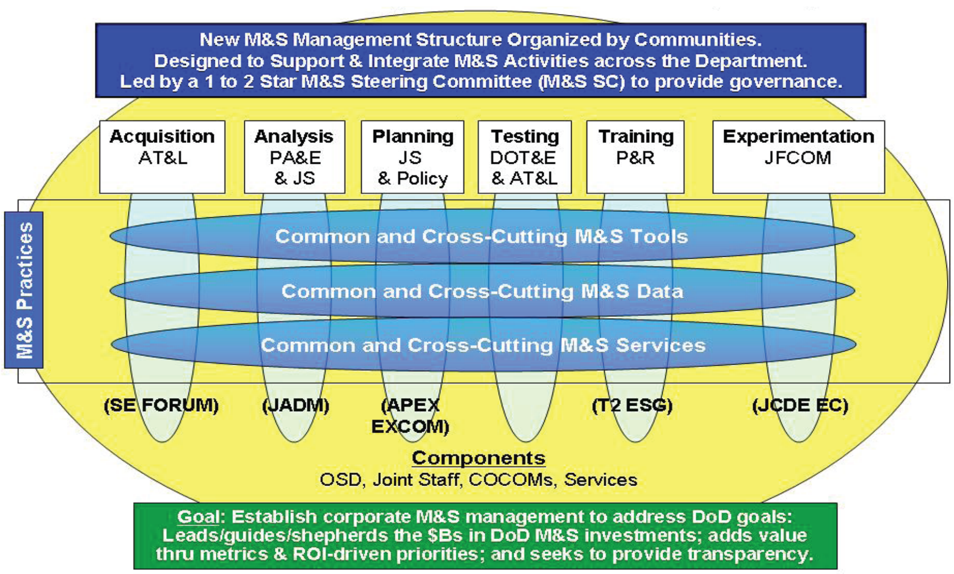

Figure 3.5.3-1. DoD M&S Vision. Management Structure.

Using this approach, a DoD M&S Assets Listing was developed. Table 3.5.3-1 lists the 27 types of assets identified.

Table 3.5.3-1. Assets Listing.

Hardware	Software	Networks	Facilities	People	Products & Procedures
Computers	Models	Lines	Buildings	Expertise	Plan
Electronic HW	Simulation	Architecture	Labs	Experience	Policies
Hardware in the Loop	Tools (CAD/CAM)	Transaction Protocols	Ranges	Skills / Education	Analysis Results
Mock-ups	Data / Databases		Physical Models	Operational Knowledge	Conceptual Models
Spares	Repositories				Management Processes
					Standards

To ensure understanding of intent and the goals of DoD M&S governance, each of these types was mapped to a DoD enterprise view. By convention, as a basis for studying DoD assets and the structure of those assets, we started with the categories identified by the DoD M&S Vision. The five categories are shown in Table 3.5.3-2, with each column listing elements of governance that are espoused within the Vision document.

Table 3.5.3-2. DoD M&S Vision Statement Governance Elements.

Infrastructure	Policies	Management	Tools	People
Accessible and Applicable	Interoperability	Discover and Share	Adaptable	Innovative
Architectures / Networks	Multi-Agency Coordination	Facilitate, Motivate, Incentivize	Comprehensive	Users
Environments (data sets)	Non-Proprietary Solutions	Provides Guidelines (VV&A)	Credible	Well Trained
Foster and Promote	Research and Development (R&D)		Timely	
Promote Standards / Common Formats	Reuse		Transparent	

Further decomposition of these five categories was found to be necessary for detailed study of M&S investment criteria, measures, and metrics. This was necessary to relate the goals and objectives of the Department to specific methods for analyzing M&S investment on a consistent basis across the DoD Enterprise.

Table 3.5.3-3 maps the assets listing of Table 3.5.3-1 against the governance elements of Table 3.5.3-2., to illustrate the relationship between the types of assets and the DoD enterprise view categories. This serves as a first cut at determining the types and kinds of assets which should be subject to Enterprise-wide M&S investment criteria. Assets are listed as the rows and governance elements as the columns. An “X” in a box has two interpretations: 1) that the asset on the row would be of interest as an investment to the governance element in the column, and 2) that there is a link between the element and the asset. For example, there is an “X” in the box at the intersection of the asset ‘Data’ and the governance element ‘Reuse’ within the Policies column. This indicates that data developed as part of an M&S investment should be subject to the DoD policy addressing reuse, which serves the goal of minimizing duplication of data and databases. In practice, this means that policies promoting reuse of M&S capabilities should require assessment of potential data reuse when investing in data for a specific DoD model (for example, the data that goes into an F-16 capability model). By doing so, DoD would encourage reuse of F-16 simulation data in other applications. A blank within the table indicates a weak correlation, and insufficient linkage to justify invoking Department investment criteria when considering M&S investment. As example, there is no “X” at the intersection of the ‘Simulators’ asset and the ‘Discovery and Sharing’ column under Management, as effort to identify new M&S techniques, tools, or processes to share across the DoD enterprise are not likely to use simulators as part of such effor**t.**

Table 3.5.3-3. Maps of Types of M&S Assets to DoD M&S Vision Statement Sub-Categories.

		Infrastructure					Policies					Mgmt		Tools						People		
		Accessible and Applicable	Architectures / Networks	Environments (data sets)	Fosters and Promotes	Standards / Common Formats	Interoperability	Multi-Agency Coordination	Non-Proprietary Solutions	R&D	Reuse	Discover and Share	Facilitate, Motivate, Incentivize	Provides Guidelines (VV&A)	Adaptable	Credible	Comprehensive	Timely	Transparent	Innovative	Well-Trained	Users
Hardware	Computers		X	X		X	X	X		X	X											
	Electronic Hardware		X	X			X	X			X											
	Hardware in the Loop					X	X		X	X	X				X						X	X
	Mock-ups		X	X			X		X	X	X		X		X							
	Spares		X						X	X					X	X	X	X				
Software	Data / Databases			X		X				X	X											
	Models	X		X						X	X				X	X	X	X	X			
	Repositories	X			X	X	X	X		X	X	X									X	X
	Simulation	X								X		X			X	X	X	X	X			
	Tools (CAD/CAM)	X				X	X		X		X				X	X	X	X	X			
Networks	Architecture		X	X		X	X	X			X											
	Lines		X	X		X	X	X		X	X											
	Transaction Protocols		X	X		X	X	X		X	X											
Facilities	Buildings		X	X							X											
	Labs		X	X	X					X		X	X									
	Ranges		X					X		X		X			X		X				X	X
	Physical Models	X							X	X						X		X	X			

Table 3.5.3-3. Maps of Types of M&S Assets to DoD M&S Vision Statement Sub-Categories.

		Infrastructure					Policies					Mgmt		Tools						People		
		Accessible and Applicable	Architectures / Networks	Environments (data sets)	Fosters and Promotes	Standards / Common Formats	Interoperability	Multi-Agency Coordination	Non-Proprietary Solutions	R&D	Reuse	Discover and Share	Facilitate, Motivate, Incentivize	Provides Guidelines (VV&A)	Adaptable	Credible	Comprehensive	Timely	Transparent	Innovative	Well-Trained	Users
People	Expertise									X				X						X	X	X
	Experience									X										X	X	X
	Skills / Education									X				X						X	X	X
	Operational Knowledge									X											X	X
Products and Procedures	Plans		X	X		X	X	X								X		X				
	Policies	X			X		X	X	X	X	X		X	X	X		X	X		X		
	Analysis Results	X								X	X	X	X	X		X	X	X	X		X	X
	Conceptual Models									X			X	X	X				X			
	Mgmt Processes	X			X	X	X			X	X	X	X	X	X		X	X		X		X
	Standards	X	X	X	X	X	X	X	X	X	X			X			X	X				

While Table 3.5.3-3 relates DoD's M&S assets to the objectives and goals of DoD's governance of M&S, there is further need to explicitly relate those assets to the community structure by which DoD manages and directs M&S activities. DoD execution of M&S policies is conducted largely through the individual communities, with enterprise level coordination managed via the M&S Steering Committee (MSSC), supported by the M&S Coordination Office (M&S CO). To effectively address and make decisions with respect to M&S investment, both the MSSC and M&S CO need visibility into the interrelationships among policies, DoD's asset base, and organizational (community) responsibilities.

To provide such visibility, Tables 3.5.3-4 and 3.5.3-5 provide illustration of community management responsibilities from two viewpoints – an organizational view, and a functional view – organized by DoD's M&S Community as listed in Figure 3.5.3-2. The first viewpoint, shown in Table 3.5.3-4, illustrates each Community's responsibilities, as listed in the mission statements of each organization [Acquisition – Undersecretary of Defense (Acquisition, Technology and Logistics); Analysis – Director, Program Analysis & Evaluation; Planning – Undersecretary of Defense (Policy); Testing – Director, Operational Test & Evaluation; Training – Undersecretary of Defense (Personnel & Readiness); Experimentation – Joint Forces Command (J9), Joint Concept Development and Experimentation Directorate].

Table 3.5.3-4. Organizational View - DoD M&S Communities.

Acquisition	Analysis	Planning	Testing	Training	Experimentation
Developmental Test and Evaluation	Program Analysis	Develop Defense Policy	Develop OT&E Policy and Procedures	Total Force Management	Experimentation
Installation/Energy Management	Program Evaluation	Integrate/Oversee DoD Policy	Review/Analyze OT&E Reports	Readiness and Training	Concept Development
Business Management Modernization	Program Analysis of Alternatives	Integrate/Oversee DoD Planning	Provide Financial Recommendations for OT&E		Deliver Capabilities
Nuclear, Chemical, and Bio Defense			Ensure Adequacy of OT&E for Operational Effectiveness		Synchronize Concept Development and Experimentation Efforts
Acquisition					
Logistics					
Research and Development					
Technology					

The second viewpoint, Table 3.5.3-5 lists the functions for which each Community is responsible at a high level. The listed functions are represented regardless of where individual functions might fall organizationally.

Table 3.5.3-5. Functional View - DoD M&S Communities.

Acquisition	Analysis	Planning	Testing	Training	Experimentation
Basic and Advance Research	Requirements	Current Situation Representation	Contractor	Basic – Skills (School House)	Discovery
Concept Exploration and Definition	Force Structure	Course of Action (COAs) Comparisons	Developmental	Basic – Skills (On the Job)	Technology
Advanced Development and Engineering Design	Manpower	Rehearsals and What-If Analyses	Operational	Intermediate – Platform or System	Doctrine
Development and Integration	Training	Results Prediction of Ongoing Activities	Acceptance	Advanced – Multi-Platform	Employment
Demonstration and Evaluation	Logistics and Sustainment	COA Correction Impacts		Joint – Multi-Service	
Procurement, Production, Deployment	Infrastructure			Coalition / Multinational	
Operations, Maintenance, and Support	Readiness				
Retirement and Remediation					

Study of Tables 3.5.3-3 through 3.5.3-5 will show a reasonably clear decomposition of DoD organizational relationships and functions with respect to M&S investment, and a high level mapping of DoD's M&S assets against the elements of governance for which DoD has responsibility. However, to provide a structure and methodology by which to evaluate and assess individual candidate M&S investment, the relationships among M&S assets, Community responsibilities, and elements of M&S governance needs to be explicit to foster and make effective Department wide consideration of M&S investment and its potential return of value to the DoD.

To bring out these relationships, the Study Team developed the following tables to relate types and kinds of M&S assets to the Community-based management structure adopted by DoD, as illustrated in Figure 3.5.3-2 above. Table 3.5.3-6 takes the organizational responsibilities of each Community, as listed under the column headings of Table 3.5.3-4, and maps them to the Assets Listing from Tables 3.5.3-1 and 3.5.3-3, over which DoD has responsibility. Similarly, Tables 3.5.3-7a and 3.5.3-7b map, for each of DoD's six Communities, the functional responsibilities of Table 3.5.3-5 to the same Assets Listing.

Interpretation of these tables is straight forward. Tables 3.5.3-6 and 3.5.3-7 represent a mapping of each Community's responsibility for management of DoD's M&S assets, based DoD's stated governance principles and management structure. Within both tables, an "X" represents a potentially significant correlation between asset management and organizational and/or functional responsibility, and indicates need for the responsible Community to consider the interests of each community having correlation to the asset. With respect to M&S investment decisions, the implication is that, for assets subject to DoD M&S investment ROI assessment, each Community having an asset correlation should be part of investment ROI analysis. Using the F-16 simulator example mentioned above, Training community consideration, under its Readiness and Training, and Intermediate-Platform/System responsibility, of investment in a new simulator asset would imply need for input from, and valuation of that investment by, each of the Community's for which a correlation is shown in either Table 3.5.3-6 or 3.5.3-7.

Table 3.5.3-6. Map of Types of M&S Assets to DoD Communities – Organizational Responsibilities.

		Acquisition								Analysis			Planning			Testing				Training		Experimentation			
		Acquisition	Research and Development	Logistics	Advanced Technology	Installation/Energy Management	Business Management Modernization	Nuclear, Chemical, and Bio Defense	Developmental Test and Evaluation	Program Analysis	Program Evaluation	Program Analysis of Alternatives	Develop Defense Policy	Integrate/Oversee DoD Policy	Integrate/Oversee DoD Planning	Develop OT&E Policy and Procedures	Review/Analyze OT&E Reports	Provide Financial Recommendations for T&E	Ensure Adequacy of OT&E for Op Effectiveness	Total Force Management	Readiness and Training	Experimentation	Concept Development (CD)	Deliver Capabilities	Synchronize CD and Experimentation Efforts
Hardware	Computers	X	X	X	X	X	X	X	X		X	X	X	X	X			X	X	X	X	X	X		
	Electronic Hardware		X		X			X	X												X	X	X		
	Hardware in the Loop		X		X			X	X												X	X	X		
	Mock-ups	X	X		X			X	X												X	X	X		
	Spares			X																	X			X	
Software	Data / Databases	X	X	X	X	X		X	X	X	X	X	X	X	X			X		X	X	X	X		X
	Models	X	X	X	X	X	X	X	X		X	X	X	X	X	X		X		X	X	X	X		
	Repositories		X	X		X	X	X				X	X	X	X			X		X	x	X	X		X
	Simulation	X	X	X	X	X	X	X			X	X	X	X	X			X		X	X	X	X		
	Tools (CAD/CAM)		X		X	X		X	X		X		X					X				X	X		
Networks	Architecture		X		X									X					X		X	X	X		X
	Lines		X	X	X	X			X			X									X	X	X		
	Transaction Protocols		X	X	X	X			X			X									X	X	X		X

Table 3.5.3-6. Map of Types of M&S Assets to DoD Communities – Organizational Responsibilities.

		Acquisition								Analysis			Planning			Testing				Training		Experimentation			
		Acquisition	Research and Development	Logistics	Advanced Technology	Installation/Energy Management	Business Management Modernization	Nuclear, Chemical, and Bio Defense	Developmental Test and Evaluation	Program Analysis	Program Evaluation	Program Analysis of Alternatives	Develop Defense Policy	Integrate/Oversee DoD Policy	Integrate/Oversee DoD Planning	Develop OT&E Policy and Procedures	Review/Analyze OT&E Reports	Provide Financial Recommendations for T&E	Ensure Adequacy of OT&E for Op Effectiveness	Total Force Management	Readiness and Training	Experimentation	Concept Development (CD)	Deliver Capabilities	Synchronize CD and Experimentation Efforts
Facilities	Buildings		X					X													X	X	X		
	Labs	X	X			X		X	X													X	X		
	Ranges		X						X												X	X	X		
	Physical Models	X	X			X															X		X		
People	Expertise	X	X		X	X	X	X			X		X		X	X	X	X	X	X	X	X	X		X
	Experience	X	X		X		X		X	X	X	X	X	X	X	X	X	X			X	X	X		
	Skills / Education	X	X		X	X	X	X	X	X	X	X	X					X			X	X	X		X
	Operational Knowledge	X	X		X		X		X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	
Products and Procedures	Plans	X						X		X	X	X	X	X	X				X	X				X	X
	Policies	X	X		X	X	X	X	X	X	X		X	X	X	X			X		X	X		X	X
	Analysis Results	X		X		X	X	X	X	X	X	X	X	X			X	X	X	X			X	X	
	Conceptual Models	X	X			X		X			X		X	X				X					X		X
	Management Processes	X	X		X	X	X	X	X		X		X	X	X	X					X	X		X	X
	Standards	X	X	X	X	X		X	X		X	X	X	X		X			X		X	X	X	X	X

Table 3.5.3-7a. Map of Types of M&S Assets to DoD Communities - Functional Responsibilities: Acquisition, Analysis, Planning.

		Acquisition								Analysis							Planning				
		Basic and Advance Research	Concept Exploration and Definition	Advanced Development and Engineering Design	Development and Integration	Demonstration and Evaluation	Procurement, Production, Deployment	Operations, Maintenance, and Support	Retirement and Remediation	Requirements	Force Structure	Manpower	Training	Logistics and Sustainment	Infrastructure	Readiness	Current Situation Representation	Course of Action (COAs) Comparisons	Rehearsals and What-If Analyses	Results Prediction of Ongoing Activities	COA Correction Impacts
Hardware	Computers	X	X	X	X						X	X	X	X	X			X	X		X
	Electronic Hardware	X	X	X	X								X			X					
	Hardware in the Loop	X	X	X	X	X							X			X					
	Mock-ups	X	X	X	X	X		X					X			X			X	X	
	Spares						X	X		X				X							
Software	Data / Databases	X	X	X	X	X			X	X	X	X	X	X		X	X	X	X	X	X
	Models	X	X	X	X	X				X	X	X	X	X		X	X	X	X	X	X
	Repositories	X	X	X						X		X	X	X			X	X		X	
	Simulation	X	X	X	X	X				X	X	X	X	X		X	X	X	X	X	X
	Tools (CAD/CAM)	X	X	X	X																
Networks	Architecture	X	X												X	X					
	Lines	X	X	X	X	X		X					X	X	X	X		X	X		
	Transaction Protocols	X	X	X	X	X		X					X	X	X	X		X	X		

Table 3.5.3-7a. Map of Types of M&S Assets to DoD Communities - Functional Responsibilities: Acquisition, Analysis, Planning.

		Acquisition								Analysis							Planning				
		Basic and Advance Research	Concept Exploration and Definition	Advanced Development and Engineering Design	Development and Integration	Demonstration and Evaluation	Procurement, Production, Deployment	Operations, Maintenance, and Support	Retirement and Remediation	Requirements	Force Structure	Manpower	Training	Logistics and Sustainment	Infrastructure	Readiness	Current Situation Representation	Course of Action (COAs) Comparisons	Rehearsals and What-If Analyses	Results Prediction of Ongoing Activities	COA Correction Impacts
Facilities	Buildings	X	X	X	X																
	Labs	X	X	X																	
	Ranges	X	X	X	X	X		X													
	Physical Models	X	X	X	X																
People	Expertise	X	X	X	X	X		X		X	X		X								
	Experience	X	X	X	X					X			X				X	X	X	X	
	Skills / Education	X	X	X	X	X				X			X			X	X	X	X	X	
	Operational Knowledge	X	X	X	X	X	X	X		X	X		X			X	X	X	X	X	X
Products and Procedures	Plans						X			X	X							X			
	Policies	X					X	X	X	X			X		X						
	Analysis Results		X			X	X	X		X	X	X	X	X		X	X	X	X	X	X
	Conceptual Models	X	X	X	X																
	Management Processes	X					X	X	X	X			X		X						
	Standards	X	X	X	X	X	X	X		X			X	X	X	X	X	X	X	X	X

* Would not invest with DoD funds

Table 3.5.3-7b. Map of Types of M&S Assets to DoD Communities - Functional Responsibilities: Acquisition, Analysis, Planning.

		Testing					Training					Experimentation			
		Contractor*	Developmental	Operational	Acceptance	Basic – Skills (School House)	Basic – Skills (On the Job)	Intermediate – Platform or System	Advanced – Multi-Platform	Joint – Multi-Service	Coalition / Multinational	Discovery	Technology	Doctrine	Employment
Hardware	Computers		X			X	X	X	X	X	X	X	X		
	Electronic Hardware		X			X	X	X	X	X	X	X	X		
	Hardware in the Loop		X			X	X	X	X	X	X	X	X		
	Mock-ups		X			X	X	X	X	X	X	X	X		
	Spares			X		X	X	X	X	X	X				
Software	Data / Databases		X			X		X	X	X	X	X	X	X	X
	Models		X			X		X	X	X	X	X	X	X	X
	Repositories					X	X	X	X	X	X	X		X	
	Simulation					X	X	X	X	X	X	X	X	X	X
	Tools (CAD/CAM)		X									X	X	X	X
Networks	Architecture								X	X	X	X	X		
	Lines		X	X		X		X	X	X	X	X	X	X	X
	Transaction Protocols		X	X		X		X	X	X	X	X	X	X	X
Facilities	Buildings					X		X	X	X	X	X		X	X
	Labs		X		X							X			
	Ranges		X	X	X	X	X		X	X		X			
	Physical Models					X		X	X	X	X				

Table 3.5.3-7b. Map of Types of M&S Assets to DoD Communities - Functional Responsibilities: Acquisition, Analysis, Planning

		Testing					Training					Experimentation			
		Contractor*	Developmental	Operational	Acceptance	Basic – Skills (School House)	Basic – Skills (On the Job)	Intermediate – Platform or System	Advanced – Multi-Platform	Joint – Multi-Service	Coalition / Multinational	Discovery	Technology	Doctrine	Employment
People	Expertise				X	X	X	X	X	X	X	X	X	X	X
	Experience		X		X	X	X	X	X	X	X	X	X	X	X
	Skills / Education		X			X	X	X	X	X	X	X	X	X	X
	Operational Knowledge		X	X	X	X	X	X	X	X	X	X	X	X	X
Products and Procedures	Plans													X	X
	Policies		X						X	X	X	X	X		
	Analysis Results		X	X	X									X	X
	Conceptual Models														
	Management Processes		X		X	X	X	X	X	X	X	X	X		
	Standards		X			X		X	X	X	X	X	X	X	X

* Would not invest with DoD funds

3.5.4 Findings

> √ ***Every M&S asset identified in this study correlates to more than one major M&S Community.***
>
> √ ***Every category has an investment interest in more than one M&S asset.***
>
> √ ***Some M&S assets are easy to value and relatively easy to determine investment costs while others are more difficult because of their nature.***
>
> √ ***M&S assets that are difficult to value and cost are still valid and must be a part of investment considerations.***

Analysis of the above tables leads to some interesting conclusions, worth noting explicitly. First, every listed asset correlates to more than one major Community. For example, in Table 3.5.3-6, the asset Models is related to every M&S Community, with obvious implications for investment management. The Table 3.5.3-3 mapping of assets to DoD M&S governance elements shows lower correlation than subsequent tables, because it is easier to see direct links between an organization or a mission to an asset than it is to see links between governance elements and specific M&S assets. Furthermore, if we look at sub-categories we see that every category has an investment interest in more than one M&S asset. Some of that may be a bit skewed as we felt that an organization/category that had an interest to invest in M&S data would automatically have an interest in M&S standards. This makes sense, a very desirable concept is being able to standardize M&S data so that it might be used on multiple platforms.

It is worth noting that the assets are quite varied. Some assets are easy to value, making determination of the cost of investing in that asset relatively easy. For example, if the DoD would like to procure an M&S laboratory for use in Research and Development, the process to determine the cost of that laboratory is well known; add up the building, land, and all internal equipment to arrive at the amount of dollars the facility, fully equipped, will cost. On the other hand, the cost of developing a DoD M&S professional is difficult to quantify simply because there are many ways to obtain that experience; obtaining the desired experience might be different each time an exercise is conducted, or a class is taken. In the same manner, calculating the value for each of these examples is difficult. In the case of the laboratory, determining the value of items such as intellectual property, prototype designs, knowledge gained by those that work there, etc., is a difficult task. The valuing of experience gained is also extremely difficult since each experience is slightly different and the same experience may have different effects upon different people. Nevertheless, it is important to note that even though the assets may be difficult to value or cost, they are indeed valid assets (meeting our definition as given at the beginning of the section) and must be considered as such when studying DoD M&S investments.

Appendix H discusses the need to view software as capital. In studying our list of assets it becomes apparent that many of them are either software or have a software component and each item in this category meets our definition of an asset. While this is not a startling revelation, it does point out that the list of assets is consistent with the discussion in Appendix H.

3.5.5 Conclusions and Recommendations

> √ ***An investment in any one M&S asset affects multiple commands, agencies, and perhaps services***
>
> √ ***To be most effective and achieve the highest ROI, investing in M&S needs to be viewed at the enterprise level.***
>
> √ ***While not as tangible, M&S assets such as knowledge, skill and experience are still important assets and the exclusion of them would hamper the calculation of a true ROI.***

A careful study of the above analysis brings some important ideas and facts to light. First, assets can not be placed neatly into bins. All assets cross functional, mission, organizational, M&S community (independent of the approach one used to view the communities), and DoD M&S Vision category lines, meaning that an investment in any one of these assets affects multiple commands, agencies, and perhaps services. All categories and sub-categories invest in multiple assets. Because of this, to be the most effective and get the highest return on investment, investing in M&S needs to be viewed at the enterprise level, not at in individual community level. While there may be some investments on a small scale that can be evaluated within a community, most will be benefit from a broader view. For example, every community has a need for M&S data, and therefore, every community should have an interest in investing in the creation of standards for M&S data. It is easy to see that the experimentation community may need the data that describes F-22 capability as they look at future fighter capability; it is perhaps not as easy that the planning and analysis communities need the same data for their analysis of current capabilities and development of future requirements. The creation of a standard may allow the same data to be used in multiple simulation events across both communities instead of generating a new model in a new format for each use. Therefore, to look at the value gained from that data standard from only the experimentation view diminishes the return on investment since there is also value to the planning and analysis communities. Since this analysis reveals investments routinely impact multiple communities, agencies, missions, etc. then in most cases to calculate a true, complete return on investment it must be done from a DoD enterprise level view or the result will likely be incomplete, or at minimum, suboptimal.

Additionally, when studying the list of items that meet our definition of an asset we note that not every item is something that is tangible and can be touched, observed, or held. Some items, such as knowledge, skills, and experience are valuable assets but perhaps not viewed as assets in everyone's mind. The exclusion of these assets would significantly hamper the calculation of a true ROI since many investments would add considerable value to skills or experience which would improve ROI. Similarly, we note that many M&S assets are software based or contain software, and that in many investment analyses, software *must* be treated as capital (an asset and not an expense or a consumable) as discussed in Section 3.1.3.7. Not amortizing software costs over the life of the investment will also impact the calculation of ROI and may lead to investment decisions based on incorrect data.

3.6 Asset Investment Cost Analysis

> √ *In order to accurately compute M&S ROI and be able to compare to alternative courses of actions, cost estimation must be both accurate and consistently applied.*
>
> √ *This study developed two specific cost element structures designed to support cost estimation from the Enterprise and the Program perspectives.*

In order to accurately compute ROI, the cost of the investment must be estimated as accurately as possible. In order to compare two or more alternative courses of action for which costs are to be one deciding factor, cost estimation must be both accurate and consistently applied. This report's analysis considers cost to be the expenditure of funds (up front and/or over time) for a particular arrangement of items or assets.

Cost estimating is a subjective activity that can be matured and improved over time as more information becomes available[43]. Therefore, for early estimates, the method used to identify costs must be transparent, so that it can be readily understood, explained, and modified. Using the most accurate information available from simulation designers, developers, and managers will help establish some level of confidence in the accuracy of the estimates. Also, through recurring refinement of cost estimates and feedback of corrections to follow-on analyses, the process of cost estimating can be improved.

3.6.1 Introduction and Background

In any exchange of goods or services, cost is one of the key considerations – often the most important. Cost is one consistent metric that can be used to evaluate any exchange of value. This is no different anywhere in the world, across business, family, and government exchange of goods and services. DoD purchasers of products or services certainly consider costs, just as purchases for the family home or business are evaluated on the basis of cost and other metrics. DoD purchases are unique in some ways, and consistent use of the cost element structure for DoD purchase decisions about M&S can facilitate comparison of costs of all logical alternatives.

Taxpayers' money is used to purchase M&S assets for DoD, and these assets support the warfighter, directly or indirectly. Whether or not the assets serve one or more of DoD's M&S Communities directly, the warfighter must benefit from the expense, and the taxpayers deserve a good bargain. The most significant results at the lowest possible lifecycle cost must be the focus of any expenditure of funds.

The methods recommended in this report leverage the ways families and businesses make purchase decisions. Families budget and spend for home improvements that add value and that hopefully return some of the investment after their improved home is sold. Or, perhaps a major family purchase will reduce long-term expenses for whatever the new purchase replaces. A business commits to investment after careful analysis of risk and of how that investment will increase future revenue. Businesses look at quantitative estimates of ROI, such as a "high enough" IRR or a NPV. These estimates are based on many educated assumptions about risk, the opportunity cost or value of money, and the improvement in the future revenue stream. Such quantitative estimates are based on the fact that a dollar in hand today is worth more than a dollar that is promised next year or anytime beyond, because the owner of the dollar could use it this year to earn an assumed rate of interest or for some other desirable benefit. Risk of repayment and inflationary factors also affect the discounted present value of future income streams.

3.6.2 Current Circumstance

Government investment is typically unique in two ways. It is financed by taxpayer-derived funds, and it does not normally yield a revenue stream from that investment. Also, as explained in Section 3.3, DoD investment involves different levels of stakeholders, whose leaders own and manage different assets that support M&S uses. Due to this unique circumstance, methods for determination of costs, cost avoidance, and results must be modified from that used in business and private sectors of the economy (see sections 3.1.1 and 3.1.2.1). For an M&S program or use, the costs to one stakeholder can be increased in order to benefit another. Therefore, one of the first steps in these analyses is to determine the total lifecycle costs across all stakeholders or for the most senior stakeholder at the enterprise level for an M&S improvement or asset use. For DoD, the costs of competing new M&S programs or services will be compared in a standard way and these funding needs will also be compared to both the cost of conducting the practice over time in the current (unimproved) way and to the cost without using (any or most) M&S assets (we often refer to this as "live"). From these cost computations and other results from the M&S investment, a formulation of ROI that uses cost avoidance will be described in this report.

It should be acknowledged that decisions based just on cost could neglect to consider significant results of an M&S investment (see section 3.7) that can make a combat-changing difference[44]. One good example of this is the success of "inexperienced" (or at least unseasoned in war) coalition armored forces in the Desert Storm Battle of 73 Easting.[45,46] Facing an ambush by dug-in and camouflaged combat-seasoned Iraqi Republican Guard armored forces, diversionary fire, and no visibility or low visibility in a sandstorm, coalition forces credited achieved an overwhelming victory to superior equipment, rigorous live training, and high-quality armored team training using a simulation called SIMNET. The development of this distributed simulation environment yielded an astounding return on investment, the 'return' including victory in combat and avoidance of combat losses neither of which are easily quantifiable in strictly economic terms. The early investment in simulation - SIMNET - gave coalition forces an opportunity and a military advantage that could not be totally foreseen.

New start or major modification M&S programs sometimes (but not often) go through a modified Analysis of Alternatives (AoA) or Evaluation of Alternatives (EoA). However, costs for competing solutions are rarely if ever compared for competing across all stakeholders for the assumed lifecycle of the asset or asset improvement. Rather, decisions about M&S are generally made using more subjective criteria. To address this, the methodology developed in this study provides a more rigorous method for estimating program costs and for comparing the costs of alternatives, including the cost of alternatives not using M&S, but instead achieving investment objectives by other means (e.g., use of live forces for conduct of a Test and Evaluation (T&E) program).

3.6.3 Approach

The study team developed two specific cost element structures, designed to support cost estimation for any M&S project, from either or both of two perspectives, the Enterprise and the Program perspective. The structures are provided in a series of five Tables, in Section 3.6.3.1 below. In sequence, they are:

- Cost Element Structure - Program Perspective
- Types of Hardware Costs
- Types of Software Costs
- Types of Labor Costs
- Cost Element Structure - Enterprise Perspective

For the Program Perspective, the major elements are the six asset categories described in Section 3.5.3 and listed in Table 3.5.3-1, *Assets Listing.* For three of these major elements, Hardware, Software, and Labor (People), an individual table listing sub-elements is provided. For the Enterprise Perspective, five major elements, and numerous sub-elements, are provided within one table. The major elements listed correspond to the five Governance Elements described in Section 3.5.3 and detailed in Table 3.5.3-2, *DoD Vision Statement Governance Elements*.

To facilitate comparison of the two Perspectives, one additional Table, "Mapping of Program vs. Enterprise Cost Elements" is provided. This series of Tables underlies the discussion which follows.

These two Perspectives were chosen for detailed illustration, as they are the two most frequently used in DoD evaluation of candidate M&S investment. From the point of view of either a requesting program manager or from that of an official at the enterprise level, what is important is visibility into all appropriate costs, and knowing at which level (of the five listed in Figure 3.3.6-1) hose costs will be incurred.

As was shown in the Stakeholder Analysis (Section 3.3), individual stakeholders have different concerns with respect to M&S investment, which results in varying cost and value estimations, dependent on the viewpoint (perspective) of the stakeholder. Consequently, the provided cost element structure has built-in flexibility for estimating costs from multiple stakeholder viewpoints. It can be used to estimate the cost of new M&S asset development, asset modification, or use of M&S assets. The M&S use cases for these cost element analyses would span new or modified assets, bench tests, desktop analyses, or distributed live-virtual-constructive operational-level events. Unfortunately, in current practice, stakeholders at the program level are too often in a position to authorize programs that unintentionally have cost impacts for other stakeholders.

The cost element structure can also be used to estimate the cost of an M&S project for the purpose of then computing ROI, comparing costs for various alternatives, and contrasting the cost estimated for the enterprise versus the cost of the program alternatives being considered. The cost element structure can also be used to estimate the cost avoided through the use of M&S in comparison to using all live forces.

Whatever use case is being analyzed, the allocation of costs to various stakeholders can have a profound impact on which alternative is deemed best in terms of cost alone. At the enterprise level, from the viewpoint of the highest level stakeholder, all long-term costs must be considered (including those consolidated/rolled up from all subordinate stakeholders). Stakeholder perspective thus becomes a vital input in determining whether individual program costs or enterprise costs are more important.

Costs can be estimated and compared using the provided cost element structure. If a stakeholder wants to estimate and compare the cost of a Program A to the cost of some Program B, cost structure elements can be used to evaluate all costs over multiple years (or the lifecycle) of each program. Costs must be discounted, using an appropriate opportunity cost rate, to get the NPV of A and B in terms of costs alone. The cost of the current solution (neither A nor B, and one that may be replaced) can also be derived in the same way. Program A, Program B, and the current solution probably have different costs at different times across infrastructure, policies, management processes, tools, and people. In Figure 3.6.3-1 the differences in costs for two options, A or B, across four years are illustrated.

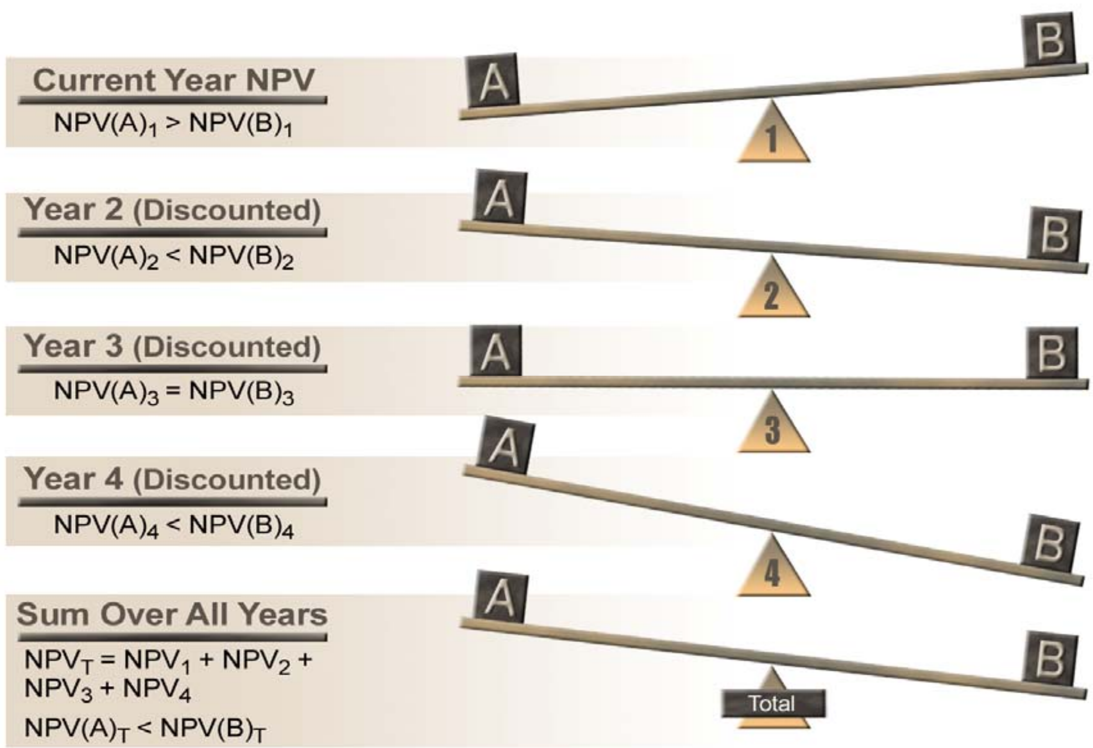

Figure 3.6.3-1. Comparison of Programs Using Discounted Cost and Cost Avoidance.

Of course, the sum of the costs and the costs avoided that can be attributed to a specific option will vary year to year. To properly compare Option A to Option B, predicted costs and avoided costs in future years need be discounted to the current year ("Current Year" in the Figure), and then summed over all years as shown.

Discounting costs and cost avoidance elements to the current year provides one way to evaluate M&S alternatives based on one standard metric. It has the advantage of providing a 'standard way' to compare the enterprise costs across an expected asset usage over many years Also, the cost of completing the expected use stream using all live assets can be compared to using the best alternative (A, B, or current), and a cost avoidance ROI can be computed. The disadvantage is that the comparison is on costs alone; other results of the investment (benefits, value obtained, etc.) will have to be compared on some basis other than costs to determine the overall best option or alternative.

Here are some examples of how the cost element structure could be used to compare alternative courses of actions:

- An analyst would like to conduct an evaluation of the Airborne Laser weapon system, and plans to compare this system with current manned and unmanned weapon systems. The analyst may want to evaluate different engagement, mission, and theater simulations to see which assortment of simulations is best for their purposes. She may need to buy or lease a model of the airborne laser system. She may have to consider license fees, database and simulation environment development, standards, and operator funding. The cost element structure could be used to compare the costs of different alternatives in addition to estimating the cost of conducting the analysis using all live forces (for a cost avoidance analysis).

- A simulation professional would like to conduct a small experiment in Alaska to evaluate the combat benefit of a new system for position determination of friendly ground forces. The simulationist will need to evaluate alternative simulations for use in this experiment. The cadre of simulation operators, even for the most commonly used simulations, is limited in Alaska, so the simulationist must not only compare various simulations but also distribution of the simulation environment from other locations. Friendly forces could be brought into the experiment live, through a constructive simulation, via virtual simulation, or as a combination of all these. The position determination system may need to be simulated or assumed. Databases for Alaska are limited, particularly for semi-automated simulations that require minimal operator support, so databases for geography and other environmental factors may also need to be purchased with lead time. Connectivity and simulation architecture costs will have to be evaluated. The cost element structure could be used to compare the costs of the different alternatives and to estimate the cost of conducting the experiment using all live forces.

- A stakeholder desires a new M&S asset for use in operational training exercises. Typically, new M&S program developments are planned and programmed such that costs are controlled or limited for an intermediate-level stakeholder. The cost element structure could be used to compare the costs of the different new development alternatives with modification of existing assets based on program costs and impacts on all relevant stakeholders over the program lifecycle. One additional point of interest could be the estimate of the cost of conducting typical operational training exercises using all live forces, and this estimated cost could be extrapolated across all expected training exercises over the program lifecycle. For this evaluation, the cost element structure would be used to estimate the costs of new product development options, modification of existing assets, and lifecycle costs of these various options across all relevant stakeholders. These costs would be compared with the cost of using all live forces for the representative exercises over the expected program lifecycle. For the simulation alternatives, supporting personnel costs will be calculated using expected staffing strengths and current payroll and per diem guidelines. Live force costs will be estimated using current Service Budget guidelines for costs of operation per hour. Some of the participants in an operational-level event are included in Figure 3.6.3-2 as an illustration of the complexity of the consideration set and the assets that must have cost estimated.

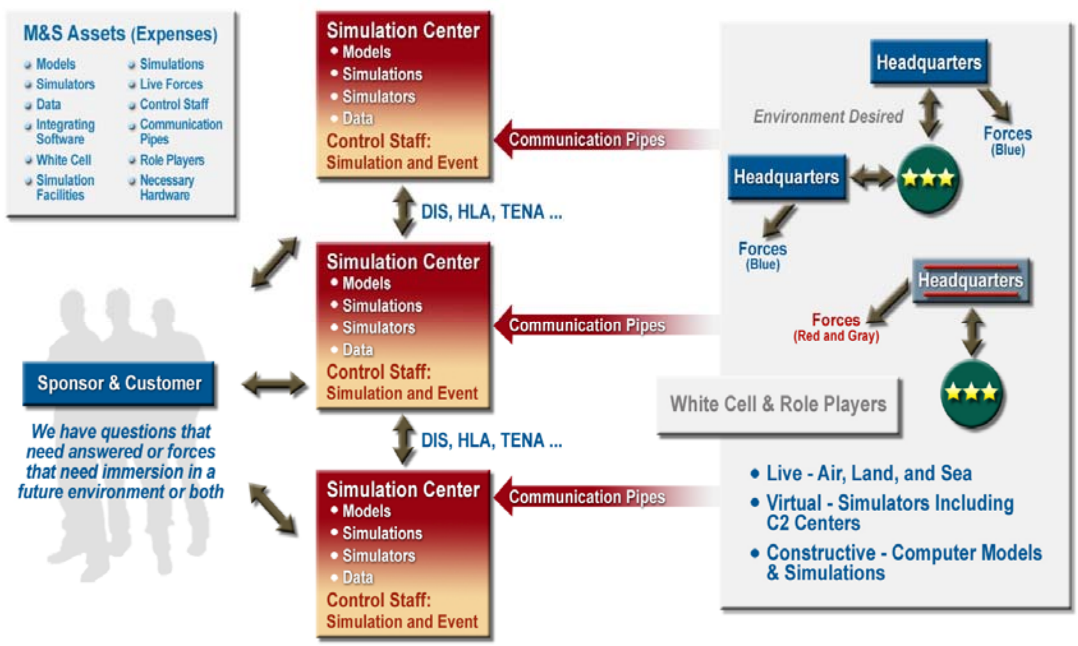

Figure 3.6.3-2. Some Participants in an Operational Level Event.

- A Joint convoy training tool is needed for pre-deployment and deployed-force training. The evaluation of alternatives for this need should consider both new development and leveraging of existing assets. Simulation and serious gaming alternatives already exist. Solutions that are distributed, loaded on hard drives, or browser-based should be evaluated. The cost element structure could be used to compare the costs of the different alternatives, of conducting training over the program lifecycle, and of running this type of training using all live forces.

- A new system for locating M&S standards and available resources is needed. The cost element structure could be used to compare the costs of modifying the current systems used for these purposes to different alternatives for meeting the requirements with other existing systems or a new development. The costs would include requirements generation, architecture engineering, software design and development or modification, database design and generation, staffing, and help desk operation. The cost element structure also could be used to compare the costs of some typical M&S projects, both with and without the new or updated locator system for M&S standards and resources.

3.6.3.1 Cost Element Structure at the Program Level

At the program level the cost element structure is described in terms of the assets that the program managers must allocate, including:

- Hardware
- Software
- Networks
- Facilities
- People
- Products and Procedures

Details of the cost element structure at the Program level are identified in several tables: Table 3.6.3.1-1 through 3.6.3.1-4 below.

Table 3.6.3.1-1. Cost Element Structure - Program Perspective.

Hardware	• Computers • Hardware-in-the-Loop • Mock-Ups • Electronic Hardware • Spares	**Software**	• Models • Simulations • Tools (CAD/CAM) • Data/Databases • Repository	**People**	• Expertise • Experience • Skills/Education • Operational Knowledge
Networks	• Lines • Architecture • Transaction Protocols	**Facilities**	• Buildings • Labs • Ranges • Physical Models	**Products & Procedures**	• Plans • Policies • Analysis Results • Conceptual Models • Management Processes • Standards

Details on cost sub-elements for hardware, software, and people are provided below in Table 3.6.3.1-2, Table 3.6.3.1-3, and Table 3.6.3.1-4, respectively, as depicted in previous studies[47].

Table 3.6.3.1-2. Types of Hardware Costs.

Hardware Cost Elements	
• Wiring	• Logistics equipment and support machinery
• Routers and filters	• Manufacturing tools
• Power supplies	• Test equipment
• Environmental control parts	• Inventory
• Planning materials and parts	• Replenishment and spares
• Host processors and accessories	• Other support hardware needs
• Computers and accessories	• Wiring

Table 3.6.3.1-2. Types of Hardware Costs.

Hardware Cost Elements	
• Support equipment and components	• Live simulations assets[48]
• Other network connectivity hardware and facility support	

Table 3.6.3.1-3. Types of Software Costs.

Software Cost Elements	
• Standards tracking and compliance	• Systems and software engineering tools
• Architecture depiction and animation tools	• Testing and monitoring tools
• Network analysis tools	• Configuration management
• Simulation environment integration software	• Commercial off the Shelf (COTS) license tracking
• Policy tracking and compliance	• Server applications
• VV&A and Verification, Validation and Certification (VV&C) compliance	• Program management administrative tools
• Data repositories	• Databases

Table. 3.6.3.1-4. Types of Labor Costs.

Labor Cost Elements	
• M&S Professional	• M&S and Systems Analysts
• Architecture Tool Designers And Operators	• Network Engineers
• M&S Environment Programmers	• VV&A and VV&C experts
• Database Technicians and Managers	• Data Analysts
• Design Engineer	• Subject Matter Experts
• Operations Researchers	• Developers
• Software And System Architects and Engineers	• Computer Programmers
• Administrative Specialists	• Technical Writers
• Test Engineers, Directors, and Managers	• Configuration Managers
• Quality Assurance	• Logistics Experts
• Facilities Engineer	• Range Personnel
• Simulation Facility Support Personnel	• Help Desk
• Training Staff	• Event Staff[49] o Planning o Control o White cell o Role players

It should be noted that many of these cost elements vary by year (over time) and by the funding stream (stakeholder) that authorizes specific asset uses and incurs specific asset costs.

3.6.3.2 Cost Element Structure at the Enterprise Level

Cost elements at the enterprise level are organized relative to the areas covered in the "Strategic Vision for DoD Modeling and Simulation" document[50]:

- Infrastructure: standards, architectures, networks, and environments
- Policies at the enterprise level (including interoperability and reuse)

- Management processes for models, simulation, and data
- Tools in the form of models, simulations, and authoritative data
- People (including well-trained and experienced users)

Table 3.6.3.2-1 illustrates the M&S Asset Cost Element Structure, and lists a number of important sub-elements.

Table 3.6.3.2-1. Cost Element Structure - Enterprise Perspective.

Infrastructure: Standards, Architectures, Networks And Environments	
• Planning o Conceptual Models o Event o New Systems or modifications	• Cost to Modify and Use Transaction Protocols o Distributed Interactive Simulation (DIS) o High-Level Architecture (HLA) o Test and Evaluation Network Architecture (TENA) o Proprietary Tools
• Cost of Architecture Design Tools Used • Simulation Facilities o Building Use Charges • Lab Charges	• Weapons or Test Range(s) o Lease Charges o Physical Models o Personnel Charges
• Connectivity - Cost to Lease / Use Communications Networks to Link all Players • Personnel Charges • Cost to Search for and Implement/ Leverage Available M&S Standards • Environmental Remediation after the Event	• Hardware o Computers - buying or renting for the event o Hardware-in-the-loop o Electronic hardware o Peripheral Hardware - buying or renting for the event o Spares
Policies At The Enterprise Level (Including Interoperability And Reuse)	
• Cost to search for applicable policies	• Compliance costs for policies
• Planning	
Management Processes for Models, Simulations and Data	
• Cost to Search for Existing M&S Capabilities that May be Leverages	• Cost of Verification, Validation, and Accreditation (VV&A) for Simulation and Simulators
• Cost of Verification, Validation, and Certification (VV&C) for Data	
Tools in the Form of Models, Simulations, and Authoritative Data	
• Program costs for new or replacement assets (government and contractor costs) o Requirements definition o Program management o System engineering, architecture, and design o System integration o Data architecture and data conversion o Risk assessment and change management o New system training o Test and evaluation o Facilities for program offices o Equipment for program offices o Program offices' security programs	• Modifying or using an existing asset o Models – development or purchase of specific systems or processes of interest o Simulations ▪ Simulations that need to be modified, purchased, or rented ▪ Support costs that includes maintenance over time ▪ Support staff that needs to be funded ▪ Deployment or distribution costs ▪ Upgrade costs ▪ Recurring license fees or use/seat fees o CAD/CAM

Table 3.6.3.2-1. Cost Element Structure - Enterprise Perspective.

o Deployment operations and maintenance ▪ Facilities ▪ Connectivity ▪ Software ▪ Hardware ▪ Recurring training programs ▪ Spares o Help desk o Other costs	o Live Forces – used to augment or replace the virtual and constructive assets ▪ Budgeted (PPBS) costs for operation of the systems ▪ Personnel costs for work hours ▪ Personnel costs for temporary living expenses ▪ Remediation for damaged property and possessions o Data – Databases feed simulators and simulations so they operate in the desired environment ▪ Weather/atmospheric ▪ Terrain ▪ Urban ▪ Force strength, laydown, and movements ▪ Other databases ▪ Repositories • Integration of data into the simulations and simulators
People (including well-trained and experienced users)[51]	
• Training of a Professional Workforce o Expertise o Experience o Skills/Education o Operational knowledge	• Event Planning Staff (home station and planning conferences) o Personnel costs for work hours o Personnel costs for temporary living expenses
• Control Staff (control the simulation and how the event runs) o Personnel costs for work hours o Personnel costs for temporary living expenses	• White Cell (observe and record progress) o Personnel costs for work hours o Personnel costs for temporary living expenses
• Role Player (augment the simulation environment to fill-in gaps) o Personnel costs for work hours o Personnel costs for temporary living expenses	•

3.6.3.3 Reconciliation: Mapping of Enterprise to Program Cost Element Structures

Cost element structures for the program and enterprise levels are equivalent in coverage, and will produce identical costs if used consistently and faithfully according to the stakeholders' perspective. The mapping in Table 3.6.3.3-1 below illustrates the correspondence between the two cost element structures.

Table 3.6.3.3-1. Mapping of Program vs. Enterprise Cost Elements.

Program Level Cost Element Structure	Enterprise Level Cost Element Structure
Hardware	Infrastructure
Software	Tools
Networks	Infrastructure
Facilities	Infrastructure
People	People
Products and Procedures	Management Processes and Policies

3.6.3.4 Example Calculations

Two examples are provided here to illustrate how the cost element structure can be used to calculate net present costs and cost avoidance for alternatives comparison.

(a). Example 1. A stakeholder has a simulation that is used for operational level readiness exercises, and wants to modify the controller interface on the simulation to allow an estimated 20% reduction in required control personnel for each future use (event). For this simulation, a 20% reduction is 3 personnel. The modification can be completed in about 12 months and will not affect ongoing training events. Therefore, the modification will reduce the cost of control personnel starting in about 1 year.

The cost of the modification is $300K now and $200K in about 12 months. The return on this investment will be the avoided costs for personnel next year and for the expected life of the simulation. For this example calculation we assume the expected life of the program to be 5 years after the modification is fielded.

The simulation is used on average as the primary simulation for 4 training events and 2 experiments per year. Some of these events are funded by other stakeholders, as are some of the personnel used as controller staff. The calculation will include those costs for all primary uses to give a complete view of the cost tradeoffs. Other uses of the simulation will not be considered in this example, but the analysis could be extended to provide a more complete view of the costs avoided.

Since the costs for this modification begin in the current year and extend one more year, costs and avoided costs over the five subsequent years will be expressed in current year dollars for comparison on a consistent basis. Costs after the current year will be discounted to the current year baseline using the assumed cost of capital of 10%. Avoided costs in terms of personnel and systems will be expressed in current year costs to avoid need for appreciation and discounting calculations.

Costs avoided will include travel, per diem, and labor costs for 3 personnel for 6 planning conferences (conservative estimate) and 6 events per year, each 6 days and 6 nights in duration. Travel costs are estimated at $1,500 per trip on average because some events are extra-CONUS. Per Diem is estimated at $200 per day. Labor costs are estimated at 40 hours per trip at $100 per hour fully burdened. In current year dollars, this cost avoidance is estimated at $241K per year for labor, Per Diem, and travel for 3 personnel at 6 planning conferences and 6 events total. The estimated net present cost avoidance is shown in Table 3.6.3.4-1.

Table 3.6.3.4-1. Example 1: Cost Avoidance NPV Calculation.

Year	Cost (CY $s)	Cost Avoided (CY $s)	Present Value
Current Year (CY) 0	-$300K	0	-$300K
Year 1	-$200K/1.10 = -$182K	$241K	$59K
Year 2		$241K	$241K
Year 3		$241K	$241K
Year 4		$241K	$241K
Year 5		$241K	$241K

After Five Years of Use Cost Avoidance NPV = $723K

Even with very conservative estimates, this cost avoidance of $723K above the cost of the modification indicates this is a good investment on the basis of cost alone, with an approximate ROI calculated at $723K/($300K + $182K) = 1.5 .

(b). Example 2. Due to the increasing cost of using live forces to conduct Forward Air Controller (FAC) training, a stakeholder wants to investigate using simulation to replace the live assets that support these quarterly training events. In order to set up the training arena, each event uses a small team (4 personnel) of friendly forces that are inserted within the training range to be the team that needs to be protected or rescued. Each event also includes one ground and one airborne command and control (C2) asset and a 3-ship of air-to-ground assets. It is assumed that half of these live training events can be replaced with simulation events while still improving training for all concerned. Operational networks and facilities are also used, but will not be included in these cost computations. Other participants in these events will get equivalent training whether the assets in question are live or represented in constructive or virtual simulation.

The simulation will cost $600K per year for modifications, improvements, integration with the Common Operational Picture, staff training, and planning and control. For simplicity, the life of this simulation is expected to be 6 years including the current year 0. For the assets represented in the simulation, 6 personnel will attend 4 planning conferences each year for 40 labor hours, 6 days and 6 nights of Per Diem at $200/day, and $100/labor hour fully burdened. Travel is estimated at $1,500 per person per trip. For each training event, 48 personnel will be deployed to support the live assets at the same rates for labor, Per Diem, and travel for 6 days and 6 nights and a 40-hour labor charge. The cost of the operational assets are estimated at 4 hours of use per day at $25K/hour for the ground C2, $100K/hour for the airborne C2, and $150K/hour total for the 3-ship of air-to-ground assets. The event includes 3 days of live-fly plus two travel days. (Note: for an actual evaluation of alternatives, these costs can be gathered from Program Objective Memorandum (POM) or Budget Estimate Submission (BES) data, and current year data can be used for all years in order to facilitate baselining of all cost data to the current year.) The annual costs avoided will be $160,800 for planning conferences, $775,200 for support personnel, and $46M for operational assets. The estimated net present cost avoidance is depicted in Table 3.6.3.4-2.

Table 3.6.3.4-2. Example 2: Cost Avoidance NPV Calculation.

Year	Cost (CY $s)	Cost Avoided (CY $s)	Present Value
Current Year (CY) 0	-$600K	$12,936,000	$12,336,000
Year 1	-$600K/1.10 = -$546K	$12,936,000	$12,390,000
Year 2	-$300K/$1.10^2$ = -$496K	$12,936,000	$12,440,000
Year 3	-$300K/$1.10^3$ = -$450K	$12,936,000	$12,486,000
Year 4	-$300K/$1.10^4$ = -$410K	$12,936,000	$12,935,590
Year 5	-$300K/$1.10^5$ = -$372K	$12,936,000	$12,564,000

After 6 Years of Use Cost Avoidance NPV = $75,151,590

This example used hypothetical data for operational systems costs, so the NPV and estimated ROI may be exaggerated. Using the data as shown, this appears to be a good investment with the estimated ROI calculated as $75,151.59K/($600K+$546K+$496K+$450K+$410K+$372K) = 26 on the basis of cost alone.

3.6.4 Findings

As discussed in an earlier section, the perspective of the stakeholder is vitally important when the cost estimating structure is employed; yet, there are other dependencies across M&S programs that should be considered when making M&S investments. One stakeholder can ignore or exacerbate the costs experienced by other stakeholders, and intelligent investment in M&S programs can have an impact across many or all stakeholders as illustrated in Table 3.6.4-1 below.

√ ***While not the only dependency to be considered, the stakeholder perspective is vitally important in employing the cost estimating structure.***

Table 3.6.4-1. Cost Contingencies/Dependencies and Perspectives.

Cost Characteristic	Depends On:	Example/Discussion
Design and development	Skill of management and engineering workforce	Well-organized professional systems engineering and tight control of requirements have significant pay-off in cost, schedule, and performance through many reuses
Labor	Training and skill of workforce	A more competent workforce completes tasks faster with better results
Labor	Usefulness and automation of the M&S assets	Lower planning, populating, and use costs are expected for M&S assets that have been developed with automation and ease of use in mind
Ease of integration of distributed live-virtual-constructive environments	Prior investment in HLA, DIS, TENA, connectivity, and follow-on programs, and a trained skilled cadre	Ease of use, flexibility, and a skilled cadre cost more up front but pay-off time after time for many re-uses
M&S program and enterprise	Allocation of costs across the program and above the program to the enterprise	In development or reuse of an M&S asset, some costs are allocated to the program while other costs may be allocated above the program level to other sponsors or stakeholders. The enterprise perspective should track all lifecycle costs
Cost to stakeholder	Perspective	At the program level, lowering costs can mean passing costs to other entities or other stakeholders. For instance, reduced development costs for simulations can be achieved through developmental shortcuts that force the requirement for more control and white cell staff at the simulation centers
Modification of existing M&S or new development	Stakeholder perspective and timeline	All lifecycle enterprise costs should be considered

Table 3.6.4-1. Cost Contingencies/Dependencies and Perspectives.

Cost Characteristic	Depends On:	Example/Discussion
Search for alternate solutions and available standards	Well populated M&S resource repositories and skilled help desks	Use of common standards and leveraging existing solutions saves time and funds

3.6.5 Conclusions and Recommendations

> √ ***Clearly, the stream of costs and avoided costs can be estimated across one or more years. Avoided costs serve as one measure of return from an M&S investment.***
>
> √ ***The full measure of an M&S investment across all dimensions of costs, cost avoidance, return, and risk is necessary.***

Clearly, for simulation alternatives, the stream of costs and avoided costs can be estimated across one or more years. The avoided costs serve as one measure of the return from the investment in M&S. In both examples used in section 3.6.3.4, multiple alternative simulation solutions could have been compared to each other, to the status quo, and to the cost of completing the task with all live forces. These methods result in net present cost avoidance and a measure of ROI, but the full measure and comparison of results and return must be combined for a reliable holistic investment decision process presented in section 3.8.1. Even as costs can be allocated willingly and unwillingly across stakeholders, costs can be lowered at the expense of less positive (or negative) results or at the expense of increased risk. Therefore, the full measure of an M&S investment across all dimensions of cost, cost avoidance, return, and risk is necessary.

3.7 Asset Investment Results Analysis

> √ ***In order to effectively calculate the ROI of an M&S investment, it is critical to define and assess rigorous measures of merit that reflect the results of its application.***
>
> √ ***Such measures must account for both qualitative and monetary dimensions.***

In order to understand the utility of M&S, it is necessary to characterize the results of its application. That is, the 'return' in 'return on investment.' Such results, whether positive or negative, need to be rigorously described in a manner that accounts for both qualitative and monetary dimensions. The approach developed here describes the metrics required for such analyses, including types, variability, and application particularities. The development of such comprehensive metrics is especially important in an area like M&S, where the effect of investment and application are not exclusively monetary, naturally quantitative, or sometimes even intuitively obvious.

For this study, the word "results", when used in the context of characterizing the return or outcome of an investment, has specific meaning. In the topic area under study, individual words convey a great deal of meaning, which can vary by context. So, for purposes of this study the word "results" is intended to convey the idea that the impact/outcome of M&S application can include both positive and negative outcomes, encompass various expressions of value, utility, contribution, benefit, impact, return, and similar terms, and allow for both monetary and qualitative expression of value or impact derived from investment. Its meaning is intended to convey the overall outcome of specific M&S investment.

3.7.1 Introduction and Background

In order to effectively apply a technology like M&S to a military enterprise, application, or program, it is critical to define and assess rigorous measures of merit that reflect the results of its application. Only through using such a structured analysis approach is it possible to properly evaluate contribution or cost effectiveness. Most efforts to assess such contributions have either generated very narrowly applicable numeric indices or general anecdotal evidence. To understand the impact of M&S investment, it is necessary to rigorously develop well defined and balanced metrics that reflect the results of M&S use within and across the relevant spectra of management, application, and programs. Only by employing comprehensive and rigorous measures can the impact of technology application or process changes be accurately assessed. Such assessments are especially critical as budgets are reduced, opportunities for live tests and exercised curtailed, and acquisition timelines shortened.

Given the importance of measuring M&S return on investment / utility, the goal is to describe a rigorous method to characterize results of M&S application in a transparent, consistent, defensible, and quantitative manner. Such a method should allow for qualitative and quantitative input parameters; include evaluation of both processes under examination and subsequent outcomes; should be relevant to enterprise wide initiatives, application or domain specific activities, and programs; and, finally, should provide an approach for including results metrics in an overall algorithm that calculates the impact of M&S investment.

3.7.2 Current Circumstance and Context

Statements that M&S improves mission accomplishment are common-place. As example in the training domain, it is often expressed that M&S allows training to be accomplished more quickly and effectively; provides insightful analytic results; and reduces acquisition timelines. Yet, equally common are calls for its contributions to be more rigorously characterized. For instance, at the May 2006 Defense Modeling and Simulation Conference Working Group Debriefs, presenters without exception called for more accurate, quantitative, and transparent calculation of return on investment, value, utility, and similar metrics.

Currently most M&S value assessments use metrics that are uneven in scope, very case specific, or not well structured. They do not reflect the value of change in all of the areas impacted nor do they allow consistent aggregation of benefits. Additionally, some measures that are used, like return on investment, are actually incorrectly defined, and others are undefined, thus making the assertions of value at best vague and at worst incorrect. Finally, all too often, important distinctions are not made between and among terms critical to consistent ROI assessment. Such incorrect distinctions are applied to metrics and measures of scale, quantity, quality, range of value, and other.

Efforts to characterize the contribution of M&S fall primarily into three categories; surveys, assessments, and methodological development, . Surveys summarize the results of efforts already conducted.[52] Methodological development articles provide insights into how to improve

M&S value calculation.[53] Assessments typically provide insights based on one of four approaches - nominal descriptives, case-based, business-oriented, and multi-attribute examination. Nominal descriptions articulate how M&S is intended to improve an outcome. Case-based studies provide insights on a particular application or area. Business case efforts focus on the monetary aspects of M&S use, while Multi-Attribute Utility (MAU) approaches seek to articulate, measure, and then combine relevant terms into overall figures of merit. All four assessment types have advanced the state-of-the-art in M&S results assessment, but they have not yielded an overall, rigorous, and effective approach for characterizing M&S investment.

3.7.3 Approach

The approach developed in this study has its basis in the MAU model, as it was found to be most useful in illuminating the elements of cost, results, and risk relative to M&S investments.

For results calculation the overall methodology begins with a series of definitions. These definitions are critical to ensure fundamental terms are understood, assumptions are stated, domains of application are appropriately described, M&S results applicability is bounded, and that metrics are characterized along with their associated terms. Then, the products of this section are presented. Fundamentally, these products take the form of matrices that, for each perspective under consideration, decompose the perspective into results-oriented component parts and associates metrics with each. Specific steps can be summarized as follows:

- Define "Results"
  - What it includes
  - Relative to benefit, utility, and similar
- Define Assumptions
  - Non-profit seeking but rational actor, relevant results can be specified
- Define Relevant Perspective
  - DoD Vision / Application Communities (Organizational and Functional)
- Define M&S Application Scope
  - Continuum of M&S application
  - Our selection for analysis and metrics development
- Define Metrics'
  - Type, Levels, Assessment, Structure
- Present Specific Results
  - Enterprise / Application Communities / Program Perspective Definition
  - Associated matrices with relevant metrics and measures
- Derive Overall Conclusions
  - Methodology and Application
  - Risks and Remediation

Three assumptions are particularly relevant to the calculation of M&S investment results. The first is that decision makers in the Department of Defense, although not profit maximizers like corporate officers and similar decision makers in the commercial marketplace, are rational actors who seek to optimize relevant outcomes. The second assumption is that relevant outcomes can be adequately specified. That is, they can be characterized, using a set of cost, asset, and result variables, the total of which encompasses the investment value of the alternative. There are no hidden agendas or over-riding private concerns. The third and final assumption is that the metrics needed to characterize the results of M&S investment and application can be quantified. That is, whether they start out as naturally numeric indices (dollars, number, percent, etc) or as qualitative inputs (high, medium, low; larger, smaller, equal; etc.) they can be transformed into numeric values.

It is also important to define a precise set of organizing principles or structures that can be consistently applied to generate rigorous M&S investment analysis results. For this effort, there are three. The first is the Enterprise perspective as articulated by the DoD "M&S Strategic Vision" with its five goals. The second is derived from the DoD "New Approach for Managing DoD M&S" ("The Surfboard Chart"). Finally, the third perspective is that of the program.

Next it is critical to define the scope of M&S application to which results determination applies. In particular, when there is no alternative to M&S, does calculating the results of its use really matter? We say yes. That is, on the continuum of M&S use; divided here into - 'negative impact,' 'augmentation,' improvement,' and 'no other way' – it is important to articulate which will be included in any analysis (see Figure 3.7.3-1 "M&S Value Varies"). Of these four major groups, all are included here, but differently. For the first three, results metrics provide input values to algorithms that calculate the return on M&S investment. In these cases, it's particularly important to allow for negative results of M&S use since generating accurate and fair measures requires that results can span the range from very negative to very positive. Next, it is critical to allow for instances where M&S provides an equally relevant alternative and also scenarios within which it provides significant improvements. Finally, in the fourth case, where M&S provides a capability where there is no alternative (nuclear weapons effectiveness assessment, major conflict analysis, system causality training, and similar) this results approach can provide inputs values to algorithms that prioritize investment in alternatives. In other words, where there is no analogous point of comparison (and thus M&S "value goes to infinity") the results metrics calculated allow the 'internal' prioritization of investment options.

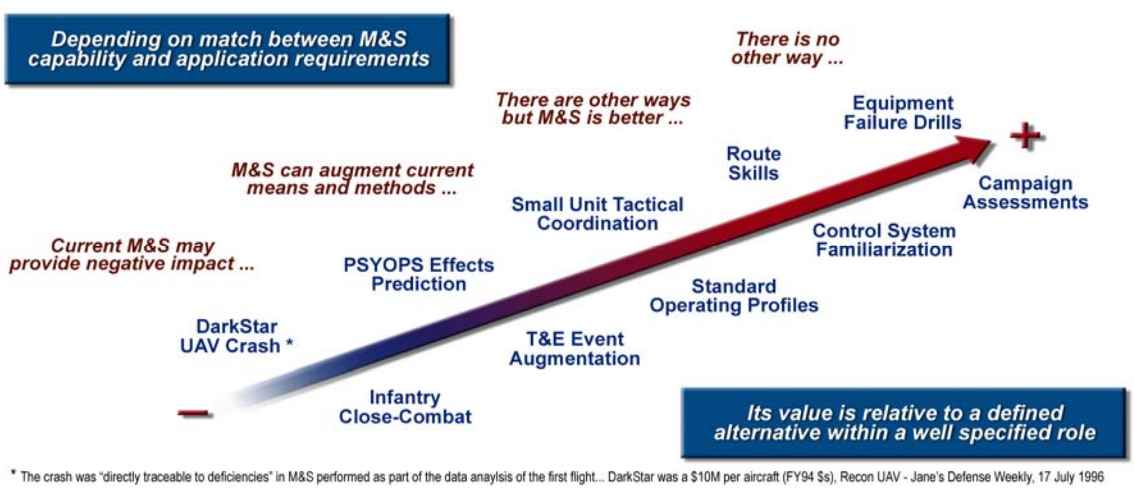

Figure 3.7.3-1. M&S Value Varies.

First, in calculating metrics that reflect the results of M&S investment, it is important to define the term 'metric' as well as its key features. A metric is a standard of measurement which, similar to variables, is given values based on the features of the item under consideration (the act of measurement). There are different types of metrics. In the DoD community, a common phrase is that M&S allows missions to be accomplished 'better, faster, and cheaper' and thus the results calculated here are divided into quality metrics (better and faster) and monetary ones (cheaper). Second, there are types of metrics. In the military operations research community the sequence of types is often: dimensional parameters / measures of activity, measures of performance, measure of effectiveness, measures of force effectiveness, measures of political effectiveness, and similar. For this effort, we develop two types of results metrics: 'activity metrics' which reflect dimensional parameters / measures of activity and 'effectiveness metrics' which reflect the rest. This is a useful feature since it distinguishes between, in training for instance, the number of students trained (activity) and the duration of learning retention (effectiveness). So, there are activity metrics that reflect basic M&S quality and monetary impacts and effectiveness metrics that reflect M&S quality and monetary aspects of performance and effectiveness. It is important to emphasize again, that in our methodology metrics reflecting quality can be positive or negative, those reflecting costs are only positive (cost savings, cost avoidance, cost reduction)[54]; the "negative" cost values (the 'cost' or expenditure of funds to do something) are accounted for under the cost section of this approach. Third, the next feature of results metric calculation that needs to be discussed is assessment approaches. The focus here is on qualitative or subjective judgments that can be numerically characterized and indices that are naturally quantitative. Fourth and finally, it is important to associate an overall, hierarchical, structure for results metric calculation (see Table 3.7.3-1 "Value Metrics Decomposition"). That is, terms like category, characteristic, property, metric, scale, range, value, and combinations need to be defined and associated.

Table 3.7.3-1. Value Metrics Decomposition.

Value Metric	Example Metric
• First are the classes / categories.	• e.g., Technical
• Associated with each group are a set of characteristics / terms describing features.	• Maintainability, Design
• Associate these with more specific properties.	• MTBF, Type
• Decompose these into metrics, which are standards of measurement, like variables.	• 1-10hrs Compiled, Interpreted
• Metrics values are relative to a scale (a specified graduated reference used to measure) and may be nominal, ordinal, interval, or ratio in type.	• 1-2-3-4-5-6-7-8-9-10 • C-I
• May range from 0 or no representation to X, which X represents a complete implementation of the areas.	• Continuously for interval and ratio data
• Metrics are assigned values, based on the features of the MS&G (the act of measurement) or MS&G requirement.	• e.g., 9, Compiled
• Values can be combined into a aggregate measures of merit.	• C=2*1, I=1, Value = 18

> √ ***The M&S ROI results metrics applicable are different for each of the three relevant DoD perspectives:***
> - ***The Enterprise View metric categories focus on implementation, business, community, infrastructure and system of systems.***
> - ***The M&S Community View metric categories reflect application-wide indicators of success or failure.***
> - ***The Program View metric categories include individual M&S systems or specific M&S support.***

We begin here with classes / categories which describe the overall type of metric. Associated with each group are a set of characteristics / terms describing relevant features. Matched with these are more specific properties with which metrics, or standards of measurement like variables, can be associated. Metric values are relative to a scale (a specified, graduated reference used to measure) and may be nominal, ordinal, interval, or ratio in type and may range from negative numbers which reflect damaging or harmful results to positive numbers which indicate beneficial or advantageous results. Metrics are given values (the act of measurement), which can be combined into aggregate measures of merit and projected in time. Like costs, results metrics have to be subjected to Net Present Value type extrapolations to account for their changes over time.

The next step in developing M&S results metrics is the presentation of the analytic products of this effort. First, three perspectives are reviewed: Enterprise, Community, and Program views. Definitions and examples are provided. Then, metrics relevant to each perspective are presented. For each, the metrics are grouped, titled, defined, and samples provided. After that, the sub-components of each perspective area are arrayed against asset investment categories, with example metrics provided for each intersecting cell. Next, overall findings are provided regarding both the methodology developed and on its potential application. Finally, associated risks are stated and remediation approached proposed.

3.7.4 Findings

There are three perspectives that apply within the DoD to the derivation of relevant M&S results metrics and the calculation of the return on their investment. They are the Enterprise View, as articulated in the Strategic Vision for DoD M&S; the Community View, as described in the Application Area Descriptions (i.e., the "Surfboard Chart"); and the Program View, which includes both M&S programs and programs or activities that use M&S. Acknowledging these three perspectives is critical, since the results metrics applicable to each are different (see Figure 3.7.4-1, below).

For instance, in the Figure 3.7.4-1 Program A – is a training M&S system that spans services and some levels of application (at least intermediate and advanced) and thus has the characteristics of a community as well as those of a M&S program: and the results metrics reflect both. Program G is an acquisition program which provides a framework for use across acquisition efforts, and has some community as well as programmatic impact. Program D on the other hand, is a service specific M&S effort, which provides value within that application. Finally, Program I is a training program that uses M&S in its development but is not itself an M&S system (say a range instrumentation sensor). So, M&S metrics at the programmatic level include individual M&S systems or specific M&S support to a program or activity and thus reflect results from those uses (while allowing for community value as appropriate).

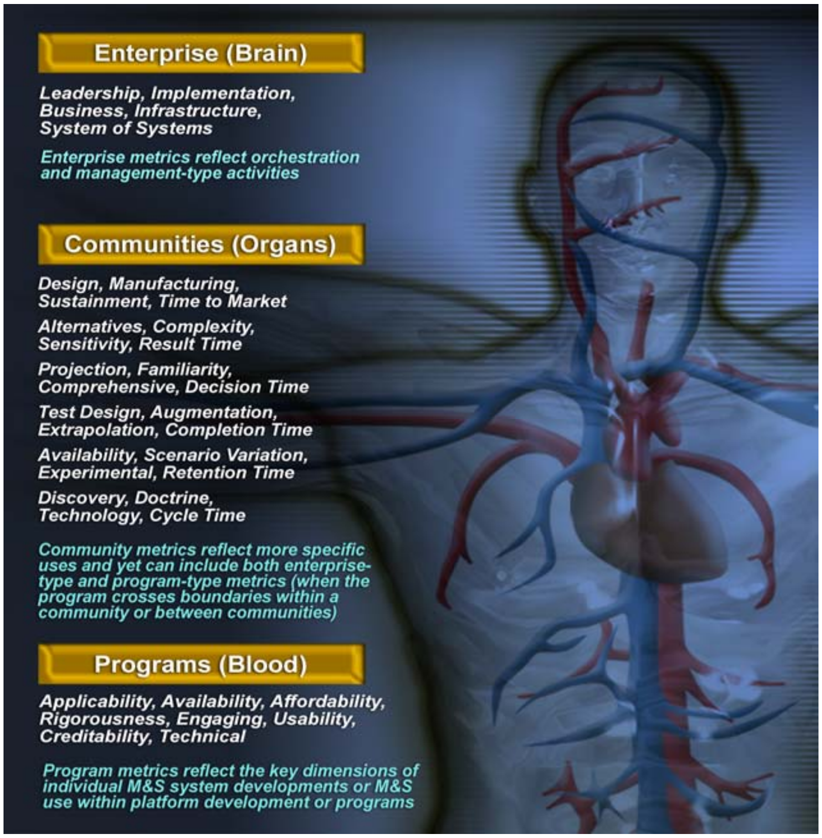

Figure 3.7.4-1. Results Metrics by Perspective.

For each of the three perspectives, critical classes / categories are named and described, and quality and cost metrics associated (see Figure 3.7.4-2, below). The information for each perspective is presented in tables. Each table states: the perspective, the classes / categories, terms / characteristics, and sample metrics (quality (activity on the first line, effectiveness on the second) and monetary).

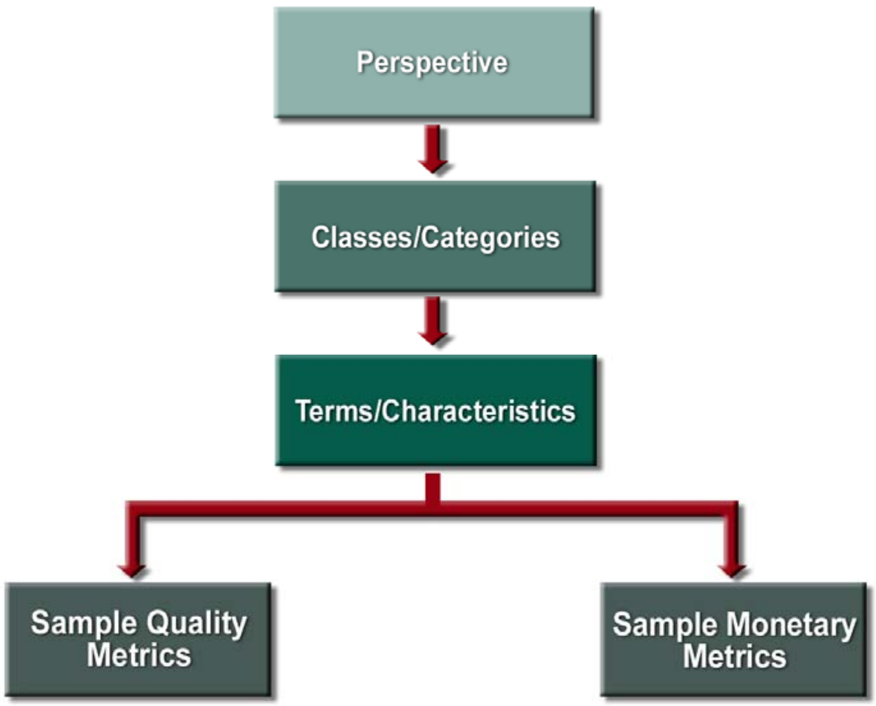

Figure 3.7.4-2. Critical Classes / Categories Drive Metrics Selection.

3.7.4.1 Enterprise Perspective

The Enterprise View focuses on M&S capabilities that apply “across the diverse activities of the services, combatant commands, and agencies” and thus presents goals that are necessarily broad and encompassing. They include standards, policies, management, tools, and people that are collaborative, interactive, and sharing of assets in a defense-wide manner that includes other “governmental agencies, international partners, industry, and academia.” Thus, the metrics that reflect the results of M&S investment at this level account for the successes and failures of the DoD’s ability to foster and promote M&S by providing accessible, applicable, and standardized infrastructure; policies that promote interoperability and reuse; management that facilitates, motivates, and incentivizes M&S use; tools that are comprehensive and credible; and users who are trained and innovative – to name a few (additional objectives / sub-components are provided in the Table 3.7.4.1-1, below).

Table 3.7.4.1-1. Enterprise Perspective.

Area	DoD Vision Goals	"Objectives / Sub-Components"
Infrastructure	1. Standards, architectures, networks and environments that: - Promote sharing of tools, data, information across Enterprise - Foster common formats - Are readily accessible and can be reliably applied by users	Fosters / Promotes Accessible and Applicable Standards / Common Formats Architectures / Networks Environments (data sets)
Policies	2. Policies at the enterprise level that: - Promote interoperability and use common M&S capabilities - Minimize duplication and encourage reuse of M&S capabilities - Encourage R&D to respond to emerging challenges - Limit use of models data encumbered by proprietary restrictions - Leverage M&S capabilities across DoD, other government agencies, international partners, industry, and academia	Interoperability Reuse R&D Non-Proprietary Solutions Multi-Agency Coordination

Table 3.7.4.1-1. Enterprise Perspective

Area	DoD Vision Goals	"Objectives / Sub-Components"
Management	3. Management processes for models, simulations, and data that: - Enable M&S users and developers to easily discover and share M&S capabilities and provide incentives for their use - Facilitate the cost-effective and efficient development and use of M&S systems and capabilities - Include practical validation, verification, and accreditation guidelines that vary by application area	Discover and Share Facilitate, Motivate, Incentivize Provides Guidelines (VV&A)
Tools	4. Tools in the form of models, simulations, and authoritative data that: - Support the full range of DoD interests - Provide timely and credible results - Make capabilities, limitations, and assumptions easily visible - Are useable across communities	Comprehensive Timely Credible Transparent Adaptable
People	5. People that: - Are well-trained - Employ existing M&S and data to support departmental objectives - Advance M&S to support emerging departmental challenges	Trained Users Innovative

The metric categories developed for this perspective focus on: leadership, implementation, business, infrastructure, and system of systems; which have been derived from a "Study of Studies" conducted by the Navy in 2008.[55] In it, reports generated by the National Academies, National Science Foundation, Department of Defense, Military Services, Federally Funded Research and Development Centers, Defense Science Board, Military Service Councils, Service Simulation Groups, and Operational Commands were reviewed and key insights deduced. These observations were placed into three groups. The first are the enterprise-wide recommendations that recognize the need for cross-organizational integration and synergy as well as the importance of taking a "cradle-to-grave" perspective. The next recognized a set of application oriented gaps, specifically in human behavior, non-kinetic and DIME/PMESII modeling, and uncertainty representation. Third and finally was the need for a warfare orientation, both in terms of including the military customer but also in terms of establishing an underlying understanding the fundamentals of future warfare. The classes / categories and terms / characteristics described in Table 3.7.4.1-2 and Table 3.7.4.1-3 in this section encompass these three areas.[56]

In accounting for the results of M&S investment from the perspective of the Enterprise, the comparison is between investments that facilitate / improve the management and orchestration of M&S at this level and those that do not. For example, providing leadership; that is: articulating a vision, updating that vision, using that vision to guide investments, and having others within the DoD adopt and adhere to that vision, improves M&S Enterprise effectiveness.

Table 3.7.4.1-2. Enterprise Metrics.

Enterprise Perspective		Sample Metrics	
Term (*characteristics*)	Definition	Quality	Monetary
Leadership (*class / category*)			
Leadership	Statement of vision and associated advocacy / support of timely actions needed for an effective enterprise (*property*)	# / currency of vision & resulting / supporting docs (*metric*) ° senior leadership adopts vision within their (other) areas	% alignment of funding to vision Savings from reduced unused sunk costs
Empowerment	Developers, managers, and users that are engaged, asked, and able to make significant contributions to M&S	# innovative ideas forwarded without solicitation % M&S decision makers attending key meetings	Reduction in costs to solicit new M&S concepts Savings from application of innovative M&S concepts
Situational Awareness	Decision maker's and user-ship's understanding and awareness of M&S standards, tools, needs, etc.	# meetings, conferences, repositories, web portals, etc. % critical information exchanged among communities	Reduction in costs to finding relevant M&S information Cost savings from the reduction of duplicative efforts
Management	Human Capital Management process for recruiting, assigning, and career development of M&S workforce	% M&S designated billets staffed with M&S qualified personnel % M&S qualified personnel promoted / retained	Unnecessary training / retraining costs Cost effective M&S decisions
Processes	Adoption of rigorous, timely, and relevant standardization and certification of M&S policy, tools, workforce, etc.	# promulgated processes consistently adopted Decreased product (policy, tool, etc.) generation time	Reduced labor, travel, and software reworks Savings from error-rate reduction
Implementation			
Implementation	Products and processes that make progress toward reaching M&S vision, goals, and guidance	# directives, instructions, master / support plans, road maps ° enterprise is conducting needed and synergistic efforts	% alignment of funding to vision categories Reduced unused sunk costs
Customer	Incorporation of perspectives from the user, operator, war fighter	# operators contacted. % war fighter requirements met ° customer is involved in design, development, deployment	Cost savings from early incorporation of user perspective Cost avoidance from reduction in product reworks
Coordination	Management / working groups / forums, activities and guidance that foster harmonized flow of information / data	# formally chartered M&S groups, teams, and similar # M&S projects not needed because of awareness	Reduction in costs of searching for resources Savings from finding useful M&S data, design, products…
Participation	Inclusion (in processes and guidance) of non-DoD Government, International, Academic, and similar organizations	# non-DoD activities actively participating in DoD M&S actions ° M&S lessons learned elsewhere being applied within DoD	Savings to DoD because of investments made by others Savings from discovery of existing M&S data, systems, etc.

Table 3.7.4.1-2. Enterprise Metrics.

Enterprise Perspective		Sample Metrics	
Term (*characteristics*)	Definition	Quality	Monetary
Guidance	Produce and promulgate appropriate M&S policy, directives, instructions, handbooks, guidelines, etc.	# guidance documents produced by type, # programs using % M&S developers and users conforming to guidance	Savings from clear lines of authority, responsibility, priority Cost avoidance of writing unique / single use, plans
Synchronization	Processes, tools, methods, and appropriately tailored actions to achieve coordinated purposeful activity	# sub-component activities support overall vision ° organizations speak with 'one voice' on key goals / objectives	Savings from reduction in unnecessary / off-track efforts Cost efficiencies from coordinated action
Training	Programs to train and educate personnel in M&S, at all levels: senior executives, managers, developers, and users	# programs at initial, intermediate, advanced, management % knowledge required by each currently achieved	Savings from decisions: at the right time, right the first time Cost effective M&S decisions
Foundation	Body of Knowledge, conceptual models, and similar keystone frames of reference	# foundational documents / databases produced # community specific, consistent, informative, sub-sets	Reduction in costs of 'higher level' activities (e.g., training) Cost avoidance of writing unique / single use, frames
Business			
Funding	Adequate, timely, and stable funding using appropriate budgeting categories	% investment in management relative to total expenditure % change in budgets over five years and within fiscal years	Cost avoidance of duplication, non-interoperability, etc. Reduction in cost of budget reworks and project start-ups
Pro-action	Early investment in development and application of M&S (e.g., for acquisition, pre-milestone A)	% investment in M&S by life-cycle phase % effective early use / decisions based on M&S	Cost savings from better early design decisions / M&S use Reduction in costs in tooling, error correction, re-learning
Incentivize	Motivation and encouragement regarding the appropriate use, and reuse, M&S	# promotions, awards, rewards for effective M&S application # cost-plus-award fee contracts	Program / area cost reductions from energetic M&S use Reduction in costs of re-hiring / training stagnant personnel
Contracting	Procurement methods that promote effective development and use of M&S	# contracts, by type, awarded across DoD for M&S ° match between contract type and goal (e.g., FFP and R&D)	Cost savings from unneeded contract renegotiation Reduction in unwarranted sunk costs in immature efforts
Intellectual Property	Contractual language that addresses relevant intellectual property concerns	# contracts procuring proprietary / COTS products ° match between application and product qualities	Cost savings from up-front understanding of licensing Cost savings from unneeded contract renegotiation

Table 3.7.4.1-2. Enterprise Metrics.

Enterprise Perspective		Sample Metrics	
Term (*characteristics*)	Definition	Quality	Monetary
Metrics	Processes to identify and capture metrics that reflect M&S investment, expenditures; usage; and impact	# M&S metrics consistently gathered, assessed, and stored # relevant decisions informed by M&S metrics	Cost savings from more effective M&S investment Cost savings from more efficient / effective M&S use
Infrastructure			
Distributed	Robust, flexible, integrated (synchronized), distributed seamless M&S networks	# networks available for M&S applications % availability of networks for just-in-time / last meter use	Reduction in costs from establishing persistent networks Operational cost savings from increase effectiveness
Composable	M&S “composability” and interoperability – including semantics – among M&S systems, databases, etc.	# systems able to join a federation without modification % of M&S system components having congruent functions	Cost savings from federation vice new development Efficiencies resulting from having a “fair fight” environment
Reusable	Awareness and sharing of reusable data, systems, and results	# of reused assets. # current entries in repositories % M&S programs adopting a reuse oriented business model	Cost savings from reuse vice new development or use Reduction in search time from current reuse repositories
Standardize	Relevant standards, guidance, codes of best practice, frameworks, architectures, application interfaces, etc.	# standards adopted and used. # standards organizations % reduction in deployment time from adoption of standards	Cost savings from application of standards Cost avoidance from reduction in instability and eccentricity
Modernize	Address hardware, software, network, and similar limitations	% hardware and software current generation / version # systems able to represent future warfighting concepts	Reduction in accident costs caused by outdated software Cost savings, especially in time, from execution speed
System of Systems			
Congruity	Match of decision maker / user’s decision style to M&S outputs / products	° match between cognitive style and system output % outputs generated correctly understood by user	Cost savings from not acting upon incorrect interpretations Cost effective M&S decisions
Representation	Dynamic, multi-agent / sided, DIME/PMESII, system-of-systems networks, and network-centric concepts in M&S	# systems including advanced representations ° critical features of advanced representations included in M&S	Savings (e.g., force structure) from including these features Reduction in manual / labor intensive representations
Systems Engineering	Systems engineering (SE) and software development coupled to M&S	# M&S efforts using SE principals. % M&S used in SE phases ° of risk reduction through M&S use in SE and SE of M&S	Cost savings from efficient and effective engineering Cost avoidance from reduction in results uncertainty

Table 3.7.4.1-2. Enterprise Metrics.

Enterprise Perspective		Sample Metrics	
Term (*characteristics*)	Definition	Quality	Monetary
Variable Resolution	Variable resolution, including aggregation and de-aggregation, along with congruent / consistent data	# of levels represented. % capabilities able to selectively view % insights gained through selective resolution	Cost savings from facilitated results interpretation Reduction labor for including external / non-integrated M&S
Secure	Systems that resolve relevant multi-level security (MLS) issues	# of MLS enabled systems. # of simultaneous levels % increase in problem space included with MSL functionality	Cost savings from ability to use accurate data sets Reduction in labor required for manual translation of data

Table 3.7.4.1-3. Enterprise Sample Metrics.

		M&S Investment Asset Categories					
		Products & Procedures	People	Facilities	Networks	Software	Hardware
Enterprise Areas	Standards	*Leadership* *Business* *Implementation*	*Leadership*	*Business*	*Infrastructure* *System of Systems*	*Infrastructure* *System of Systems*	*Infrastructure* *System of Systems*
	Policies	*Implementation* *Business*	*Leadership* *Business*	*Business*	*Infrastructure* *System of Systems*	*Infrastructure* *System of Systems*	*Infrastructure* *System of Systems*
	Management	*Leadership* *Implementation*	*Leadership* *Implementation*	*Leadership* *Implementation*	*Leadership* *Implementation*	*Leadership* *Implementation*	*Leadership* *Implementation*
	Tools	*Infrastructure* *Business*	*Leadership* *Implementation*	*Implementation*	*Implementation*	*Implementation*	*Implementation*
	People	*Leadership* *Implementation* *Business*	*Leadership* *Implementation*	*n/a*	*n/a*	*n/a*	*n/a*

3.7.4.2 Community Perspective

The next perspective is that of the DoD M&S Communities. It is articulated in documents that describe the "new approach for managing DoD modeling and simulation (M&S)" and which describe six application areas: acquisition, analysis, planning, testing, training, and experimentation. M&S investment results metrics within this perspective describe the impact of M&S application within that domain and may be unique (metrics on the 'number of dangerous profiles allowed' are important within training but not within assessment). Thus, the metrics described at this level reflect application oriented indicators of success or failure. They structure the evaluation of M&S relative to the relevant alternatives (see Table 3.7.4.2-1 below). In other words, there are many alternatives for accomplishing a mission / goal, of which M&S is one option.

Table 3.7.4.2-1. Community Perspective.

	Community				
	Acquisition	**Analysis**	**Planning**	**Training**	...
Sample Alternatives	Diagrams / Drawings Computer Aided Design Bread boards Hardware in the Loop Emulators Prototypes Mock-ups Wargames M&S	Manual Operations Research Spreadsheet Historical Working Groups Wargames M&S	Manual / Heuristic Plan / Map Briefs Working Groups Operational Rehearsal Wargames M&S	Personalized School House Embedded On the Job Range Command Post Wargames M&S	…

Thus, for example, in research, the ability to reflect the strengths and limitations of differing experimental environments like outdoor settings, laboratories, and simulations. The metrics, when measured relative to each environment, reflect environmental quality and monetary considerations. Foundational work in this area has been conducted by the Navy, both in assessing the value of M&S and in drafting areas of application.[57] See Tables 3.7.4.2-2 and 3.7.4.2-3 that follow.

Table 3.7.4.2-2. Community Metrics.

Community Perspective		Sample Metrics	
Term	**Definition**	**Quality**	**Monetary**
Acquisition			
Research	Representation of fundamental empirical phenomena, especially molecular, physics, and information-based activities	# areas included (e.g., electrical, optical, material, information) ° effects included (e.g., stability, durability, power, heat, light)	Cost savings from M&S of "leap ahead" investigations Reduced investment in areas of limited potential
Technology	Applied research on characteristics of technologies and essential features of their application	# modular, reconfigurable, elemental technology components ° fidelity, variability, accuracy; re known / estimated values	Cost savings from M&S of technology application areas Cost avoidance as a result of not pursuing immature areas
Design	Alternative analysis, especially high fidelity systems representation, and assessing concepts versus defined user needs	# alternatives considered. # user requirements included ° insights relative to key performance parameters by scenario	Cost savings resulting from fewer physical mock-ups Cost avoidance from reduction in design errors
Development	Demonstrate and validate concepts, relative to user needs, considering system parameters, human factors, and similar	# parameters in prototypes. # variables that change over time % performance attributes considered in thresholds / analyses	Reduction in costs from more effective user inputs Cost savings from rapidly changeable, accurate prototypes
Integration	Threshold / objective tradeoffs - performance attribute analysis and integrated system relative to stated specifications	# integration specifications included. % inclusion completeness # insights on system interdependencies / modularity	Cost avoidance from early error detection and correction Cost savings from fewer interface incompatibility fixes
Manufacturing	Product description, manufacturing assessment and automation, assembly approaches, and distribution system	# engineering changes. ° design integrated with manufacturing ° effectiveness of build versus buy analysis. ° real-time checks	Cost savings from manufacturing efficiencies Cost avoidance from reduction in manual interventions
Operations	Utilization of platform, system, or system-of-systems in deployed environment, including scenario variations	% system failures forecast. # correct environmental predictions ° impact on warfare mission and support area effectiveness	Reduction in fuel, wear-n-tear, etc. from optimized routes Cost avoidance from duplicative weapon's employment
Sustainment / Logistics	Supply support / maintenance processes, alternatives, trade-offs. Operational logistics activities and predictions	# items tracked re status, location, … # / rate / % items used % logistics represented. Association / impact on warfighting	Cost savings from effective just-in-time maintenance Cost savings from efficiencies in logistics coordination
Time to Market	Elapse time from concept development to operational deployment	° match between requirements and acquisition system delivery t duration of design, manufacturing, first assembly, etc.	Cost savings from reduced labor hours, travel, per diem Costs avoided from effective collaboration reducing time

Table 3.7.4.2-2. Community Metrics.

Community Perspective		Sample Metrics	
Term	**Definition**	**Quality**	**Monetary**
Analysis			
Alternatives	Input, scenario, force structure, output, and similar variability	# alternatives, scenarios / variables, analysis runs, outputs ° match between baseline / excursions and planning guidance	Cost savings from reduced labor hours given quicker turn t Cost avoidance from reduced (SME) personnel utilization
Complexity	Number, level, and sophistication of the interconnectivity between interactions, processes, and outputs generated	# representations by level. # output types produced per run ° adequate representation of key scenario interactions	Cost savings from relevant analysis – train, man, equip, … Cost avoidance from reduced reliance on disparate tools
Reproducibility	Degree results can be re-generated or repeated at a different time or location	# input parameters and # outputs. # sources of variation. % difference between original and subsequent results	Cost avoidance from automated / robust sensitivity analysis Cost savings from labor, travel, etc. needed to repeat event
Visibility	Ability to view and understand the internal workings of the system and comprehend the results	# analysis-oriented results. # layers / interactions observable ° results are understandable re / relevant to input scenario	Cost reduction from decreased interpretation labor hours Cost savings re time to generate results summaries
Accuracy	Correlation between the outputs of the tool / approach and empirical / actual results	% deviation – overall and by input, type, area, process, output ° connections between warfighting, C4ISR, logistics, etc.	Cost avoidance from reduction in uncertainty intervals Cost savings relative to using actual equipment for analysis
Results Time	Elapse time from problem definition to results generation	t match between requirements and analysis product delivery ° subsequent decisions more informed based on early results	Cost savings from reduced labor hours given quicker turn t Cost avoidance from earlier analytic inputs to decisions
Planning			
Automation	Incorporation of guidance, tasking orders / common operational picture (COP) in decision support system (DSS)	# robust C4ISR interfaces. % match relevant COP and DSS ° effort required to enter relevant scenario into DSS	Cost savings from reduced labor to manually insert data Cost avoidance from poor decisions from incomplete data
Projection	Ability to accurately forecast relevant outcomes. Causal reasoning to predict future events and conditions	% match between predicted and actual outcomes ° system includes areas of interest and reflects dependencies	Cost savings from being able to anticipate and adapt Cost reductions from increased acquisition efficiency
Familiarity	Prior to plan execution, the scenario knowledge gained. Operationally via mission planning / mission rehearsal systems	% match between scene generated and actual ° plan execution is more effective given scenario awareness	Cost savings from improved planning and error avoidance Cost savings from effective task allocation to performers

Table 3.7.4.2-2. Community Metrics.

Community Perspective		Sample Metrics	
Term	**Definition**	**Quality**	**Monetary**
Comprehensiveness	Capability to represent all critical aspects of plan or mission. Quality and quantity of plans / courses of action assessed	# sub-components, linkages, conditions / states included ° system includes adequate representation of key variables	Cost avoidance from reduction in errors of omission Cost savings from reduction in uncertainty of outcomes
Proximity	Location of support tools, decision support systems, tactical decision aids, etc. Co-located, local, reach-back, etc.	d distance from users. # available underway / in theater ° DSS outputs are available where needed to support planning	Cost savings from reduction in travel to provide results Cost savings from increased accuracy due to local iteration
Alteration	Ability to modify original plan / course of action analysis to adapt to new data, inputs, conditions, situations, scenarios	# steps / entry points required. % associated data updated ° DSS can be altered in a timely manner to adapt to changes	Cost avoidance from reduced error / delta from old data Cost savings from reduced labor hours to enter new data
Cycle Time	Elapse time from planning / course of action entry to evaluation output or mission rehearsal environment completion	t duration between plan input and results generation ° subsequent decisions more informed based on early results	Cost savings from reduced labor hours given quicker turn t Cost avoidance from earlier inputs to planning decisions
		Testing	
Design	Develop effective T&E events, venues, systems, supporting ranges / federations, sequences of activities, and similar	# alternatives able to consider. # / % interfaces included ° assets / events augment each other and are orchestrated	Cost savings from effective use of least-cost alternatives Cost avoidance from limited use of live assets / ranges
Augmentation	Extend, extrapolate, or add data generation / analysis opportunities	# / % insights generated synthetically. # data-points added ° output, unavailable from live venues, provides critical insights	Cost savings from synthetic representation vice live Cost reduction from less acquisition error from limited data
Adequacy	Assess sufficiency of tests types, locations, capabilities and limitations, etc. to achieve objectives – near and long term	# outputs / objectives able to include. % variation understood ° coverage, strengths, weaknesses, and risks articulated	Cost savings from T&E results understanding / optimization Cost avoidance from effective use of T&E venues / types
Extrapolation	Extend scenario / venue availability and results, especially given range / live test restrictions	% derived data. # additional variables. ° confidence in results ° result extensions add insights, especially at T&E boundaries	Cost savings from synthetic extrapolations vice live events Cost avoidance from T&E event tailoring given prior results
Completion Time	Duration between test planning and event output / analytic product delivery	t duration between T&E event and analysis product delivery ° match between T&E activities and system requirements	Cost savings from faster T&E results in system production Cost avoidance re delivery time (fewer scheduling fixes)

Table 3.7.4.2-2. Community Metrics.

Community Perspective		Sample Metrics	
Term	**Definition**	**Quality**	**Monetary**
		Training	
Accessibility	Degree to which an appropriate venue exists, can be reached, and is ready	# locations available. # of restrictions by type. % time open ° venue meets requirements (profiles, weapons use, etc.)	Cost savings from travel reduction from co-located trainers Cost avoidance from rescheduling training given weather ...
Flexibility	Ability of the system to be used within other application areas / communities	# other communities can use. % change required for use ° system, data, infrastructure can be use for other applications	Cost savings from multiple use of common asset Cost avoidance from being able to tailor tool for new uses
Force Management	Capability to orchestrate events, schedules, qualifications, personnel, needed assets, and similar to meet goals	# relevant factors considered. # of factor interconnections ° system tracks, stores, projects, reconciles relevant factors	Cost savings from efficient and effective training delivery Cost avoidance from schedule, class, student, … changes
Environmental	Consideration of environmental concerns; local, state, national, and international; near, mid, and long term	# ecosystems considered. # system interconnections ° system can help avoid, minimize, remediate training damage	Cost savings from reduced environmental impact Cost avoidance from unintended environmental damage
Readiness	Impact on personnel / force capabilities to conduct operations	# systems & ready units. # students / forces using system. ° correlation between force readiness and use of system	Cost savings from meeting readiness goals - not over/under Cost avoidance from readiness (less need for redundancy)
Retention Time	Length of time that students are able to recall lessons presented	t duration / degree of learning / personnel readiness over time ° match between training and user / operational requirements	Cost savings from timely training and retraining re goals Cost avoidance from error reduction given timely training
		Experimentation	
Discovery	Ability to represent novel / unique problem-spaces / scenarios – re processes, events, organizations, technologies, etc.	# innovations included. ° innovations associated (intra, inter) ° original systems, concepts, … can be meaningfully included	Cost savings from 'leap-ahead' innovations Cost avoidance from technical benefits to existing systems
Doctrine	Represent and adjudicate initial – and subsequent / matured - war fighter concepts of operation, mission procedures	# doctrines, by mission area, represented. % doctrine included ° doctrine accurately impacts system and overall outcomes	Cost savings from asset efficient doctrine development Cost avoidance from effective doctrine re current systems
Technology	Specific technology / system representation, coverage, understanding, and relevant verification / validation	# technologies, by type. ° / % technology included. # impacts ° technology, and associated changes in procedures, included	Cost savings from 'leap-ahead' technologies Cost avoidance from effective integration of technologies

Table 3.7.4.2-2. Community Metrics.

Community Perspective		Sample Metrics	
Term	**Definition**	**Quality**	**Monetary**
Employment	Capability to use operational data, reach-back to relevant facilities, and stress systems to failure	# / ° operational C4ISR systems, data, links, etc. incorporated ° employed / deployed systems are meaningfully included	Cost avoidance from not deploying immature items Cost avoidance from reducing potential mistakes / errors
Cycle Time	Duration between experiment planning, execution, and after action review	t duration between experiment and analysis product delivery ° match between experimental actions and requirements	Cost savings from earlier results in systems acquisition Cost savings from reduced labor / travel in synthetic events

Table 3.7.4.2-3. Community Sample Metrics.

		M&S Investment Asset Categories					
		Products and Procedures	**People**	**Facilities**	**Networks**	**Software**	**Hardware**
Communities	Acquisition	*Acquisition*					
	Analysis	*Analysis*					
	Planning	*Planning*					
	Testing	*Testing*					
	Training	*Training*					
	Experimentation	*Experimentation*					

3.7.4.3 Program Perspective

The third and final perspective is that of the program; which is especially critical yet equally complex. The criticality comes from the fact that DoD-wide enterprise and/or community M&S investment often manifests its result at the programmatic level. The complexity comes from, in part; the nature of M&S programs – which sometimes span multiple communities, multiple areas within a community, are themselves a program, or are applied within a program.

They have been structured using the results from an Office of Naval Research (ONR) effort to develop and describe a set of modeling and simulation, (and game) characteristics. In this effort, forty one characteristics were grouped into eight classes. The first three classes of applicability, availability, and affordability are the first ones that must be addressed by a program manager attempting to build or procure a model or simulation. The next set of characteristics describes M&S features that are important in the system's application. Whether the model or simulation provides sound analytic results, is entertaining, or user friendly. Another feature that is often important to assess when reviewing M&S are their credibility. That is, how accurate are they and how accepted is their use and the results they generate. Finally, the technical features of a model or simulation can be very critical. That is, whether the system is modular, interoperable, portable, and similar concerns.[58]

From the Program perspective there are at least two key applications of M&S investment metrics. The first is in comparing M&S program development concepts. For instance, how does simulation program A compare to simulation program B in supporting a mission or producing a product – like analysis. The second is in the evaluation of M&S use in support of accomplishing specific program missions relative to other alternatives – manual, live, war games, etc. (which is similar to the community perspective, but this view is more detailed (system-specific) in it's examination (see Tables 3.7.4.3-1 and 3.7.4.3-2 below).

Table 3.7.4.3-1. Program Metrics.

Program Perspective		Sample Metrics	
Term	**Definition**	**Quality**	**Monetary**
Applicable			
Applicability	Tool or system provides outputs / measures that support mission or application accomplishment	# / % relevant measures of merit. # application needs met ° system outputs, products meet / match mission requirements	Cost savings through meeting mission goals efficiently Cost avoidance from reduced need to develop new tools
Impact	Inputs, processes, and outcomes, relative to the mission's goal or application use	# inputs / processes / outcomes. % change from previous ° system effects the accomplishment of the mission or activity	Cost savings when impacts positive / promote efficiencies Cost avoidance when impacts obviate expenditures
Longevity	Useful outputs, impacts, insights, etc. over a long time	t duration outputs remembered / used. # passed down / reused ° outputs (positive and negative) are useful over time	Cost savings from not having to rediscover outputs Cost avoidance from applying lessons learned over time
Available			
Availability	Systems exist, and if so, are attainable - along with supporting data, infrastructure, licensing / rights, etc.	# references. # systems. t between identifying, wanting, getting ° applicable system can be found and used efficiently	Cost savings from reduced searching, development Cost avoidance from pre-existing system use, documents...
Fidelity	Represents (includes) important features / items: in terms of both types and numbers	# items included, by type. # specific / unique features by item ° system matches the types, numbers, interactions needed	Cost savings from % items non-live / synthetic Cost avoidance from commonality of items re management
Resolution	Includes relevant features / items at a particular level (e.g., physics, engineering, mission, theater, campaign, political)	n level. % items at specified level. # inter / intra-interactions ° system has level needed and in / outputs from above / below	Cost savings from accurate results at level specified Cost avoidance from understanding of interactions
Affordable			
Affordability	Can achieve mission goals within the budget specified: near, mid, and long range	% budget used. °system procurement (build, buy, lease / rent, reuse) makes option reasonable relative to viable choices	Cost savings from un-needed changes re budget overruns Cost avoidance from realizing affordable solutions
Cost Effectiveness	Provides benefits that are worth the costs required for the system's development and use	# / ° cost adjusted benefits accrued. t duration of benefit ° system provides capability in excess of its expenditures	Cost savings as compared to less efficient approaches Cost avoidance to others from application reuse

Table 3.7.4.3-1. Program Metrics.

Program Perspective		Sample Metrics	
Term	**Definition**	**Quality**	**Monetary**
Manageability	Can be used, and results obtained, without undue expenditures on coordination and oversight	# managers / locations / licenses / hardware suites / databases ° configuration stable, personnel experienced, plan detailed	Cost savings from unneeded labor, travel... for coordination Cost avoidance from reduction in uncertainties
Support Needs	Manpower, facilities, computers, licenses, networks, or other infrastructure	# / % t of support, by type and over time. # owned, leased, … ° needs for system set-up, application / runs, post-processing	Cost savings from applications with 'small footprints' Cost avoidance from reducing fractional use of support
Analytic			
Traceable	Outputs can be associated with inputs, interconnections determined, and processes understood	# inputs / outputs. % correlation outputs and inputs. ° causality, dependency, sequences, etc. can be determined	Cost savings in labor from manual output reconstruction Cost avoidance from reductions in misunderstandings
Powerful	Provides key insights to users / decision makers, in a format they understand and can apply	# insights. % significant. % delta from initial state/assumptions ° system provides useful outputs or positively changes ideas	Cost savings from rapid understanding of key data Cost avoidance compared to manual / labor intensive tools
Innovative	Includes significant new capabilities or provide functionality in a exceptional way	# innovations. % difference from prior. # old items replaced ° analytic functionality/algorithms/implementation are unique	Cost savings when innovations reduce labor, runtime, etc. Cost avoidance through reduction in factors not included
Confidence	Degree error propagation and uncertainty are understood and output confidence intervals / probabilities represented	# error types. % input and output error. # errors displayed ° output presentation includes error / uncertainty indices	Cost savings from more informed decision making Cost avoidance from reduction in misguided choices
Engaging			
Emotive	Involves players by stimulating feelings of competition, loyalty, fear, adventure / discovery, challenge, or similar	# emotive dimensions. # interactions with user and % changes ° user is drawn in / motivated to participate in environment	Cost savings from achieving goal (e.g., training) quickly, … Cost avoidance through reducing impact of distractions
Interactive	Provides appropriate and timely responses (continuous, reactive, etc.) to user input	t delay between input / system reaction. # / rate of changes ° system properly responds to user inputs / actions	Cost savings from achieving goal (e.g., training) quickly, … Cost avoidance through reducing impact of distractions

Table 3.7.4.3-1. Program Metrics.

Program Perspective		Sample Metrics	
Term	**Definition**	**Quality**	**Monetary**
Adaptive	Ability of the system to adjust the environment / scenario to user inputs, reactions, skills mastered, goals achieved, etc.	# scenario scripts / threads. % alteration allowed. # branches ° system changes to meet user needs / goals seamlessly	Cost savings from achieving goal (e.g., training) quickly, … Cost avoidance through reducing impact of distractions
Verisimilitude	Promotes suspension of disbelief and immerses users in the environment. Appears to be real	% delta between environment / reality. # immersive cues ° users / players / participants forget the environment's not real	Cost savings from achieving goal (e.g., training) quickly, … Cost avoidance through reducing impact of distractions
Usable			
User Friendliness	Can be employed without extensive training	# hours training required. # help entries. % items with help ° system is intuitive / includes guides and defaults gracefully	Cost savings in labor from ease in understanding system Cost avoidance from reduction in user disinterest
Accessibility	Data and algorithms can be inspected and are maintained in a manageable form	# data & algorithm views. # macros for parsing. # standards ° users can access, understand, & view results re algorithms	Cost savings in labor from ease in understanding system Cost avoidance from reduction in manual processes
Inter-visibility	Allows observation of interactions between levels of abstraction, processes, functions, or activities	# / % levels accessible. # interaction points / threads. ° users can access, understand, & view relevant connections	Cost savings in labor from ease in understanding system Cost avoidance from reduction in manual processes
Credible			
Credibility	Produces results that are logical	# results. % results match expectations. % can be explained ° system generates outputs that are reasonable	Cost savings in labor from ease in understanding system Cost avoidance from reduction in manual processes
Accredited	Been formally recognized as being appropriate for an application	# accreditations. # applications. % match accreditation / use ° system has been accepted (risks acknowledged) for use	Cost savings from reduction in more costly approaches Cost avoidance from consistent results in application
Validity	Correctly represents the critical variables, for a given application	# / % critical variables included. # relevant applications ° system accurately / usefully includes key factors	Cost savings from accurate representations of systems Cost avoidance from labor to manually reassess
Accuracy	Faithfully represents the relevant features of the original	% deviation from original / empirical. # abstractions / HWIL ° system correctly includes the relevant	Cost avoidance from reduction in errors of omission Cost savings from reduction in

Table 3.7.4.3-1. Program Metrics.

Program Perspective		Sample Metrics	
Term	**Definition**	**Quality**	**Monetary**
		features	uncertainty of inclusion
Repeatability	Yields the same results when input conditions are the same	# input variations. # stochastic processes. % error / uncertainty ° system will produce similar / same outputs with same inputs	Cost savings from automated repetition of system variation Cost avoidance from reduction in output uncertainty
Verified	Acts according to its design	# data sets / algorithms / outputs tested. % deviation ° system acts as intended / designed in outputs / products	Cost savings from stable representations of systems Cost avoidance from understanding of system interactions
Technical			
Maintainability	Allows the identification, understanding, and correction of errors	# access points. # error correction routines. ° t MTBR ° system can be updated and problems resolved	Cost savings from automated vice labor intensive functions Cost avoidance from reduced down-time due to errors
Modifiability	Construction / composition can be changed and updated (e.g., source code)	# components / algorithms. # / type programming language ° system can be enhanced to add functionality	Cost savings from reduced labor due to sound design Cost avoidance from reduced time to enhance / update
Re-configurability	Input values and parameters can vary (e.g., data files)	# / location / modularity / flexibility of input files / databases. ° system can be altered to run on other systems / hardware	Cost savings from not having to develop a new system Cost avoidance from modularity, thus simplified re-hosting
Adaptability	Can be used in a different application area or in a different way	# additional applications / innovative uses / roles / outputs ° system can be modified to address additional requirements	Cost savings from not having to develop a new system Cost avoidance from reducing labor, etc. in new uses
Expandability	Can include features not originally envisioned / encoded	# additional functional areas / layers / types of expansion ° system can be grown to meet new / additional needs	Cost savings from not having to develop a new system Cost avoidance from reducing labor, etc. in new uses
Time Flexibility	Can adapt to the timing parameters of a new application	# time approaches available. % available relative to real time ° system can slow down or speed up to meet requirements	Cost savings from not having to develop a new system Cost avoidance from reducing labor, etc. in new uses
Supportability	Resources needed (manpower or funds) to conduct / run it	# labor hours / personnel required: normal, per upgrade, etc. ° system requires labor to run / keep it	Cost savings when supportability is low because of design Cost avoidance from reduction in labor to

Table 3.7.4.3-1. Program Metrics.

Program Perspective		Sample Metrics	
Term	**Definition**	**Quality**	**Monetary**
		current	use system

Table 3.7.4.3-1. Program Metrics.

Program Perspective		Sample Metrics	
Term	**Definition**	**Quality**	**Monetary**
Modularity	Components are internally consistent and loosely coupled	# modules. % interconnected. # inheritance layers and types ° system can be coupled and decoupled to meet needs	Cost savings from efficient and effective design re logistics Cost avoidance from reduced labor to understand design
Composability	Can be quickly reconfigured and federated with others; often via automated tools	# additional systems that can be included. T taken to include ° system, architecture, meta-data allow automated federation	Cost savings from combining system modules vice new Cost avoidance from reduced labor to interoperate systems
Scalability	Can accommodate a large increase in users, workload, or transactions without strain	# / % delta between normal / peak user ship / processes / etc. ° system gracefully allows increases in users, processes, etc.	Cost savings from not having to develop a new system Cost avoidance from reducing labor, etc. in adding users
Interoperability	Has the capability / can be modified in a timely manner to pass / receive results / data, syntactic, semantic information	# systems it can interoperate with. % / ° interoperability. ° system has stable / defined interfaces / can exchange data	Cost savings from not having to develop internal modules Cost avoidance from reduced time / labor to add functions
Standardization	Conforms to standards including hardware, software, database, interface, application, databases, etc.	# standards / version # conformed to. ° / type of conformance ° system adheres to adopted / consistent frameworks, etc.	Cost savings from increased efficiencies / understandability Cost avoidance from reduced time to upgrade, expand, etc.
Efficiency	Executes quickly given their architecture and size / lines of code	t runtime. Operations / functions / activities per unit time ° system runs acceptably given size, complexity, outputs, etc.	Cost savings from reduced time to generate results Cost avoidance from effective / efficient design
Portability	Can be employed / conducted at alternate sites or using varied hardware or software configurations	# / type hardware / operating systems can run on ° system can be transferred from one location to another	Cost savings from not having to develop a new system Cost avoidance from reducing labor, etc. in new uses
Reliability	Will run without errors, is stable and dependable	# errors per unit time. T mean-time between failure ° system predicts as expected / with low errors / crashes	Cost savings from reduced system down-time when used Cost avoidance from reduced confidence in system

Table 3.7.4.3-1. Program Metrics.

Program Perspective		Sample Metrics	
Term	**Definition**	**Quality**	**Monetary**
Architectural Flexibility	Supports distributed, synchronous / asynchronous, multi-level application	# / ° architectures supported. Specific versions implemented ° architectures are described, used, allow elasticity	Cost savings from not having to develop a new system Cost avoidance from reducing labor, etc. in new uses

Table 3.7.4.3-1. Program Metrics.

Program Perspective		Sample Metrics	
Term	**Definition**	**Quality**	**Monetary**
Fundamental Features	Includes speed, lines of code, design, architecture (empirical characteristics)	t elapse time per function. # lines of code. # interconnections # / type database used. Programming language. Access type	n/a

Table 3.7.4.3-2. Program Sample Metrics.

		M&S Investment Asset Categories					
		Products and Procedures	**People**	**Facilities**	**Networks**	**Softwar e**	**Hardwar e**
Program Areas	Basic and Advance Research	*Applicable* *Available* *Affordable*	*Analytic* *Engaging* *Usable* *Credible*	*Technical*			
	Advanced Development and Engineering Design						
	Development and Integration						
	Demonstration and Evaluation						
	Procurement, Production, Deployment						
	Operations, Maintenance, and Support						
	Retirement and Remediation						

3.7.5 Conclusions and Recommendations

Calculating metrics that reflect M&S investment must use an approach that is rigorously constructed and applied; terms accurately defined; asset, cost, and result factors consistently structured; and results fairly presented. This effort has made significant strides in these areas. Specifically, the methodology defines key terms, requisite assumptions, and relevant perspectives; accounts for the complete range of results alternatives; provides metrics with specific types, levels, assessment methods and structure; articulates sample metrics by perspective; and derives specific and overall conclusions and results. The results methodology also generated a set of metric types, specific to point of view, that begin to encompass measures that reflect the impact of M&S investment in that area.

- √ ***The approach used for calculating M&S investments metrics must be rigorously constructed and applied, terms accurately defined, results factors consistently structured and results fairly presented.***
- √ ***Although this effort made significant strides in advancing the state-of-the-art there is important work that needs to follow.***

Although this effort made significant strides in advancing the state-of-the-art in M&S value assessment, there is significant work that needs to follow. The structure developed needs to be refined, the metrics developed matured, the guidance on application considerably extended, and the requisite data gathering significantly expanded. Only when these additional steps are complete will the methodology be ready for comprehensive application.

3.7.5.1 Issues, Risks, and Remediation Approaches

There are two significant challenges to the implementation of the results metrics approach described in this section. The first is relative to the data needed. Each of the proposed metrics must be measured in a consistent and accurate manner. The next challenge to implementing the approach is the complexity brought on by the three perspectives. Each needs to be adequately considered in the development and application of the processes described.

Two ways to help remediate these risks are to take an incremental approach – with a focus on 'crawl, walk, run' proof-of-principle cases. That will allow the approach to mature and improve as it is applied. The next remediation strategy is through the use of lessons learned from other domains. M&S, as an information technology tool, is similar to other tools that have been developed, applied, and assessed (see GAO report). Thus, applying the insights learned through similar analysis in parallel technology areas will help lessen the risk of utilization.

3.7.5.2 A Next Step

Calculating metrics that reflect the results of M&S investment, like in most analytic efforts, will benefit from increased specificity. For instance, further decomposing the three perspectives, with individually identified objectives / sub-components against which more detailed metrics can be associated would be beneficial. A sample is shown in Table 3.5.5.2-1 below.

Table 3.7.5.2-1. An Example of Progressively Detailed Metrics.

Area	Objectives / Sub-Components	Activity Metrics		Effectiveness Metrics	
		Quality	Monetary	Quality	Monetary
Infrastructure	Fosters / Promotes	# repositories # rep entries and registered users # presentations given # advertisements Time from query to reply	$s saved from search reduction time and complexity $s saved on labor, travel, etc. for information gathering	# extracted and reuse repository entries # programmatic / M&S relevant changes based on information learned	$s not spent on local / specific M&S repository development $s not spent on duplicative and previously unknown M&S functionality
	Accessible and Applicable	# / rank within search engines # M&S systems in repositories # total / # relevant found Time update rates of holdings	$s saved from search reduction time and complexity $s saved from reduction in time to understand M&S capabilities	° consistent semantics / DB structure used % match between need and M&S repository holdings	$s not spent on M&S development $s not spent on M&S tailoring

3.8 ROI Algorithm Options

ROI is an intuitive and suggestive indicator of investment viability. However, ROI is itself sensitive to alternative interpretations in both public and private sector environments. In this study these distinctions were articulated and used to guide development of an approach to the definition and use of a form of ROI best suited to DoD investment analysis.

3.8.1 Introduction and Background

> **√ ROI is a common metric used systematically and effectively in private sector investment system analysis.**
>
> **√ Peculiarities of the DoD public sector business model necessitates analysis of nominal ROI calculation and creation of suitable derived metrics better suited to government business practice.**

The phrase "financial analysis" means the manner in which economists and other specially-trained professionals go about evaluating the decisions made by individuals or enterprises that operating in a capitalistic, free-market system. The Chartered Financial Analyst (CFA) Institute[59] defines 'financial analysis' as, "The process of selecting, evaluating, and interpreting financial data in order to formulate an assessment of a company's present and future financial condition and performance."[60] While the CFA Institute focuses on commercial, for-profit enterprises, the principals of thorough analysis, thoughtful consideration, and meticulous examination are equally relevant to study of DoD's M&S investment practice.

3.8.2 Current Circumstance and Context

The concept of "return," in its most basic formulations – the *return* on an investment, the *return* on a solar panel, the *return* on one's time, the *return* of a financial instrument (such as a bond), etc. – is essentially a way to measure the benefit received as the result of some action, or set of actions. Specifically, calculations that consider return are really trying to answer a question, or set of questions, about how much benefit (or value) is/was derived from an activity, use of capital, or some specific endeavor.

In financial analysis, the concept of return is principally used to measure the change in “value” of something, usually over time. As such, return is generally used by the financial community to determine both whether or not the benefit of an investment (or similar action) was a) positive or negative – we will refer to this as the “direction” of the change, and b) how positive or negative the change was – we will refer to this as the “magnitude.” Financial analysts typically calculate only one value from which an analyst can ascertain both direction and magnitude (a number and a positive or negative sign). The singularity of the calculation is possible because analysts are typically comparing changes in a single, same quantity: money – in the U.S., dollars.

Whether we are discussing the value of a stock’s performance, looking at how much a company’s sales have increased due to management’s changes, or considering the affects of purchasing a piece of equipment, financial analysts are subject to applying various industry conventions, which enable apples-to-apples (dollars-to-dollars) comparisons. Similarly, accounting standards (e.g., US GAAP[61] or International Financial Reporting Standards (IFRS)[62]) and other conventions (taught in finance classes, codified by professional groups, and used by practitioners in the field) are applied to help analysts convert the “value” of goods, services, equipment, time, energy, and all the rest into dollars.

3.8.3 Approach

Financial and accounting industry conventions work very well for those groups, since the transactions covered by those conventions have certain basic similarities; that is, the transactions meet specific criteria. A full description of scope and effectiveness of financial, economic, and accounting conventions is beyond the scope of this report; but of note, accounting conventions is very much a topic of debate among professors, policy makers, and the rest.

The DoD differs from a for-profit organization in many aspects. Section 3.1 of this report addresses the differences between a free-market environment and the operational setting existing within the DoD in considerable detail. From that study, and examination of asset analysis and metrics as described above, two characteristics have been identified that serve as primary discriminators between DoD and non-DoD/commercial investment practice.

First, DoD M&S investments do not, in general, have “revenue” associated with them; that is, when the DoD expends resources and receives (for, or related to, that expenditure) a product or service, no cash flow is expected to come back into the DoD. Rather, the DoD receives a product or service – one that certainly has benefit/value, but one that does not (and, most likely, never will) generate revenue for the Department. The lack of revenue-generating ability is not a bad thing, but it creates a requirement to adjust the methodologies[63] used in financial analysis so as to make them suitable in the DoD M&S environment.

Second, within the DoD there is no pricing – or valuation – system that is similar or comparable to that provided by the "free market." In a capitalist, free-market economy, the "value" of a good or service is what someone else will pay you for it; that is, supply and demand determines value. Within the DoD, however, there is no external - or, impartial - system of "price discovery", due to the fact that there are a fixed number or projects to choose from that will satisfy the aims that have been decided on either by situational necessity or policy makers, and a specified budget to achieve those ends. The DoD practice is rather to typically rely primarily on comparisons between the expense (cost) of different projects. While expense is one way in which monetary value can be/is assigned to a project/program, the cost paid for a product is neither a complete nor sufficient means of evaluation.

As noted above, DoD-M&S investments typically do not have "making money" as their primary aim. Rather, the aim is related to the project's (or relevant mission's) individual priorities – whether these are increasing the accuracy of a missile, better protecting ground forces, evaluating the results of a tactical choice, or any of the thousands of other items the Department must continually evaluate. The critical point to note here is that the "benefits" – that is, the "value" – that results from a DoD-M&S investment include, almost always, significant non-financial aspects. The limitations of using only expense (cost) of a project/program as a method of evaluation is addressed in detail in Sections 3.6 and 3.7 of this report. Value is not easily (or efficiently) translatable into dollar terms, primarily since there is 1) no revenue or cash flows resulting from the investment, and 2) no way in which the value can be assigned by a marketplace price mechanism.

So how do financial analysts typically calculate return? There are, broadly speaking, three different methodologies, which we will refer to herein as the "Three Formulations." The First and Second Formulations are based on percentage calculations, and are the methods typically associated by most individuals with "ROI." The Third Formulation takes into account the amount of time over which the task is to be performed and the relative risk involved.

The first two ways financial analysis measures return is: (1) as a percentage increase in a holding's value between two time periods,[64] and (2) as the amount of cash (or, revenue) generated from a set, fixed asset base[65]. Herein, we will refer to the proceeding two general methods of calculating return as the First Formation and the Second Formation, respectively. To be sure, there are differences in the precise nomenclature used, and the specific attributes of a business or investment measured, when applying the general formulation to specific instances. However, the general forms of these two expressions (and corresponding equations) are maintained.

The First Formulation – return as a percentage increase in a holding's value between two time periods – is generally expressed as:

$$\% \text{ Return} = [(V_{end} - V_{begin} + CF) / V_{begin}] * 100$$

Where: V_{end} is the value at the end of a portion of time, V_{begin} is the value at the beginning, and CF is the sum of all cash flows that come about as a direct result of having made the investment.

The Second Formulation – the amount of cash (or, revenue) generated from a set, fixed asset base – is commonly found in corporate finance when an analyst/investor is interested in calculating how value can be derived from something the organization owns. Here we use the general form of the Second Formulation as:

% Return = [(benefit) / (base)] * 100

Where: Benefit is the results (such as net income, revenue, yield, etc.) from a fixed Base of some type (total assets, total equity, total capital expenditure, etc.).

While the First and Second Formulations are suitable as a way in which to calculate return for most circumstances, both fail to take into account two very important attributes: (1) risk, and (2) the time value of money (TVM).

Financial analysis is virtually obsessed with risk. And, there are many different types of risks to which financial analysts pay attention.[66] One of the most basic ideas in financial analysis is that in an efficient market risk and return are related.[67] A result of this relationship is that the greater the amount of risk a project has the higher the potential return should be.[68] As such, financial analysis seeks to adjust calculations – such as return – based on the risk level. The amount of time a project takes – its duration – is also a factor that affects the risk level. It is these attributes that the First and Second Formulations, when used in isolation, do not take into account. However, by using "discounting rates" to adjust values we can take into account these attributes.

TVM is simply the idea that a dollar today is worth more than a dollar in one year.[69] There are a great many ways to express this concept; however, all one really needs to do is consider the price of stamps, which are more expensive now than they were three years ago, a trend that is unlikely to abate. Regardless of whether the adjustment for the TVM is positive (inflation) or negative (deflation), the basic point that time matters – that is, that time affects the value of money – remains constant. Therefore, the issue simply becomes how – the manner and magnitude – we adjust for this feature.

Typically in financial analysis, TVM comes into play most frequently when we look at discounted cash flows (either expenses or revenue). As such, when we calculate either a NPV[70] or IRR[71] of a project/initiative/investment, we use discounting rates. While the discounting rate can (and is) used to adjust for TVM, it can also be employed to adjust for the risk of an investment. In order to adjust for higher risk, we simply use a greater discounting rate. The discounting rate then becomes the sum of the adjustment needed to compensate for TVM plus an "extra" adjustment for risk.

The magnitude of the risk-related adjustment varies from case-to-case and is determined by the analyst/decision-maker. That no one set of "standard adjustments" exists does not present a problem, since we are always comparing a fixed set of options against each other. What is far more important than adhering to an external, rigid set of "standards" is that we apply both our adjustments and tools consistently when evaluating the different options we have available to us. The concept of consistency is something that we will return to at the end of this section.

3.8.4 Findings

So how *do* we apply the concepts of financial analysis to DoD-M&S projects in the face of the differences we have mentioned? As we have seen, a one-to-one transposition of financial analysis concepts (the Three Formulations for evaluating ROI) is not possible due to the differences in operational environments that we have just reviewed. However, financial analysis does provide us with two key items that we must "carry forward" into our evaluation.

First are the concepts of magnitude and directionality that we touched on at the beginning of this section. In order to make a decision between a finite set of options, one does not necessarily need to rank said choices according to a specific number. Rather, what is needed is to be able to get a relative sense of order; that is, be able to say which one is better than the others. Therefore, while we might not be able to assign a specific dollar value to the benefit of one choice over another, by using directionality and magnitude, we can arrive at a "relative ranking" that will let us compare those options we are seeking to decide between. The Three Formulations used in calculating financial returns all make use of the concept of magnitude and direction.

Second is the notion of "internal consistency" in evaluating different options. If we are not able to gain an absolute value (such as, say 83%), but are to rely on relative values (A is better than B, which is better than C), we must make sure that we are consistently applying the same evaluation criteria to all the potential choices. Likewise, in Section 3.6 of this report we will thoroughly look at how we should evaluate the costs/expenses associated with the various options we wish to judge. After all, we must not only seek to be consistent with regard to the benefits of a project, but also about how we calculate costs.

The actual manner in which we arrive at an answer using the concepts described above is described thoroughly in Section 3.9. However, the methodology used in that Section is completely consistent with the manner in which financial analysis seeks to evaluate return. The only variations between our methodology and using one of the three formulaic expressions described above arise because of the differences in the operating environments in which for-profit organizations and the DoD operate.

> √ ***When dealing with non-probabilistic data and wanting to make objective decisions, a process is required which does not rely on chance, takes into the account the data gathered as part of this study, is fundamentally simple to explain and defend, and is consistent.***

3.9 Investment Decision Process

3.9.1 Introduction and Background

Having now determined metrics for the costs and value associated with an investment, we now are in a position to decide whether or not to make the investment using these metrics and others. There are many different ways to make decisions, some as simple as flipping a coin (which ignores all the data), others as sophisticated as multi-level algorithms perhaps involving neural networks and machine learning techniques (See Appendix J for a more complete discussion of the decision processes). However, in situations like these where we have non-probabilistic data and we wish to make a objective decision, or at least as objective as we are able, a decision process which does not rely upon chance, takes into account the data we have gathered, is fundamentally simple to explain and defend to outside agencies, and that is consistent (would give the same answer each time with the same data), is most desirable.

It is important to note that even if there is only one option, there is always a choice. There is always the decision to invest in a project or keep the status quo (not invest in anything). Keeping the current state may mean that a DoD mandate does not get met, or that a capability that is deemed essential is not developed, but that is still always a choice and to leave this option out of the decision process would be incomplete. It may be that all the alternatives are worse than the status quo and that would cause one to "go back to the drawing board" to look for different ways to meet the requirement.

3.9.2 Current Circumstance and Context

Currently we do not know of any structured decision process that is employed by the DoD in determining how to invest in M&S assets. There is a procedure to submit a project or idea and compete for funding, but no methodical, objective, decision process is used to decide among the various M&S investments that are presented to the DoD. Therefore, our proposed method will be new to the DoD procedure and we cannot build simply on what already exists in the DoD M&S investment process.

3.9.3 Approach

Rational actors, when faced with a decision will choose that option which maximizes their gain by some measure. If you are faced with choosing between two vacation destinations you may look at factors such as desire for that location, potential friends at one or the other location, possible new adventures available, ability to participate in enjoyable activities, etc. While we may not write all these measures down, we typically evaluate them, in our minds, with respect to the amount of money it will cost us to travel to that destination. Essentially, it comes down to a decision about balancing expense and benefits (value) considerations. This consideration of expense versus benefit is a very legitimate way to make a decision, and in many cases is the metric used for commercial business to decide whether or not to invest in a project.

In section 3.6 and 3.7 we have presented methods to evaluate the costs and benefits results of an M&S investment. One decision process is that the ROIs for all the investments under consideration are calculated and then ranked with the largest number being chosen for investment expenditure until the available funds are depleted. ROI can be calculated based upon one of the three methods presented in section 3.8. However, caution is necessary when calculating ROI for the DoD. As stated in section 3.8 typically ROI is calculated with units of dollars and the result gives a percentage ROI. To take this approach we would have to monetize the metrics given in section 3.7, that is assign a dollar value to every measure, so that we could take the ratio of dollars and dollars. In some cases this monetization may be difficult, if not impossible, to perform. For example, how does one put a dollar value on the increase in readiness achieved because of an urban training simulation? Even more confounding is the attempt to put a value on any system where its use is thought to save lives since that involves putting a dollar value on human life.

If one cannot monetize the measures then another unit of measure that can be consistently applied over the set of applicable metrics would be required. If the decision is between a new M&S investment and the current status quo, then percentage could be the units. For example, if the new investment produces 60 percent more value for an increase of 10 percent in cost, then we can calculate an ROI in the (Value-Cost)/Cost spirit equal to (60-10)/10 = 5 or equivalently 500%. This ROI calculation will, in general, not equate to the same number as the standard ROI calculation presented in section 3.8:

$$\% \text{ Return} = [(V_{end} - V_{begin} + CF) / V_{begin}] * 100$$

While not the same number as traditional ROI calculations, this formulation is a measure of ROI that does more than allow you to rank order choices (such as discussed in the latter part of section 3.8), but also gives you some measure of the return. However, if the decision is among *new* M&S investments the calculation of ROI may be more difficult.

When deciding among several new M&S investments there is no status quo to use for comparison as you are evaluating a new capability. Additionally, one may have to decide among several M&S investments that are fundamentally different in nature and, therefore, require measuring different metrics. For example, you might be choosing among a new campaign model for analysis, a new training system for submarine crews, and a new Live, Virtual, Constructive architecture that is thought to enhance warfighting capability. Therefore, since these are new capabilities, the idea of increasing cost by a percentage and increasing value by a percentage is not applicable. In this case, some other unit measure of evaluating ROI must be determined (remember, we are assuming that the measures cannot be monetized). Techniques to solve this dilemma come closer to that described in the last few paragraphs of section 3.8 than to one of the more traditional methods. One method is to rate each value metric on a scale from 1 to 10 and then take the sum of these evaluations. Then, evaluate the costs on a scale 1 to 10 based upon the maximum cost and use the (Value-Cost)/Cost formulation to attain a number for ROI. For example, suppose the new campaign model cost \$2M and had a value metric sum of 24.2, the submarine training system had a cost of \$10M with a total value metric score of 38.6, and the Live, Virtual, Constructive architecture had a cost of \$8M and a value metric score of 32.8 total. Since the largest cost is \$10M then the cost measure for the campaign model is 2 since the cost is 20% of the maximum, the cost measure for the submarine trainer is 10 since it is 100% of the maximum, and the cost measure for the Live, Virtual, Constructive architecture is 8 since it 80% of the highest cost. Then, the “ROI” calculations become:

Campaign Model: (24.2 – 2.0)/2.0 = 11.1

Submarine Trainer: (38.6 – 10.0)/10.0 = 2.86

Live, Virtual, Constructive Architecture: (32.8 – 8.0)/8.0 = 3.1

In this case, clearly the Campaign Model scores the best and this technique gives you a relative idea of the return of each investment related to the cost. However, this is not a true ROI in any traditional sense because a “ROI” of 11.1 does not mean that for every dollar invested there will be an 11.1 dollar return. This method meets the criteria specified in section 3.8 of magnitude and directionality as well as internal consistency and is one way for determining an ROI-like measure when the value cannot be monetized.

3.9.3.1 Multi-Attribute Decision Making

While ROI is one way to make a decision, in those cases where only a ROI-like calculation exists or when one wishes to consider other factors in addition to or instead of ROI, there are some very robust decision making techniques available for use. An exceptional method is Multi-Attribute Decision Making (MADM), which has the qualities of being robust, relatively explainable, objective, and consistent. It initially requires a team of subject matter experts to set up some criteria, but once that is established is can be executed fairly simply.

3.9.3.2 MADM Examples and Explanation

MADM is not new and has been shown to work well in many instances when assistance is desired in making complex decisions involving a multi-dimensional decision space (several variables/inputs). At its simplest instance it is just a weighted sum. For a simple example, suppose one desires to buy a new car. First, you consider what things or attributes are important to your decision. This list should cover <u>everything</u> that you feel will factor into your choice, each attribute must be measurable by some method, and the attributes must be mutually exclusive (no duplicates and no overlapping areas). It may be that you decide that gas mileage, number of passengers, safety (crash rating), and 3-year resale value are the attributes that will determine your decision. Once that is established you need to decide what the relative weightings are for each attribute. In this example, perhaps you decide that gas mileage is your most important factor, followed by safety, then number of passengers and 3-year resale value. You decide that the relative "weightings" are .35 for gas mileage, .30 for safety, .20 for number of passengers, and .15 for 3-year resale value. Note that the relative weights in this technique must add up to one and the assignment of weights involves trade-offs, i.e. If one decides that gas mileage should be more important, then another attribute has to be given less weight since their total cannot be greater than one. This process assumes that the decision maker well understands the relative weightings of the attributes that will maximize the satisfaction level of the purchase[72]. After this is accomplished, you must choose how you will evaluate each car under consideration. There are a number of ways to do this. Some examples are: each attribute can be evaluated on a linear scale, a logarithmic scale, or a simple binary value where it is one if it possesses that attribute and zero if it doesn't. Additionally, each attribute score will need to be normalized (scaled to be between 0 and 1 inclusive) over all the choices so that an attribute with high values (such as resale value) doesn't overpower an attribute such as number of passengers which would be orders of magnitude less. In this case, let's suppose we score/evaluate each attribute on a linear scale. Therefore, for the gas mileage we consider a car getting 50 miles to the gallon as a normalized score of 1, for safety the ratings are excellent(4), good(3), average(2), marginal(1), and poor(0) so excellent will normalize to a score of 1, number of passengers will go between 9 and 2 with 9 normalizing to a score of 1 and 2 to a score of 0, and 3-year resale value will be scored as the percentage of the original purchase price which because it is a percentage is on a 0 to 1 scale. To further explain this method, Table 3.9.3.2-1 below shows the raw (non-normalized) data for three different automobiles for each attribute.

Table 3.9.3.2-1. Raw Automobile Data.

	Gas Mileage	Safety	Num of Passengers	3-year resale
Automobile #1	40	Average	4	62%
Automobile #2	32	Good	5	54%
Automobile #3	19	Excellent	8	49%

Table 3.9.3.2-2 shows the scores in their normalized form which will be used as inputs into the method.

Table 3.9.3.2-2. Normalized Automobile Data.

	Gas Mileage	Safety	Num of Passengers	3-year resale
Automobile #1	.8	.5	.29	.62
Automobile #2	.64	.75	.43	.54
Automobile #3	.38	1.0	.86	.49

Now that we have the individual attributes with normalized scores it is time to get a total evaluation score for each automobile or utility score. The total utility score is calculated by multiplying each attribute normalized score by its relative weighting assigned earlier and then adding up all the products. In mathematical notation it is:

$$\sum_{attributes} (attribute\ score) * (relative\ weight)$$

While there are other formulae used to calculate the utility score, such as a non-linear method where some scores are squared or cubed and all the weights are set to equal values[73], the weighted linear method is most often used due to its simplicity and transparency[74].

A diagram of the process for the first automobile is given below in Figure 3.9.3.1-1. Each automobile's utility score is calculated using the relative weights given above and the normalized scores in Table 3.9.3.1-2 and the results are shown in Table 3.9.3.1-3 below.

Table 3.9.3.2-3. Utility Score by Attribute with Totals for each Automobile.

	Gas Mileage (.35)	Safety (.30)	Num of Passengers (.20)	3-year resale (.15)	Total Utility
Automobile #1	.2800	.1500	.0580	.0930	.5810
Automobile #2	.2240	.2250	.0860	.0810	.6160
Automobile #3	.1330	.3000	.1720	.0735	.6785

Based upon the assigned weights and the attribute scores we see that Automobile #3 gives the best overall utility to meet the determined criteria. This means that based upon the items that were ranked important to the decision, the decision maker will be happiest overall with Automobile #3. It is worth noting that if the weights change, then the Total Utility will change and perhaps the decision will change as well. However, note that the attribute scores will not change unless the evaluation scoring method (this example used linear) changes since the attribute scores are based upon raw data.

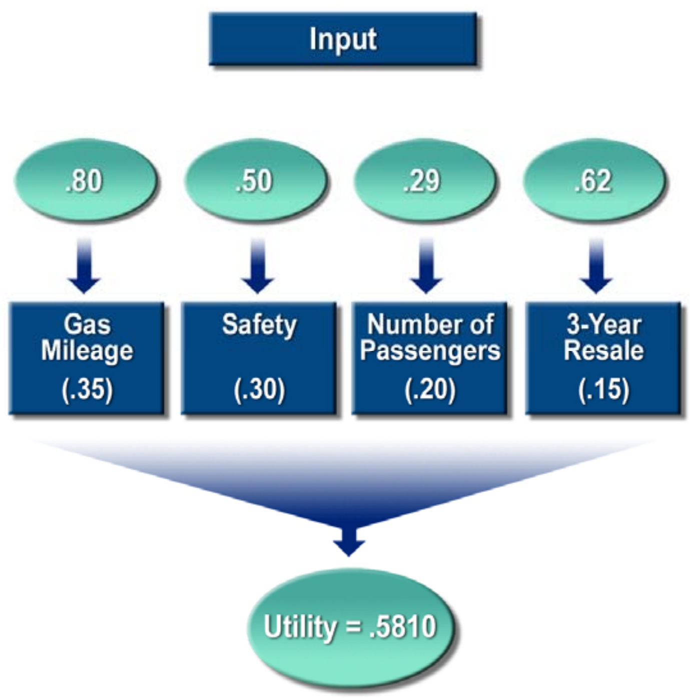

Figure 3.9.3.2-1. Diagram of MADM Process for Automobile #1.

In this example, if someone else were to decide the weighting and choose: Gas Mileage - .45, Safety - .30, Number of Passengers - .10, and 3-year resale - .15, then the Total Utility scores would change as follows: Automobile #1 - .6320, Automobile #2 - .6370, and Automobile #3 - .6305. In this case, the decision maker would be happiest with Automobile #2, but difference in overall utility is much closer than the previous weightings and as such, the difference in overall happiness is not as great as the previous weightings. This means that in this case choosing any one of the three automobiles would most likely be acceptable, whereas with the previous weightings there is a sizeable difference between the utility of Automobile #1 and Automobile #3 and choosing Automobile #1 would probably not be acceptable.

3.9.3.3 MADM Applied to M&S Investment

Just as MADM was applied to the purchase of an automobile, it can be applied very similarly to M&S Investment for the DoD. Figure 3.9.3.3-1 below is a diagram of the MADM process applied to M&S Investment for DoD organized by M&S Community. Note that while the process in our example was a single layer this diagram has two layers, one that lists all the communities, and the next one for attributes/metrics. In this case, multi-layers are desirable for a few reasons. First, it allows for the higher level DoD decision makers to put different emphasis on certain communities by assigning different weights to each community. Note that on each layer weights which sum to 1 on that layer are assigned and the input values multiplied by these weights. For the second layer that contains the M&S communities, the inputs are the summations of the weighted products from the previous layer.

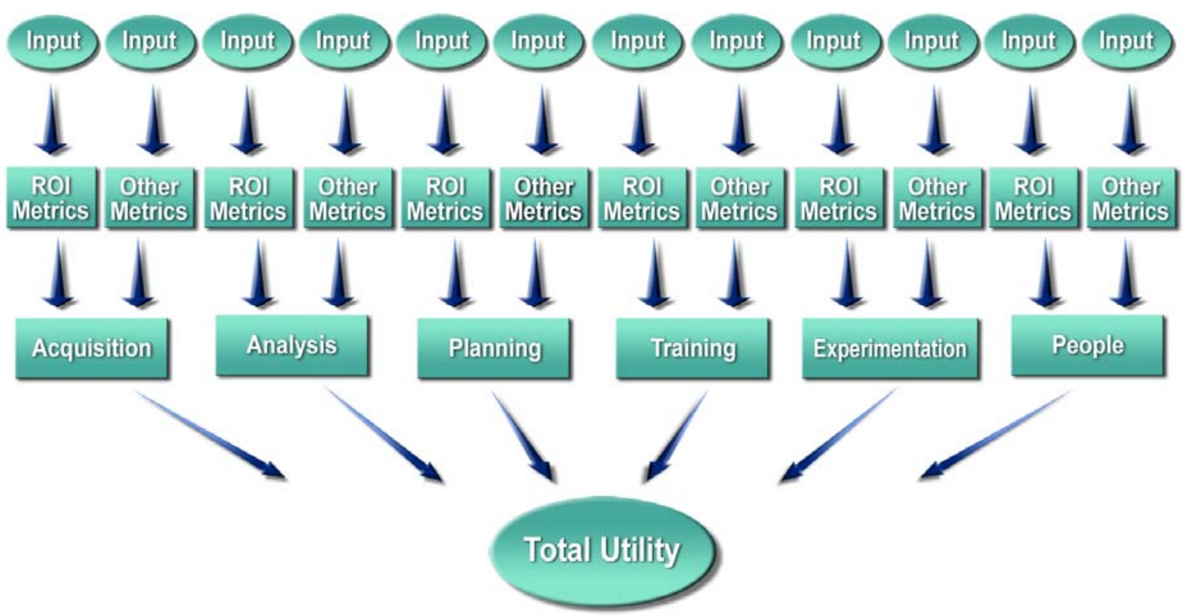

Figure 3.9.3.3-1. Diagram of MADM Process for DoD M&S Investment Organized by Community.

Another reason that multi-layers are desirable is for transparency. By grouping the metrics by community it is easier to see how certain measures impact the overall utility score and thus makes the process easier to explain to decision makers and other interested parties. Additionally, this grouping allows one to determine which communities are impacted the most (or benefit the most) from an M&S investment. For these reasons a multi-layered MADM approach is a good method for this decision.

Before discussing some of the pitfalls of this organization for the MADM method, it is worth noting that the attributes being measured are the ROI metrics listed in sections 3.6 and 3.7, Cost and Value measures for M&S investments. Since costs and value measures are opposing measures and both will be used as input the issue of how to incorporate both measures must be addressed. It would seem the easiest and most logical way of dealing with both cost and value, and our suggested method, is to make cost a negative value which would serve to decrease the overall utility score. This is consistent with desiring investments with lower cost as compared to value thereby yielding a higher ROI. The "other metrics" depicted on Figure 3.9.3.2-1 would be those not listed in this study (perhaps because they would not figure in an ROI calculation), for example, if the project fulfills a requirement from a higher headquarters, agency, or government branch might be a metric that would be considered significant in the decision process.

However, there are pitfalls to the organization of the MADM method shown in Figure 3.9.3.3-1. Typically, as mentioned above, when applying the MADM method it is a requirement that there are no duplicate attributes measured and that no attributes overlap (they are mutually exclusive). This is necessary to ensure that one measure does not impact the total utility score by a higher amount than is desired in the weighting scheme. In the M&S Communities organization of the MADM method, it would be easy to measure attributes more than once since values and costs can apply to more than one community. In order to not measure an attribute more than once, careful descriptions of the attributes, and careful allocation of costs and values are required. Where allocations to each community are not possible then these attributes need to drop down a layer to the "community" layer in Figure 3.9.3.3-1 so that they are only measured and accounted for once in the total utility calculation. For example, suppose a wargaming system is being evaluated which will be used for analysis, training of military members building warplans, planning, and a small part for experimentation and the cost of this system is $8M. To measure this as a cost to all four communities (analysis, training, planning, and experimentation) in the MADM method of Figure 3.9.3.3-1 would give the cost elements four times the (negative) impact on the utility score! Therefore, the cost must be apportioned over each community affected by some method. One such way would be to split the costs evenly so that analysis accounts for $2M, training accounts for $2M, planning accounts for $2M, and experimentation accounts for $2M. Another technique would be to apportion the costs on a percentage basis based upon criteria determined by the DoD enterprise or amongst the communities. Some examples are to apportion the costs based upon impact on mission or usage. This might mean that the analysis community accounts for 40% of the cost, planning 15%, training 35%, and experimentation only 10%. However this apportionment is done, the cost metrics affected must have the same weighting by each community as they feed into the community layer or the total utility score will be skewed. In another example, from the Report on Defense M&S Efforts submitted to Congress it says discusses a number of joint efforts for M&S investment[75]. Therefore, one metric might be that an investment be an asset that has joint capability. Caution is in order here also as it would be easy for this metric to be measured by more than one community. That is acceptable as long as the total for the normalized measure for the metric over all communities is no greater than 1 and again, the weights must be the same across all communities. Since this would be a metric that most likely would be measured as a binary value (1 if the investment is Joint, 0 if the investment is not Joint), this is an example of a metric that might be best moved to the lowest layer and be directly input in the Total Utility calculation.

As just discussed, ensuring that measures are counted appropriately and if they fall into more than one category that the measures are acceptably apportioned across the categories, is an important task. Another method to handle this dilemma is to use different categories. Figure 3.9.3.3-1 shows one way to organize a MADM network for DoD M&S investment. However, there are other options. Figure 3.9.3.3-2 shows a MADM method organized by the DoD M&S Vision statement categories. Corresponding metrics to measure cost and results would need to be developed as in sections 3.6 and 3.7.

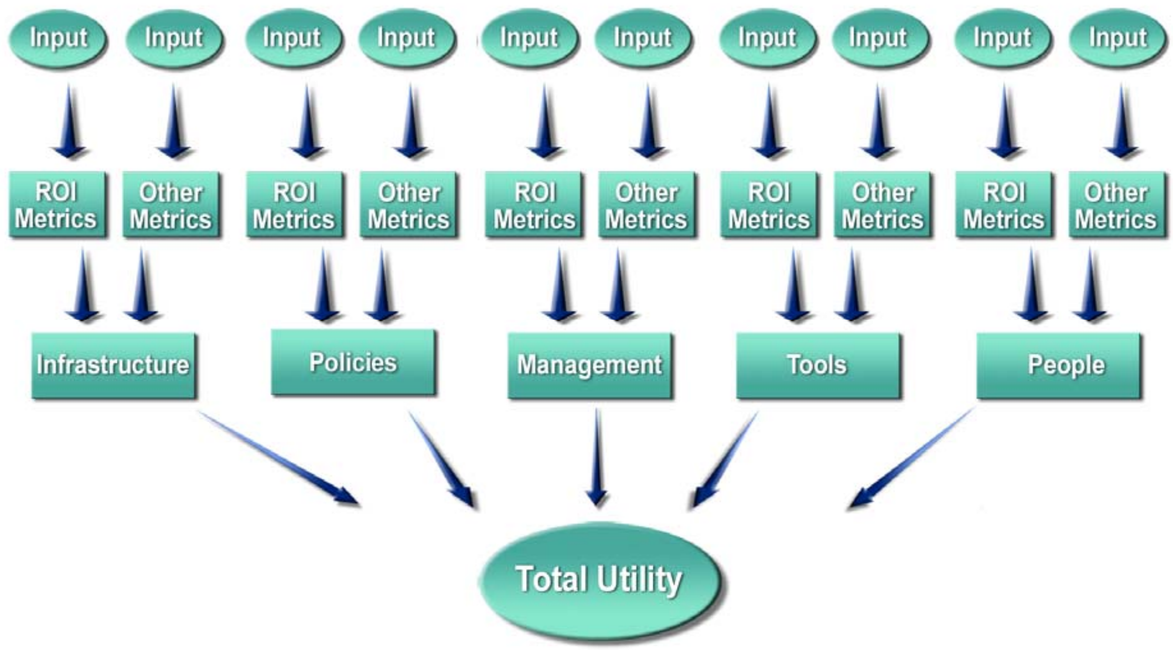

Figure 3.9.3.3-2. Diagram of MADM Process for DoD M&S Investment Organized by DoD M&S Vision Statement Categories.

Yet another option would be to look at M&S investment through the M&S asset categories delineated in section 3.5. These categories are mapped to the DoD M&S communities as well as the DoD M&S Vision statement, but may provide less overlap when looking at costs and value. Figure 3.9.3.3-1 shows the MADM network for this view, which may provide the least amount of cost and value overlap.

3.9.3.4 Determination of the Weights in the MADM Process

There are several ways to determine the weights in a MADM process. The simplest way is that one person decides his or her preferences and assigns the weights. If you, as an individual, are making a decision where you are the primary (perhaps only) stakeholder, then deciding the weights from an individual perspective is most appropriate. However, as was noted in section 3.3 there are many stakeholders in the DoD and the viewpoint of a single individual may not fit the majority of the stakeholders leading to weights that do not provide the best decision. Typically a group of subject matter experts representing the entire community would meet and through a guided meeting/focus group or series of meetings would come up with a consensus of the weight values, see Figure 3.9.3.4-1.

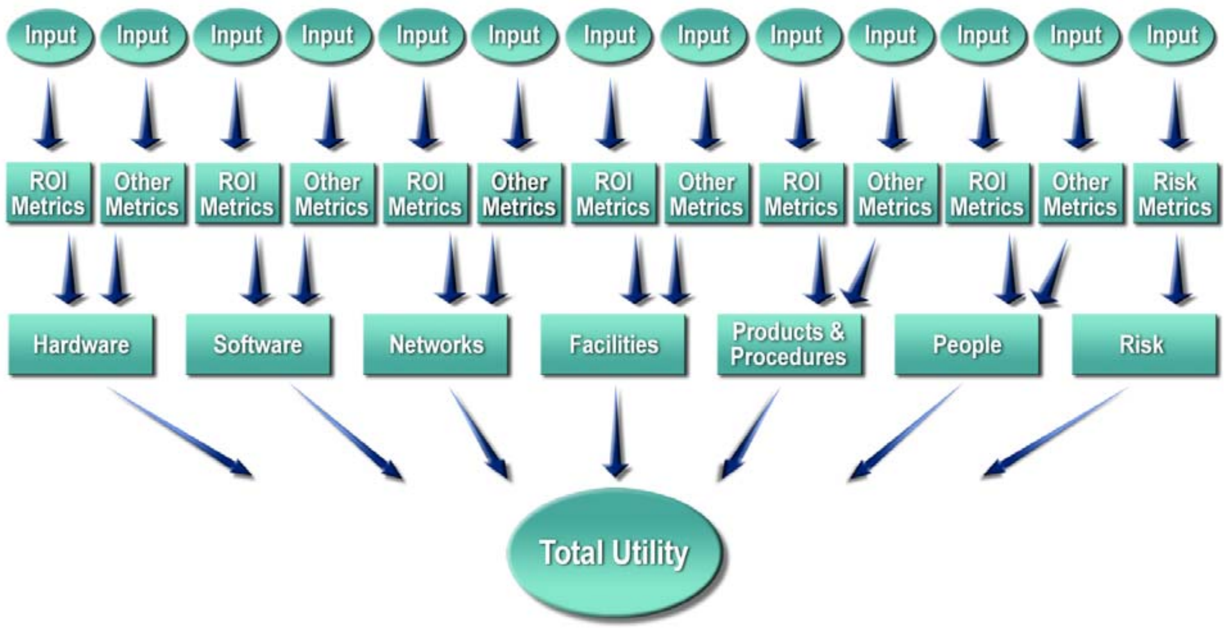

Figure 3.9.3.4-1. Diagram of MADM Process for DoD M&S Investment Organized by Asset Categories.

It is worth noting that there are some pitfalls with this approach. First of all, the group preference may not completely reflect all the individuals' perspectives[76]. This may be because they do not speak out or are unable to adequately express their viewpoint. Additionally, the group could inadvertently impose a preference on an individual through subtle cognitive processes that may be difficult to detect by a moderator or facilitator[77]. Then, it is also possible that people's confidence could be reduced through inappropriate or poor group interaction and hence may not articulate their preferences[78]. While methods to deal with each of these issues are beyond the scope of this report, it is important to recognize that weights need to reflect the enterprise's preferences and developing good weights is important.

Additionally, weights are not static and need to be re-evaluated on a regular basis (each fiscal year would seem to be a good practice). One year the Secretary of Defense (SECDEF) may decide that training is the DoD top priority and so the M&S investment decision process needs to weight training investments more heavily. The next year it may be M&S policies and standards or new M&S facilities that are priorities and the weights need to change to match the SECDEF or executive branch's desires.

3.9.3.5 Risk

Whenever there is an investment there is risk that must be evaluated, mitigated to the extent possible, and when comparing among investments it must be factored into the decision process. There are two types of risk that affect the MADM decision process, the risk of the M&S investment, and the risk inherent in the MADM process.

Even if all the risks associated with a project are determined and mitigated to the extent possible, there is still some risk that must be accepted and must be factored into the decision process. There are at least two ways to incorporate risk into the MADM process, 1) add risk as its own category at the lowest level that feeds directly into the total utility calculation, or 2) incorporate risk into the cost metrics as an additional cost (since risk has a high influence on cost and schedule which ultimately impacts cost). As risk is an important element and one that should be readily visible to decision makers, it is suggested that the second method be used - including risk as a separate attribute at the lowest level in the MADM network, as shown in Figure 3.9.3.5-1, which illustrates the MADM process organized by asset category. Listing risk metrics explicitly, rather than burying them in other cost metrics where risks impacts would be much harder to determine, facilitates and makes judgments easier regarding risk impacts on total utility.

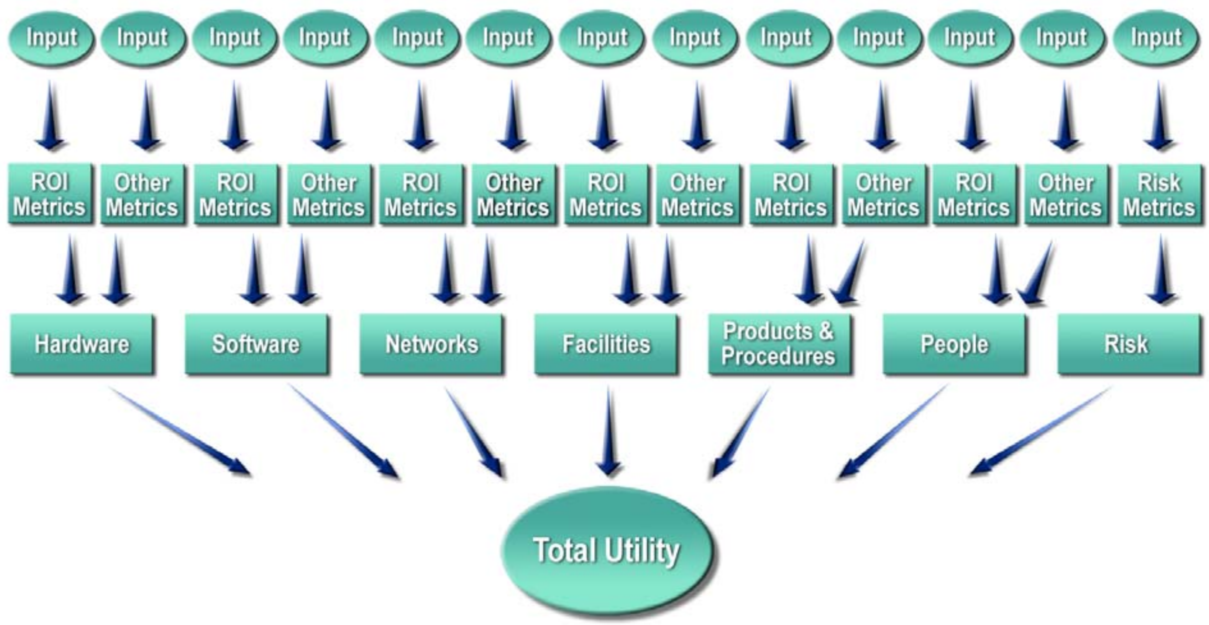

Figure 3.9.3.5-1. Diagram of MADM Process for DoD M&S Investment Organized by Asset Categories with Risk.

Another type of risk in this decision process is the risk inherent in the MADM process itself. Every complex decision process will have some element of risk involved. The MADM method has some risk that is intrinsic in the process. The biggest risk is the determination of the attribute weights. As seen in the example of buying an automobile, a change in weights can change the decision. This risk is mitigated by employing a team of subject matter experts that represent each stakeholder in the M&S investment process and using an experienced facilitator to lead the meetings/discussions. The subject matter experts also need to ensure that they have a good sense of what is important with respect to M&S in the community/stakeholder that they represent. If these steps are followed the risk should be significantly lowered.

Another risk of the MADM method is that the attributes do not span the space of interest, that is they do not completely cover all the areas that we care about in making the decision. The opposite end of this is that the attributes overlap and some metric measures are counted more than once. We addressed the multiple attribute problem and provided different options to alleviate that issue, so that risk is very low. The risk of not covering the entire space of interest is real, but is mitigated similarly to that of assigning weights. Typically, a team of subject matter experts can come up with an all-inclusive list and one that is mutually exclusive with relative ease. If the MADM network is multi-layered the mutual exclusivity is somewhat harder as described earlier in this section, but that risk was addressed above. With the approach of a team effort to develop the list of attributes the risk of not covering the areas of interest is very low.

Other risks associated with the MADM process are those that are inherent to any decision support tool or method. Every decision method that allows subjective data to be quantified and used as input has some risk associated with the process of quantifying subjective data and at times the quantification is subjective itself. For example, if you are measuring the realism associated with a simulator interface, you may interview 50 experienced pilots, ask them to rate the realism on a scale of 1 to 10, and take the average score as your measure of that metric. By interviewing a reasonably large number the data will tend to be an accurate representation of a subjective measure, but there is still some risk that it isn't, especially if the numbers are small. However, this risk is one that is built into allowing subjective data and one that occurs in all decision methods using subjective data as input.

3.9.4 Significant Findings

> √ ***Based upon the kinds of decisions necessary to make DoD M&S investments, a robust method is required that accepts large amounts of data, is objective, is relatively transparent in function, is easy to explain, is non-stochastic, and is consistent.***
>
> √ ***Our analysis of these criteria finds that the method that rose to the top is the multi-criteria decision analysis.***

Analysis of the different decision methods as discussed in Appendix J shows that there are several decision methods that exist. However, based upon the kind of decisions necessary to make regarding DoD M&S investments we require a robust method that accepts reasonably large amounts of data, that is objective, is relatively transparent in function and relatively easy to explain, is non-stochastic (does not rely on chance), and is consistent. In analyzing those criteria the decision method that rose to the top was a multi-criteria decision analysis (also known as multi-criteria analysis) tool. These methods are used for evaluating multidimensional decision problems where there are multiple conflicting objectives and multiple evaluation criteria measured in different units[79]. One of the easiest to understand and also one of the most robust methods of this class is MADM. Not only does it meet the requirements spelled out above, but it can be modified and adapted to perform in most any situation as shown by the different ways the MADM network could be organized. With the highly varied kinds of assets that can be purchased via DoD M&S investment an adaptable method becomes highly desirable as well.

Our analysis also revealed that ROI for DoD M&S investment is difficult to calculate (see section 3.8 for further discussion). While not the main focus of this section, it comes into play since we can use ROI metrics and ROI-like calculations in the decision process. One can calculate a "score" using formulae that are typically used in the calculation of ROI, but with input that are not traditional costs and returns in terms of dollars, but might be percentages or costs and returns evaluated with respect to other units. This produces an ROI-like score that can be used to rank order M&S investment possibilities. At the very least, this process can be used to make a decision on the most beneficial M&S investments for the DoD. If more fidelity is desired, another option is to use the MADM method described above, which uses ROI metrics of cost and value as input and gives the option to incorporate other metrics including investment risk. Furthermore, it is acceptable to rank order M&S investments with respect to an ROI-like score as well as applying the MADM method and comparing each list to make the investment decision. Therefore, these two methods allow for a robust decision process which should be able to assist on any M&S investment decision.

Additionally, there are risks and assumptions associated with the decision method proposed in this section. Our assumptions are that the choice of the weights in the MADM process will yield values that are accurate and when the method is correctly applied will result in the best investment having the highest total utility. The choice of weights is also the highest risk as discussed in section 3.9.3.5. Another assumption is that the weights will be regularly updated or at least reviewed to ensure they are in line with current DoD management desires. Failure to do this will result in the MADM method not reflecting the correct emphasis and, therefore, potentially not arriving at the best investment decision. Other risks are noted in section 3.9.3.5.

3.9.5 Conclusions and Recommendations

The conclusions and recommendations from this section are fairly straightforward: we recommend that the DoD use a Multi-Attribute Decision Making method potentially coupled with an ROI-like calculation to evaluate and help decide where to make investments in M&S. Currently, we believe that the DoD does not use any objective decision method to choose where to make M&S investments and specifically does not have a method to give insight into the ROI of an investment. The decision process described in this section incorporates ROI metrics and has the ability to factor in other metrics and measures as well. Additionally, the MADM method is robust and the network can be organized or arranged to evaluate a number of different investment scenarios. We recommend that the risk of the investment be incorporated in such a way that it is highly visible to the decision maker and that the weighting values be determined by a facilitated team of subject matter experts so that the risk of the method is minimized. Furthermore, the weights need to be reviewed and potentially updated on a regular basis to incorporate any changes in the DoD Commander's intent as put forth by the SECDEF or Executive Branch. Following the methods and guidelines given in this section should allow the DoD to make M&S investment decisions which result in an increased return on investment when compared to the current state.

SYNTHESIS

Establishment of a comprehensive process whereby M&S investment decisions can be executed, one that includes the significant features of ROI-type metrics and quantitative and qualitative criteria, is the objective of this study effort.

It is our thesis that such a canonical process, including guidance and ample opportunity for tailoring contingent the particularities of investment asset, stakeholder perspective and decision style, is both possible and highly useful, and that its use is fairly described and justified in the prescriptive instructions that follow.

In communicating the recommended investment management process, synthesized from the topical elements studied, we do the following:

1. Review briefly the analysis topics results and implications derived above, indicating how the recommended M&S investment decision process follows relatively directly from those findings and commenting on the degree to which the potential success of a synoptic, canonical investment process model may be sensitive to the particularities of those analysis topic issues
2. Identify the steps or modular activities that comprise the objective process.
3. Describe the separate process steps , indicating the necessary conditions for their execution and their expected consequential results
4. Discuss control flow among the process modules and their contingent dependencies, and
5. Execute a few nominal use case instances by way of illustrating the use of the synthetic process, its flexibility to cover a broad range of M&S investment decision space relevant to the US DoD, and the concreteness whereby stakeholders of various stripe might employ the same process, suitably tailored, thereby preserving a considerable degree of consistency of practice across the DoD M&S investment community.

4.1 Process Specification[80]

In order to facilitate the explication of our recommended process model a word about the conventions we have elected to signify and communicate process itself is in order. Several tools and methodologies have been developed to guide and manage information supporting the development of systems, particularly information systems, as illustrated in Table 4.1-1, below. For convenience, these methodologies have been classified as process / flow models, data models, and object-oriented models. This list is not exclusive, nor exhaustive, but, is suggestive of the large number of methods in use by industry today. A more detailed analysis of these alternatives is provided in Appendix K.

Table 4.1-1. Common Methodologies And Process Documentation.

PROCESS / FLOW MODELS	Business Process Modeling Notation (BPMN)
	Integrated Definition for Data Modeling (IDEF)0 Function Modeling
	IDEF3 Process Description Capture
	Data Flow Diagram
	SIPOC
	Program Evaluation and Review Technique
	Gantt Chart
	Flow Chart
	Arrow Diagram
	Diagram
DATA MODELS	IDEF1 Information Modeling
	IDEF1X Data Modeling
OBJECT ORIENTED MODELS	IDEF4 Object-Oriented Design
	Unified Modeling Language (UML)
	System Modeling Language (SML)
	DoD Architecture Framework

Even a cursory review of the semiotic artifacts, associated with such notational schemas as these reveals a high degree of commonality in at least the ontology of 'what's in the picture'. Naturally some schemas, having been derived for one or another purpose and being evolved to execute one or another functional operation within the implementing computer application in which they may reside exist; nevertheless, the least common denominators of three typical and powerful schemas are indicated in the center of the diagram, Figure 4.1-1, that follows.

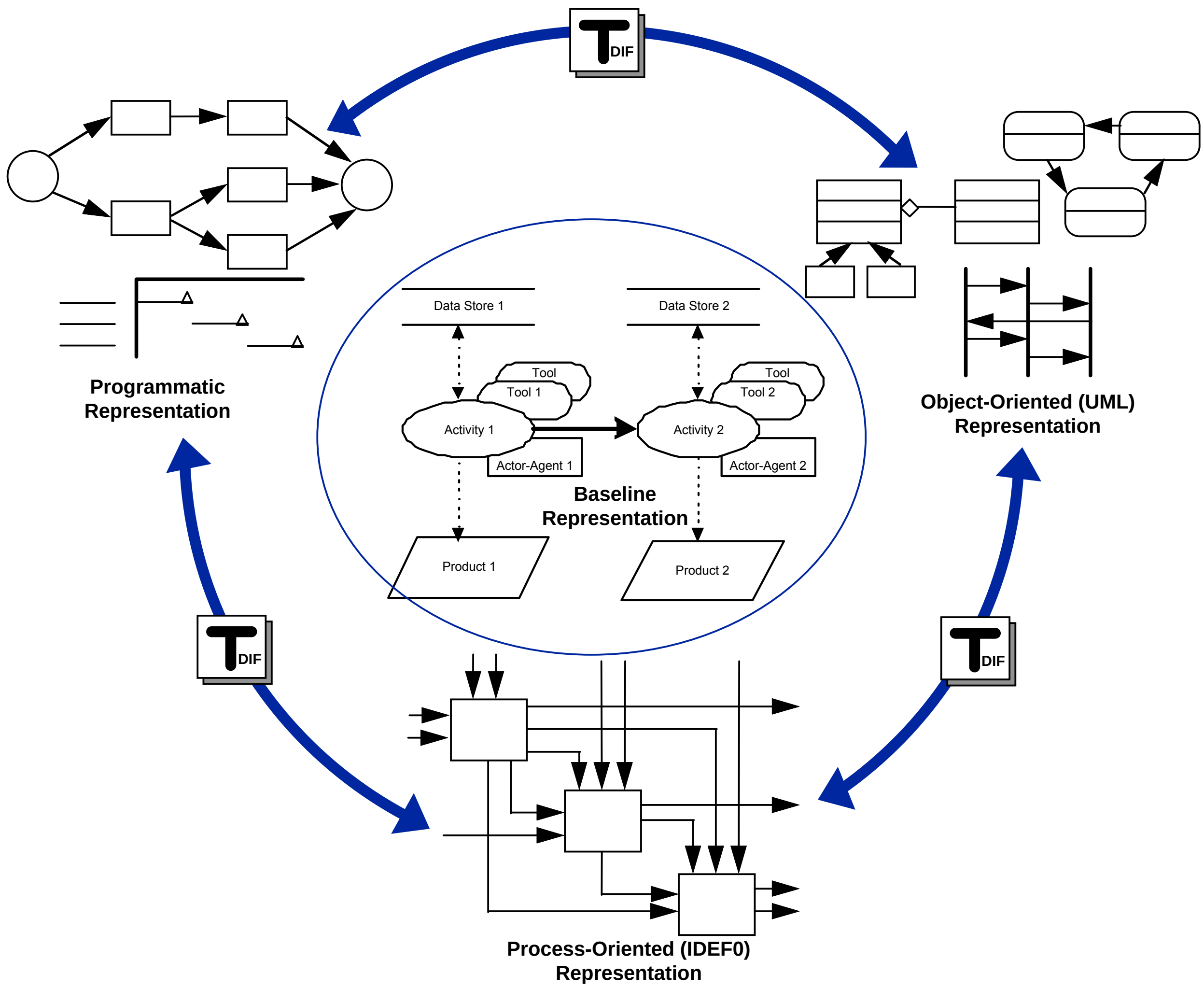

Figure 4.1-1. Alternative Canonical Views With Information-Preserving Transform Operations Are Possible, Facilitating Use Of CASE-Supported Native Representations And Guaranteed Information Sharing.

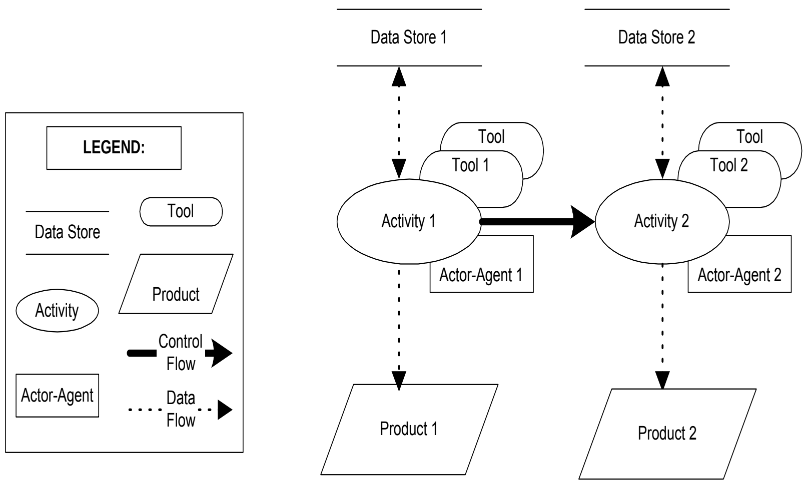

Figure 4.1-2. The Diagrammatic Template Provides a Suggested Baseline Graphical Representation for Indication of Activities and Their Relationships with Other Entities in the FEDEP Model.

In order not to precipitate 'religious debate' on systems engineering or process specification practice, we will use henceforth the simplified notational schema of figure xxx above wherein activities are in ovals, actor-agents (e.g. stakeholder agent) is in rectangle, tools are in ovals, data stores input or output are indicated by double bars, and physical or information products not serving as information for other subsequent process steeps are denoted as trapezoids. Control and data flow are solid and dotted arrows respectively all indicated within the accompanying legend.

In the discussion that follows, we will address primarily a process step activities as central, for which a 'generic' typical activity characterization table is indicated below. A full compliment of activity characteristics tables and the fully integrated activity network are provided in Appendix M.

We note with intentional emphasis, that *the process denoted in detail in Appendix L constitutes the recommended M&S investment process culminating from the effort of this task*. In the generic table, we have indicated how each component activity of the process will be specified. By providing such a template, we indicate both: a) what the individual attempting to follow the process might expect actual activity characterizations to signify; and b) to the administrator of the process specification how alternative prescriptive guidance should be added or modified by way of evolving the process to a more robust and comprehensive process standard.

Table 4.1-2. Activity-Specification Format

ACTIVITY CHARACTERISTIC	INFORMATION
Activity identity	• Activity Name and aliases
Activity description	• Activity Rationale / Need / Motivation
	• Activity Classification
Activity initiation	• Entrance criteria
Activity method	• Activity Procedure
Activity uses	• Previous uses
	• Prospective Applications
Inter activity relationships	• Activity sequence and control-flow
	• Activity information flow
Associated entities	• Tools
	• Actor-agents
	• Information pools
	• Product-object-artifacts
Problem (Risk) management	• Problem Identification
	• Problem Amelioration
Completion	• Exit Criteria

4.2 Process Description

Based on the preceding analysis, the entire flow diagram proposed for M&S investment within the DoD is indicated in the following diagram. There eight component procedures with control flow and data flow relationships are indicated. The first two activities, Needs and Requirements analysis and Stakeholder Analysis are executed in concert and establish the context of the investment decision. Subsequently, Use-Case Analysis and Investment Asset Identification are executed in concert establishing the intent of the investment decision. Cost Analysis and Results Analysis can occur concurrently and are succeeded by calculation of ROI and other metrics. These activities are indicated in the diagram as the assessment phase. Finally in the investment determination is the Decision activity.

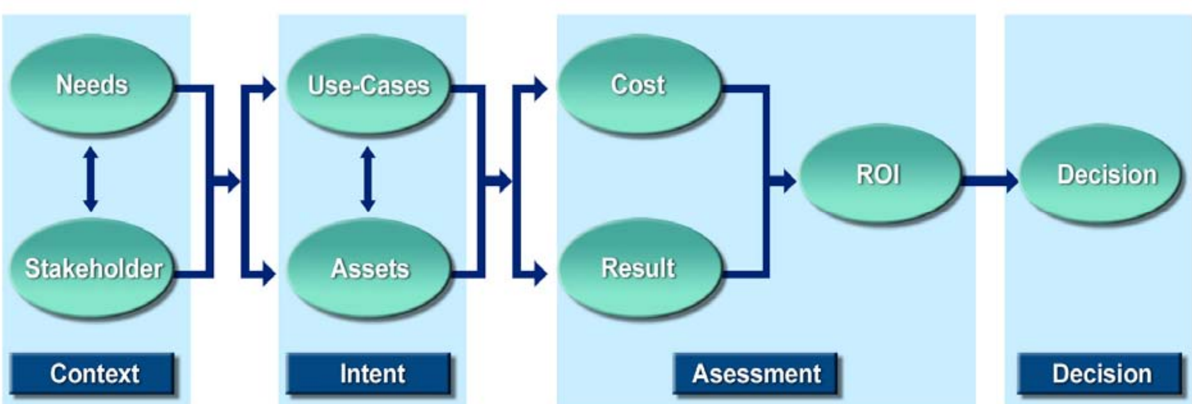

Figure 4.2.1-1. Process Flow.

Having indicated the generic specification of each activity in Table 4.2-2 above, the complete specification of all the activities of the recommended composite recommended DoD M&S investment process is provided in the series of completed tables of Appendix M. Since that specification is exceptionally detailed, there follows an abbreviated description of each of the process activities indicating only the activity procedure steps. This description however is indicative of the full suite of task elements necessary and sufficient to complete the entire recommended DoD M&S investment decision process.

,

4.2.1 Needs and Requirements Analysis

Procedural guidance for the execution of the needs / requirements analysis activity by its designated action agent are provided in the list that follows. For each procedural or algorithmic step, identify: relationships to other activities, needs for tools or information, and expected work-products in order to be defined in detail below..

1. Identify investment decision problem
2. List known stakeholders
3. Capture and document stakeholder needs for subject decision, citing constraints, preferences, risk sensitivities.
4. Educe problem requirements from comprehensive analysis of needs, indicating necessary and sufficient conditions for requirements satisfactions. Specify test or evaluation method and exit criteria.
5. Document and justify any needs or interests likely to remain unmet upon completion of requirements compliance testing.
6. Document needs and requirements analysis in suitable memorandum or report, and archive requirements analysis data for reference.

4.2.2 Establish Stakeholder Decision-Posture And Participation… 'Business Case'

1. From the M&S Stakeholder Category table provided in section 3.3.2 identify the categories of stakeholders impacted by the M&S investment under consideration.
2. Identify specific information about the specific stakeholders within these categories, including the office/roles they hold.
3. From the M&S Stakeholder Perspectives table provided in section 3.3.3 identify the perspectives of each of the stakeholders identified in Step 2.
4. Where possible, identify the timelines for each identified stakeholders' decision/return process (see section 3.3.3)
5. For each identified stakeholder/community conduct analysis to determine their specific concerns relevant to the M&S investment under consideration. Show each stakeholder the preliminary results of the needs capture and requirements generation activity and seek a preliminary confirmation of completeness of identification of needs and interests, reasonable devolution of needs to requirements, and acceptability of exit criteria for requirements evaluation.
6. Consider developing a plot of the stakeholder space as shown by the example in Figure 3.3.6-1.

Articulate Use Cases

1. Postulate a relevant situation/decision involving an M&S investment of the class under consideration. Use this to "sets the stage" for developing the parameters in the use case framework.
2. Determining the primary M&S market *categories* involved with the situation/decision (these should be restricted to the primary categories since many might be involved).
3. Identifying the specific (generic) stakeholders in the primary market *categories* and their *perspectives* (placing them in the stakeholder space) for the situation/decision.
4. Delineate the generic issues or concerns of these stakeholders for the situation/decision.
5. Specify the types of M&S investment metrics that are available and applicable for the situation/decision, and elucidates the *data support* issues involved with these metrics. For example, if the data needed for an investment metric is very difficult, expensive, or time consuming to develop for the postulated situation/decision, then that metric is not useful and should be discarded for another (for that situation/decision).
6. Execute the Use Case by executing the relevant steps of the Investment Decision Process.

4.2.4 Identify Investment Asset Option (s)

Identifying the type of asset is a subjective process, but one that is easily repeatable.

1. From the asset list given in section 3.5 identify use the needs and requirements analysis to determine what asset type satisfies the requirement.
2. Using the cross-correlation tables given in section 3.5 verify that all potential interested stakeholders for that asset type have been considered.
3. The asset type is then used to determine applicable cost and result metrics.

4.2.5 Evaluate Cost

Management directs that cost data for alternatives be calculated, and management provides the guidance and the information sources needed to complete the calculations. The analyst(s) then complete the following steps:

1. Identify the alternatives being compared.
2. List known stakeholders and identify the program or enterprise perspective to be used.
3. Document the use cases assumed, time horizon, and frequencies of uses assumed.
4. Document the discount rate that management directs.
5. Identify the budgetary or programmatic costs to be used for each geographic site to be used in the estimates for personnel, systems, and infrastructure.
6. Receive the government-reviewed development or purchase costs for each of the M&S alternatives. Verify that hardware, software, infrastructure, and personnel costs are known for each alternative. Each alternative probably needs different levels of control staff, role players, operators, computers, distribution infrastructure, facilities, set-up, and other characteristics that affect cost.

4.2.6 Evaluate Benefit Results

Procedural guidance for the execution of the results analyses is:

1. Establish perspective (enterprise, application, program)
2. Identify alternatives being compared
3. Define relevant metrics
    a. Select from samples
    b. Expand as required
4. Measure metrics
    a. Produce current values
    b. Project and normalize values
5. Assess results
    a. Relative to status quo
    b. Relative to each other
6. Provide outputs to decision algorithm
7. Repeat / iterate as possible
8. Document and archive data for reference

4.2.7 Calculate ROI

There are, broadly speaking, three different methodologies used in Finance to calculate ROI – the "Three Formulations" as they are referred to in the report:

1. as a percentage increase in a holding's value between two time periods[81]

   $\% \text{ Return} = [(V_{end} - V_{begin} + CF) / V_{begin}] * 100$

   Where: V_{end} is the value at the end of a portion of time, V_{begin} is the value at the beginning, and CF is the sum of all cash flows that come about as a direct result of having made the investment.

2. as the amount of cash (or, revenue) generated from a set, fixed asset base[82].

   $\% \text{ Return} = [(\text{benefit}) / (\text{base})] * 100$

   Where: Benefit is the results (such as net income, revenue, yield, etc.) from a fixed Base of some type (total assets, total equity, total capital expenditure, etc.).

3. as the sum of a series of cash flows, discounted by an appropriate rate. There are, typically, two ways that financial analysts go about these calculations.

   Net Present Value (NPV): $\sum [CF_t / (1+r)^t] - \text{Outlay}$

   Where: CF_t = cash flow at time t (usually after tax), r = discount rate
   Outlay = cash required/needed (@ t=0) for project to proceed

   Or

   Internal Rate of Return (IRR): $\sum [CF_t / (1+r)^t] = \text{Outlay}$

Where: CF_t = cash flow at time t (usually after tax), r = discount rate
Outlay = cash required/needed (@ t=0) for project to proceed

While the discounting rate can (and is) used to adjust for the time value of money, it can also be employed to adjust for the riskiness of an investment. In order to adjust for higher risk, we simply use a greater discounting rate. The discounting rate then becomes the sum of the adjustment needed to compensate for TVM plus an "extra" adjustment for risk.

For public (and very large private) corporations, the discount rate generally used is equal to the cost of capital for that firm. As the CFA Institute writes, "The most common way to estimate this required rate of return is to calculate the marginal cost of each of the various sources of capital and then calculate a weighted average cost of capital (WACC)."

$$WACC = (w_d)(r_d)(1 - t) + (w_p)(r_p) + (w_e)(r_e)$$

Where: w_d = proportion of debt that the company uses when it raises new funds, r_d = the before-tax cost of debt, t = marginal tax rate, w_p = the proportion of preferred stock the company uses when it raises new funds, r_p = marginal cost of preferred stock, w_e = proportion of equity that the company uses when it raises new funds, r_e = marginal cost of equity.

In the above equation, the cost of equity is usually equivalent to the "rate of return required by a company's common shareholders." (CFA Institute) In order to calculate the cost of equity (or, necessary rate of return on common), typically financial analysts use the Capital Asset Pricing Model (CAPM):

$$E(Ri) = R_f + ß_i[E(R_M) - R_F]$$

Where: R_f = risk free rate (usually the rate of a US Treasury bond with suitable maturity), $ß_i$ = the return sensitivity of stock i to changes in the market return, $E(R_M)$ = the expected return on the market, $E(R_M) - R_F$ = the expected market risk premium.

4.2.8 Execute Decision Process

The decision method at a high level is fundamentally simple:

1. Determine the stakeholder/viewpoint by which to evaluate the M&S investment
2. Determine the metrics by which one wishes to evaluate M&S investments.
3. Measure those metrics by some objective means.
4. Determine the relative importance of each metric and potentially group of metrics.
5. Execute the decision process algorithm using the weightings and input data.
6. Review Results With Stakeholders In View Of Existing And Suggested Use Cases

Each one of these steps may take days or weeks (in the case of the determination of algorithm weights) and may require management direction. More detail on each of these steps can be found in the Decision Process section of the body of the report.

5 EVALUATION

Evaluation of the recommended process for DoD M&S investment was conducted principally by means of the analysis of representative Use Cases conceived specifically to illustrate and characterize the subject process. The text that follows indicates the nature of the three exemplary/evaluative use cases employed, while the detailed explication of each use case is reserved to Appendix M. Implications of the Use Case evaluation exercise are documented below in discussion of Determinations and Findings in the following chapter.

5.1 Evaluation Context

The three sample problem Use Cases employed for process evaluation are described as follows:

5.1.1 Use Case 1

A simulation professional would like to conduct a small 4-day experiment in Alaska to test the combat benefit of a new system for position determination of friendly ground forces.

The simulationist will need to evaluate alternative simulations for use in this experiment. The cadre of simulation operators, even for the most commonly used simulations, is limited in Alaska, so the simulationist must not only compare various simulations but also the need to have distribution of the simulation environment from other locations. Friendly forces could be brought into the experiment live, through a constructive simulation83, via virtual simulation, or as a combination of all these. The position determination system may need to be simulated or assumed. Databases for Alaska are limited, particularly for semi-automated forces (SAF) simulations that require minimal operators, so databases for geography and other environmental factors may also need to be purchased with lead time. Connectivity and simulation architecture costs will have to be evaluated. The cost element structure developed in this report could be used to compare the costs of the different alternatives, estimate the cost of conducting the experiment using all live forces, and calculate cost avoidance ROI.

5.1.2 Use Case 2

Joint Forces Command (JFCOM) is responsible for warfighter training. In order to improve training quality, JFCOM observed that constructive simulation alone was not providing sufficient training effect; and they inferred that the existence and use of a standard, seamless live-virtual-constructive (LVC) practice could significantly improve training quality. Pursuant a gap analysis, and identification of needs and requirements; an LVC study was begun. Observing that integration of LVC components within an architectural schema is difficult, and that integrating simulations across dissimilar architectures is even more difficult; attention has been focused on ways to improve interoperability within and across architectures.

This specific subject is being addressed by an ”LVCAR Study” on behalf of the DoD M&S Steering Committee. Discussions with study participants revealed that study topics include: a) technical issues related to object modeling approach and specific object model specifications, and the reconciliation of simulation federation systems engineering process via SISO's DSEEP Distributes Simulation Engineering and Execution Process (supplanting the HLA's FEDEP – Federation Development Process); and b) management concerns. This study may conclude that homogeneous architectures will not be achieved in the near-term, and that no new overarching M&S architectures should be attempted. Nevertheless, in order to pursue LVC technical and management initiatives, investment in simulation federation 'middleware' must be made.

A variety of middleware software is required to integrate components compatible with disparate simulation federation architectures ("flavors"), for instance Common Training Instrumentation Architecture (CTIA), Test and Training Enabling Architecture (TENA), and High Level Architecture (HLA). Middleware assets that are sufficient to support the requisite diversity are available; but no single middleware artifact will "do it all" for users, and these assets are provided under variable procurement, custody, and distribution business models. For instance, in order to distribute the subject LVC practice across DoD and to share it with coalition partners, the need is perceived for more flexibility in licensing, commercial versus GOTS acquisition, cost of use in federation development, and middleware bill-payer distribution and dissociation with user/benefit recipient. For instance, JFCOM uses middleware, but so might NATO; some middleware is commercial with fixed-site licenses while others are GOTS; middleware development is distributed among several commercial and government agencies with no single set of standards or guarantees of full compliance with existing standards.

Based on the prevailing circumstances, which is the preferred investment:

(a) DoD-wide licensing of commercial products, all other things being equal,
(b) Develop a fully supported certified GOTS middleware solution,
(c) Do nothing (maintain the status quo),
(d) In addition to (c), move existing government middleware code to open source, or
(e) Develop and enforce middleware standards for LVC across DoD.

5.1.3 Use Case 3

The Missile Defense Agency is proceeding to implement, field, and initialize for operations the nation's only ballistic missile defense capability. The MDA Director specifically reports to the Under Secretary of Defense for Acquisition, Technology and Logistics.

Modeling and simulation is clearly and expressly critical to the MDA program and the successful operation of the evolving Ballistic Missile Defense System (BMDS). The Deputy Director of MDA recently cited that the first of his top three priorities upon assuming duties as the MDA Director is ensuring that M&S accurately reflects the physical BMDS and environments.

One factor in establishing such the necessary M&S capability is the creation (and use by all enterprise constituents) of a coherent, evolving, and formally managed simulation conceptual modeling (CM) effort. This task is particularly important and difficult because BMDS is a system-of-systems enterprise, entailing the coordinated development and use of hundreds of models and simulations over the BMDS evolutionary life-cycle.

The CM effort should be based on development and use of effective technical standards and best practices by the disparate BMDS community of interest, and endorsed and provided strategic guidance at the Agency enterprise level. The significance of CM is readily apparent in other such system-of-systems programs such as the NASA Space Exploration Program and the Army's Future Combat System.

Conceptual models serve as the common basis of representation of all entities within models and simulations. They provide support for common appreciation of the mission space by dispersed and differentiated members of the MDA M&S community of practice and anchor the development and qualification of all simulation assets. Failure to conduct a comprehensive and systematic M&S conceptual modeling program virtually guarantees inconsistent simulation representations and inefficiency in system-of-system engineering and system safety assurance.

For this circumstance, what is the relative expected return on investment in CM? Predictive results will be tracked through the program and confirmed at program milestones to ensure efficient investment and results recovery.

In this case, accurate, valid M&S outputs for the BMDS are essential for national security. So models that can be examined and challenged in order to develop more accurate representations, with perhaps faster run times, are essential. An elegantly simple yet complete model can more easily be evaluated through the VV&A process, where we judge readiness to perform accurately for the purposes intended. With hundreds of models and simulations, linked differently depending on the nature of the event, it is vitally important that the current models be evaluated conceptually and that future modeling efforts incorporate CM. Through the discipline of CM, the model that will give the best outcome for the intended purpose can be chosen, and the model performance, confidence in the model, and expected resource use can be understood.

For the proposed CM effort, management is faced with two choices:

(1) Authorize an ongoing CM effort to evaluate, understand, and improve the current and new M&S support to BMDS or

(2) Continue the status quo of limited or no CM after this 3-year trial.

5.2 Evaluation Process

In each of the three sample problems, Team members were asked to use the recommended process and to capture lessons-learned bearing on the efficacy of the overall investment management process, the core investment decision algorithm and the particular ROI computations that pertained to their problem. Exercise reports are included with the details of each use case in the Appendix, and generalizations from the three sample problem experiences were included along with results from analysis activity in the Determinations and Findings account of Chapter 6.

While it is obvious that no finite set of use case samples can exhaust the domain of intended applicability of the recommended M&S investment process, the cases posited were specifically chosen to exhibit both diversity and relevance characteristics to circumstances known (or expected_) to arise within the DoD community of practice. Nevertheless, one recommendation that followed from this evaluation exercise was that consultation with stakeholders for whom these problems are typical should be pursued. Another emphatic recommendation is that execution of the recommended M&S investment decision process should be conducted as part of any follow-on effort in order both to extend the range of test cases and to ensure that the proposed processes are tractable for DoD M&S investment decision agents themselves.

6 RECOMMENDATIONS AND FINDINGS

The sections below summarize the sample and relevant DoD and non-DoD initiatives that may include the establishment of M&S standards and specifications that promote interoperability and reuse and may address some of the issues/concerns that were evident in the recent survey conducted at Fall SIW.

6.1 Determinations and Findings

In the text that follows, summary determinations (observations) and findings (inferences) of the study are provided. Topics are addressed in the same order as were analysis subjects and determinations and findings that have logical inference relationships are paired.

6.1.1 Market Context and Business Practice

D1: Commercial (e.g. private sector) investment practice is a reasonable basis for DoD ROI metrics and investment processes. However, peculiarities of government organization, mission, and business practice are not sufficiently congruent with private-sector practice to permit direct employment of commercial ROI and investment processes.

F1: Adoption and adaptation of commercial practices based on differential characteristics of private and public sector business practices is necessary.

D2: Business process re-engineering recommended in this report will likely require concurrent adjustment to closely allied business processes.

F2: Identification of complimentary, enabling business process re-engineering elements necessary and sufficient to: support execution of the subject recommended investment decision process; facilitate evaluation and improvement of the subject candidate process; and support to collection, storage, and retrieval of data associated with M&S investment decision calculations for use by the Department.

6.1.2 Needs and Requirements Analysis

D3: User needs sufficient for the subject analysis were able to be derived from study task guidance, current practice, preliminary use case analysis and analyst intuition

F3: User needs and requirements discrimination is significant to dissociate stakeholder felt-needs from solution attribute criteria.

D4: Technical requirements sufficient for evaluation of recommended practice were established and confirmed.

F4: Further needs and requirements analysis should follow based on stakeholder participation. Included should be particularly usability criteria and stakeholder specialization features.

6.1.3 Stakeholder and Community-of-Practice Specification

D5: Stakeholder (actor-class) roles are strongly contingent and clearly implied by market context transactions types. Likewise, investment metrics and process are strongly dependent on stakeholder perspectives.
F5: Thorough specification of stakeholder types is necessary and viable. Standard, persistent stakeholder role specifications, suitable for reference and appreciation across the DoD M&S enterprise environment are desired.

D6: Stakeholder specification in terms of a list of parametric characteristics simplifies and systematizes stakeholder types and contingent sensitivities.
F6: Stakeholder perspectives influence on technical requirements should be explicitly identified and qualified.

6.1.4 Use Cases

D7: Use case analysis of systems- or process-employment is common practice, familiar across defense and industrial systems engineering communities, and demonstrably effective.
F7: Use case analysis is practically imperative in ‘hardening’ draft processes, or in establishing the receptiveness of communities who may be asked to adopt the subject process.

D8: Use case analysis illustrates stakeholder’s execution of subject processes and serves as story-line for exposition of subject process specification and use.
F8: Whenever possible, execute stakeholder specification with cooperation of representative agents; or confirm use cases derived otherwise with representative agents.

D9: Several methodologies for use case generation and specification exist which are generally self-consistent and sufficient for their intended purpose.
F9: Selection and consistent use of (any) one well accepted use case specification schema throughout process design and deployment is likely to be effective.

6.1.5 Asset Identification

D10: Potential M&S assets in which DoD investment is possible are hugely diverse. In addition, any single project, program or initiative is likely to entail investment in a considerable variety of such asset types.
F10: Precise investment type identification is essential to concomitant cost and results (utility, benefits) identification and estimation.

D11: M&S investment costs and results are relatively sensitive to M&S asset class. Asset types are somewhat dependent on DoD application domain categories and among actor-stakeholders with respect to need and perceived value; although considerable cross category interest in many investment classes exists. In addition, the difficulty of estimation of cost and results for alternative investment categories varies considerably. Finally, intangible assets whose cost or benefit ire relatively variable and difficult to quantify are likely to be particularly significant especially in enterprise environments.

F11: Consideration and accommodation in recommended practice of enterprise net assessment of desired asset investment is necessary. In particular, attention to free-rider dynamics and positive (or negative) externalities arising in association with any particular use case is prudent. [NOTE: this concern is inherited by cost and results determinations and findings as well, and introduces the fundamental question of how multi-scope collaborative decision-making can be optimally conducted.][84]

6.1.6 Cost Evaluation

D12: Cost estimation is especially sensitive to dissociation of bill payers and users or benefit recipients

F12: Cost estimation of potential investment must be systematic and clearly documented to facilitate follow-up reviews and analyses.

D13: Investment cost estimates may consist of a variety of component, distributed over time and incurred by a variety of bill-payer/stakeholder agents. In particular, cost estimation parameters vary considerably between alternative stakeholders (bill-payers) especially those whose scopes of interest are significantly different.

F13: Standard practices such as cost-estimation to compute NPV and bundling of cost data with results, scoping for ratio measurement estimation, are prudent.

6.1.7 Results Estimation

D14: Results analysis for identification of results types and valuation is most closely related to DoD M&S mission and vision accomplishment.

F14: Audit traceability of results categories to mission and vision topics is essential; and results metrics must be commensurate with those whereby accomplishment of mission/ vision is to be accomplished.

D15: Establishment of the results of an investment transaction is particularly difficult. In addition to time- distributed recovery (and consequent need to adjust to net present value); results estimation requires the quantification (monetary or non-monetary) and qualitative components whose significance is highly sensitive to the needs and interests of respective stakeholder communities.

F15: Evaluation of results via any recommended prescriptive process needs to be: a) well qualified with trisect to assumption of results elements and valuation included, and b) clearly and explicitly congruent to the stakeholder's perspective whose needs are intended to be met.

6.1.8 ROI Evaluation

D16: Well defined ROI evaluation practice exists for commercial / private-sector enterprise that needs to be preserved in adapted forms proposed for DoD.
F16: Attributes of ROI metrics should include a) non-dimensionality, b) time adjustment to net present value, c) weighted composability, d) derived across commensurate scope with respect to: stakeholder, transaction, asset, organizational effect.

D17: Government investment mentality is fundamentally insensitive to revenue recovery.
F17: ROI metrics must be generated from cost and results factors that are significant within the M&S mission and vision domain, using relevant cost and results factors.

6.1.9 Decision Process

D18: Decision process development, evaluation and deployment requires process specification that is explicit, systematic, comprehensive, and intuitive.
F18: While several process specification schemas exist that would be suitable, a simple generic combination of tabular and graphic (activity-on-node, control-flow-on-arrow) notation is preferred.

D19: Process content needs to be simple, communicable, structurally stable, and algorithmically specific, and executable within the existing multi-player collaborative decision context of the DoD M&S oversight committee, while still being tailorable to decision context.
F19: Multi Attribute Decision Process (MADP) style formulation meets all criteria and is preferred as a baseline decision approach.

6.2 Recommendations

Recommendations that follow are provided on behalf of the US DoD M&S Steering Committee via the DoD M&S Coordination office. These recommendations, unless otherwise qualified or limited, may be assumed to have the following attributes, namely, they are:

- Generated from the determinations and findings of the study and the constructive inferences of the study team
- Auditably traceable to the DoD M&S Vision statement or its direct implications
- Designed to constitute the pursuit and successful culmination of the topical investigation begun in the subject study
- Formulated in such a way as to cultivate the DoD M&S community of practice in taking ownership of the recommended best-practice.
- Selected to emphasize activities on the critical path to the important issue of successful management of M&S investment and recovery of desired value there from.

- Intended to support directly the establishment of comprehensive, operationally concrete, unbiased, and tailorable best-practice guidance for M&S investment for the DoD.
- Expected to initialize performance of the recommended best practice at several levels of application ranging from DoD corporate to specific projects to M&S infrastructure components
- Expected therefore to provide benefit to components across the DoD, communities of practice, Military Services, Program executive authorities and Program Managers.

For each activity topic cited below, a brief indication of the effort comprising the intended activity, its rationale, and its consequent product or resulting value.

6.2.1 Phase 1

- **Brief Phase 1 results to steering committee** – Communicating the results of the Phase 1 study to the Steering committee will provide them a view of the effort and its status without requiring too much motivated research. Communication with this body seems essential; particularly, since coordination with task sponsors during the period of performance was declined on grounds of time pressure. Understanding and acceptance of the recommended investment management strategy developed so far is prerequisite to any subsequent activity and certainly a necessary condition to successful, deployment. The community's understanding of the results of efforts to date, strategies recommended to be pursued, may help establish receptiveness for topical pursuit.
- **Compile comments and consequent requirements** – Capturing constructive comments and recommendations from the Steering Committee and other interested parties will improve understanding of the receptiveness of the community to the recommended best-practice, and will augment requirements criteria. Persistence of information on the topic oaf M&S investment practice and continuity of best practice evolution is desired regardless of what agent is executing tasks. Therefore, documenting such feedback is prudent.
- **Amend recommended process accordingly** – Being provided with relevant feedback on current effort and status, prompt remediation of the recommended practice serves to provide continuous process improvement, and to establish the habit of continuity in pursuit of the subject. Identify associated business process re-engineering necessary and sufficient to enable the recommended process implementation.

6.2.2 Phase 2

Considering the funding and schedule allocated for the subject tasking, a multi-task program of activity in pursuit of improved M&S investment management was recommended in task initiation briefings to M&SCO and members of the DoD M&S Steering Committee. Following activities constitute a somewhat more detailed prescription of follow-on effort in light of progress made and lessons-learned garnered in execution of subject tasking.

Phase 2 recommendations comprise substantially completion and refinement of best practice strategies and processes identified and provisionally evaluated in the subject study. They include practical, concrete, challenging exercise of the recommended process in milieu including significant organizational, programmatic, and stakeholder participation.

- **Establish Phase 2 Tasking** – The present study illustrates at least the plausibility of some systematic technique for metrication of investment effectiveness and for decision-making in questions of investment in M&S. Even if the specific process reported herein are not considered suitable for pursuit, the subject of M&S investment management within DoD is sufficiently important to the DoD M&S Vision, that some form of pursuit of the subject is warranted. Therefore, it is recommended that Phase 2 tasking be negotiated and initiated as soon as practical, contingent on direction or re-direction from the strategic trajectory of the subject study and selection of execution agents most likely to achieve deployable practices within the scope of phase 2 activity.

- **Analytically re-evaluate and harden process** – A specific process is advanced in the subject study for general use within DoD for M&S ROI metrication and for investment decision management. Analytic evaluation of the premises of the study, and its consequential procedural recommendations by both the Steering Committee or their agents and by the Phase 1 execution team. While the recommended best practice processes are considered to be appropriately comprehensive in scope of applicability, systematic in specificity of definition, and relevant to the need to manage M&S investment under diverse conditions; nevertheless, the process as offered may benefit from being closely scrutinized and 'hardened' by the remediation of any deficiencies identified. In addition to making corrections and emendations to the recommended process, specification of the process in the form of one or another formal schematic notations may be fruitful in improving the clarity, completeness and consistency of the process itself.

- **Simulate recommended process** – Insofar as the core of the constructive product of the subject study is a process specification; it seems prudent to implement that process in a form wherein its actual dynamic behaviors under conditions of parametric variation may be observed and evaluated – that is the process should be simulated and simulation exercise trials used in the same spirit as the formal process specification s recommended above, to improve the clarity, completeness and consistency of the process itself. In addition, process simulation representations should serve throughout the deployment of practice, as well as for future refinement or extension of process.

- **Conduct proof-of-principle demonstrations of recommended practice**[85] – Probably the most significant follow-on activity is conduct what amount to 'acid-tests' of the recommended investment decision process and ROI metrication by conducting proof-or-principle experiments. A few, carefully selected set of such exercises should:

    a) Be selected from real-world problem space rather than hypothetical or notional use cases. Adequate provision can be made for the process to be executed in parallel with other decision process dynamics so that no possibility of unanticipated pathological results being mad the basis of significant investment transactions.

b) Illustrate diversity and versatility of process by including significant 'points' in the manifold of investment problem space
c) In include participation of relevant stakeholders in each case including particularly the investment decision authority
d) Serve to validate the process at lease across the range of a domain of application – providing evidence of efficacy of the process for some significant class of decision types, and justification for its employment in earnest for problems within or near to the validated application domain.
e) Confirm or 'validate' the process simulation, providing evidence and justification for: a) revising the simulation to better reflect the behaviors of the process for real-world applications, and b) using the process simulation to illustrate how one or another investment decision might be addressed by the recommended process.

- **Generate Lessons-learned report –** Considering the extreme value of customer- / user-centric product or process prototyping, failure to document lessons-learned from proof-of-principle prototyping would be practically irresponsible. Independent of the possibility that alternative agents may be tasked to pursue M&S investment process evolution, the fact that the establishment of new business practice is an enterprise level activity needing to be shared over time and stakeholder constituencies, necessitates documentation of practical lessons. Such records will certainly serve to support continuous process quality improvement and will provide records from which implications for process de3ployment may be derived.

6.2.3 Phase 3

However appropriate the recommended process for supporting M&S investment decisions is found to be, the need exists to deploy and support the use of that process to the M&S DoD community of practice investment agents in order that its value be realized. Efficacy is a necessary but not sufficient condition for acceptance of any novel practice. Appreciation of the motivations of M&S investment agents and cultivation of their understanding of how the recommended best practice can serve their needs is imperative. Even modest facilitization and incentivization of the adoption of new practice may prove decisive.

- **Establish Phase 3 Tasking -** Commitment to deployment and support of a new M&S investment business practice and related process will be manifest by the conception and implementation of a program of activity focused on that purpose. Based on previous initiatives in standards (HLA) and best practice (VV&A)) it seems clear that successful launch and sustainment of M&S investment business practice will be most likely if accompanied by a specific, funded, program of activity.

- **Draft deployment and operational use plan –** Investment practice deployment and use is distinctive insofar that it involves virtually all components of the DoD M&S community of practice. In order to establish shared intention and expectation and to provide the opportunity for various elements of the community to influence the desired business-process-engineering, a concrete plan is desired. Citing, need, intention, strategy, activities, resources, schedule, management and collaborative organization, and resulting products or consequential effects, such a plan will serve to document the commitment to achieve systematic M&S investment practice.

- **Modify process and establish accoutrements in preparation for deploymen**t – In preparation for deployment of the M&S investment process for use within the DoD, several steps are prudent. Some prudent prefatory activities are indicated in the following list:

  a) Detail process model, and formalize its expression in a schema most suited to communication to potential users. This activity and consequent result are distinguished from the technical formalization of the process recommended for Phase 2 where process design was the most significant consideration. Here clarity of exposition, simplicity and resulting acceptability to users is paramount, while still preserving sufficient detail and precision of expression to support the user's execution of the recommended process.
  b) Specialize process and indicia for congressional rationale. Since congressional enquiry and oversight into the investment and cost effectiveness of M&S within the DoD has been overt during recent years, it may be necessary to review the recommended process in the light of its correct appreciation by congressional members and staffers. This review and potential amendment too is intended to address clarity of expression, ease of appreciation without sacrificing utility of the subject process in employment by elements of the DoD.
  c) Specialize by tailoring for stakeholder constituencies. In the spirit of continuing to make the proposed M&S business practice attractively acceptable to relevant stakeholders, elaboration of the process by providing specialization degrees-of-freedom, expressly to facilitate the assumption of the process by particular stakeholder classes such as the DoD "Application Domains" is recommended. These specializations would be manifest as elective options for the user in execution of the baseline process.
  d) Compile simulation for user familiarization. By providing a compiled version of the process simulation, users can themselves experiment in virtual space and time with prospective investment problems. Consequences of this capability include the prospect of users learning the investment process through the exercise of the process simulation, as well as of their continuing to evaluate and participate in the continual improvement of the investment process.
  e) Build prototype tool for process user(s). With an interactive tool, users can be supported to practice execution of the decision making process or to actually execute the process in particular applications. Automation via GUI interaction should both facilitate acceptability and utility of the subject process.
  f) Establish help desk support for users. No process, however articulate or logical is likely to positively need the sort of personal coaching-on-demand that is common for almost any software product or innovative practice. Given the potential barrier to entry for any DoD enterprise business-process-engineering, help-desk activity is strongly recommended.

- **Launch deployment with prototype employment (coach first 3 decisions) –** Fundamentally, the proof of the pudding is in the eating. For the subject investment decision process to be accepted and to take root within the DoD, evident, the fact and perception of significant successes are absolutely necessary. Close coaching to investment decision-makers will facilitate the achievement of first-out-of-the gate success, and will admit to real-time remediation (if and when necessary) and proceed on to completion of the specific M&S investment decision.

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APPENDIX A - ACRONYMS

ACROYNM	DEFINITION
AAR	After Action Review
AARS	After Action Review System
ABCS	Army Battle Command Systems
AFAMS	Air Force Agency for Modeling and Simulation
AHP	Analytic Hierarchy Process
AoA	Analysis of Alternatives
ASW	Anti-Submarine Warfare
AV	All View
AWACS	Airborne Warning and Control System
BCTC	Battle Command Training Center
BES	Budget Estimate Submission
BMDS	Ballistic Missile Defense System
BOM	Base Object Model
BPMI	Business Process Management Initiative
C2	Command and Control
CACCTUS	Combined Arms Command and Control Upgrade System
CAP	Combat Air Patrol
CBCSE	Common Battle Command Simulation Equipment
CFA	Chartered Financial Analyst
CM	Conceptual Modeling
CO	Coordination Office
COP	Common Operational Picture
COP	Community of Practice
COTR	Contracting Officers Technical Representative
COTS	Commercial off the Shelf
CSAR	Combat Search and Rescue
CTIA	Common Training Instrumentation Architecture
DAC	Days After Contract (award)
DAU	Defense Acquisition University
DFD	Data Flow Diagram
DIS	Distributed Interactive Simulation

ACROYNM	DEFINITION
DoD	Department of Defense
DSEEP	Distributes Simulation Execution Process
EG	Event Generator
ELKA	Entity-Link-Key-Attribute
EoA	Evaluation of Alternatives
ER	Entity-Relationship
EVA	Economic Value Added
FAR	Federal Acquisition Regulation
FEDEP	Federation Development Process
FY	Fiscal Year
GAAP	Generally Accepted Accounting Principles
GAO	General Accounting Office
GCCS	Global Command & Control System
GFE	Government Furnished Equipment
GFI	Government Furnished Information
GFP	Government Furnished Property
GOTS	Government off the Shelf
HDC	HLA DIS Bridge
HLA	High-Level Architecture
HQ	Headquarters
IAM	Intangible Assets Monitor
IAW	In Accordance With
ICOMs	Inputs, Controls, Outputs and Mechanisms
IDEF	Integrated Definition for Data Modeling
IFRS	International Financial Reporting Standards
IPR	In Process Review
IPT	Integrated Product Team
IRR	Internal Rate of Return
IT	Information Technology
JCATS	Joint Conflict and Tactical Simulation
JEDI	Joint Enterprise DoDIIS (DoD Intelligence Information Systems) Infrastructure

ACROYNM	DEFINITION
JFCOM	Joint Forces Command
KBSC	Korea Battle Simulation Center
LVC	Live, Virtual, Constructive
MADM	Multi-Attribute Decision Making
MAU	Multi-Attribute Utility
MCA	Military Construction Army
MCDM	Multi-Criteria Decision Making
MDA	Missile Defense Agency
M&S	Models and Simulations Modeling and Simulation
MS&G	Modeling, Simulation and Game
MSSC	M&S Steering Committee
NATO	North Atlantic Treaty Organization
NET	New Equipment Training
NISPOM	National Industrial Security Program Operating Manual
NIST	National Institute of Standards and Technology
NLT	No Later Than
NPV	Net Present Value
O&M	Operation and Maintenance
OCONUS	Outside Continental U.S.
OMG	Object Management Group
ONR	Office of Naval Research
OO	Object Oriented
OSD	Office of the Secretary of Defense
OSS	Open Source Software
OSTD	Object State Transition Description
OV	Operational View
PCO	Procurement Contracting Officer
PERT	Program (or Project) Evaluation and Review Technique
PFD	Process Flow Descriptions
POM	Program Objective Memorandum
PV	Present Value

ACROYNM	DEFINITION
QAP	Quality Assurance Plan
R&D	Research and Development
ROI	Return on Investment
SADT	Structured Analysis and Design Technique
SAF	Semi-Automated Forces
SBA	Simulation Based Acquisition
SECDEF	Secretary of Defense
Sim	Simulation
Sim/Stim	Simulation/Stimulation
SISO	Simulation Interoperability Standards Organization
SME	Subject Matter Expert
SOW	Statement of Work
SRS	Software Requirements Specification
SV	Systems View
T&E	Test and Evaluation
T&M	Time and Materials
TENA	Test and Evaluation Network Architecture
TV	Technical Standards View
TVM	Time Value of Money
UML	Unified Modeling Language
URL	Universal Resource Locator
US	United States
USARAK	U.S. Army Alaska
VV&A	Verification, Validation and Accreditation
VV&C	Verification, Validation, Certification

APPENDIX B - LEXICON / GLOSSARY

TERM	DEFINITION
Analysis Results	The products of an assessment project or effort that articulates the consequences and provides the residual value.
Appropriability	The environmental factors that govern an innovator's ability to capture profits generated by an innovation.
	Ability to recover the benefit of investment or invention. This is facilitated by IP control, IR&D practice, etc.
Approver	Individual who supports, endorses, or accredits an M&S tool, data, or service.
Architecture	The conceptual structure and overall logical organization of a process or system from the point of view of its use or design. A particular realization of the above.
Assessment	Estimation, evaluation; official valuation of property or income for the purposes of taxation; the value assigned to it.
Asset(s)	Something, either tangible or intangible, that has value to a/an organization / individual / department / entity / project.
	"Resources controlled by an enterprise as a result of past events and from which future economic benefits to the enterprise are expected to flow." (CFA Institute)
	a) Something of monetary value that is owned by a firm or an individual. Assets are listed on a firm's balance sheet and include tangible items such as inventories, equipment, and real estate as well as intangible items such as property rights, patents, or goodwill. b) Something (in accounting) that has <u>future</u> economic benefit and is available to be converted into cash (or is cash) to meet liabilities if necessary
Attribute(s)	A quality or characteristic ascribed to any person or thing. A parameter by virtue of possession of which classes are distinguished and by whose values individuals within that class may be distinguished.
Benefit(s)	(Pecuniary) advantage, profit, or good
Business Case	A 'Business Case' is an expression in economic terms of how some practice may be perceived as appropriate by the relevant stakeholders and so support their judgment to commit to the practice. A given business case will be contingent upon such factors as: business process / practices, roles / perspectives, cost / benefit management, and context of interpretation, cf. http://www.solutionmatrix.com/, http://www.prosci.com/t3.htm,
Buyer	A purchaser, purchasing agent, or expender of funds

TERM	DEFINITION
Capital	Embodied knowledge of productive processes, captured within a tool, process, or procedure, and how they may be carried out. It is knowledge captured and embodied in a form ready to apply to some use in production. In this sense, capital is developed to accomplish some purpose. [in regards to software, it becomes, with this definition, a package of accumulated, intangible knowledge that has been harnessed to accomplish some defined purpose.]
	Money or assets put to economic use. Economists describe capital as one of the four essential ingredients of economic activity; along with land, labor and enterprise. Capital takes different forms. A firm's assets are known as its capital, which may include fixed capital (machinery, buildings, and so on) and working capital (stocks of raw materials and part-finished products, as well as money, which are used up quickly in the production process). Financial capital includes money, bonds and shares. Human capital is the economic wealth or potential contained in a person. [The Dictionary of Economics by the *Economist*. http://www.economist.com/research/economics/]
	Any asset or group of assets – financial, physical, or intellectual – capable of generating income.
Capital Asset	A firm's assets are known as its capital, which may include fixed capital (machinery, buildings, and so on) and working capital (stocks of raw materials and part-finished products, as well as money, that are used up quickly in the production process). (The Economist Dictionary of Terms)
Capital Expenditure	a) Funds used by a company to acquire or upgrade physical assets such as property, industrial buildings or equipment. This type of outlay is made by companies to maintain or increase the scope of their operations. These expenditures can include everything from repairing a roof to building a brand new factory. b) In accounting an expense is considered to be a capital expenditure when the asset is a newly purchased capital asset or an investment that improves the useful life of an existing capital asset.
Community of Practice	A group of people who share a concern, a set of problems, or a passion about a topic, and who seek to deepen their knowledge / expertise and improve the area by interacting on an ongoing basis.
Commodity	A comparatively homogeneous product that can typically be bought in bulk. It usually refers to a raw material – oil, cotton, cocoa, silver – but can also describe a manufactured product used to make other things, for example, microchips used in personal computers. [The Dictionary of Economics by the *Economist*. http://www.economist.com/research/economics/]
	In economic theory, a commodity is a tangible good or service

TERM	DEFINITION
	resulting from the process of production. In general usage, a primary product, e.g. coffee, copper, cotton, wool, rubber and tin.
Complementarity (goods)	The ability of a capital resource (asset) to work with other capital resources to increase the output or efficiency of their productive use. Software (a form of digital capital), for example, is useless until it can be married to 'complementary' hardware on which it can run. Capital cannot be combined arbitrarily – only certain modes of complementarity are possible (e.g., railway lines can accommodate only rail cars designed with wheels have the same gage; for software, application protocol interfaces (APIs) represent a typical form of interfacing separate software products).
	Pairs of goods for which consumption is interdependent (e.g. cars and petroleum or cups and coffee) are complimentary goods and changes in the demand of one will have a complimentary affect upon the demand for the other. Complimentary goods can create difficulties in the application of the theory of marginal utility, since the level of utility yielded by a complimentary is not provided by that good in isolation.
	Finding the future value of a single sum or series of sums using appropriate interest rate(s) for the cost of money or the expected return on the investment. Also, the ability of an asset to generate earnings, which are then reinvested in order to generate their own earnings. In other words, compounding refers to generating earnings from previous earnings (Investopedia).
Compound Interest	The calculation of total interest due by applying the rate of interest to the sum of the capital invested plus the interest previously earned and re-invested. In contrast 'simple interest' is calculated only on the capital invested.
Conceptual Models	A software independent description of the model that is to be constructed. Specifies all of the needed the elements and the rules that determine their behavior. [R. J. Brooks and S. Robinson, Simulation, with Inventory Control (author C. Lewis), Operational Research Series, Palgrave, Basingstoke, 2001.]
Consumable	An item that is capable of being expended; that may be destroyed, dissipated, wasted, or spent. "Consumable commodities."
Consumers/Users	The end user of an analysis, study, or system, or of a tool, data, or service. Here the focus is on analysis, studies, or systems that employ M&S and M&S as a tool, transformer of data, or provider of a service.
Consumption	The process of expending money by a/an organization /individual/department/entity/project that does not result in an increase of assets.
	Process of using products in order to satisfy needs and desires (self-generated or imposed; real or imagined) so that the products

TERM	DEFINITION
	are used up, transformed, or deteriorated in such a manner as not to be either reusable or recognizable in their original form. In economics, the final using up of goods and services. The term excludes the use of intermediate products in the production of other goods (e.g., the purchase of buildings, machinery, or software by an enterprise). Also, Consumption can be viewed as a basically subjective phenomenon, with individual or organizational utility, or satisfaction, having primary importance in the valuation of the product(s) consumed.
Cost	"The amount or equivalent paid or charged for something" or the "loss or penalty incurred especially in gaining something" (http://www.merriam-webster.com/dictionary/cost). Normally, the value of a liquid asset or cash that must be paid for a good or service.
Cost Avoidance	Costs that were not budgeted / paid (i.e., avoided) because of the use of a changed product, system, tool, or process or because of another action taken. Alternatively, a management accounting term referring to an expense one has avoided incurring; it is commonly used in the field of energy management to describe the energy costs you avoided due to energy management initiatives. (Wikipedia)
Cost Benefit	A method of reaching economic decisions by comparing the costs of doing something with its benefits. Especially useful when contributing factors are inherently monetary – can be complex when the decision being contemplated involves some cost or benefit for which there is no market price or which, because of an externality, is not fully reflected in the market price.
Cost Model	An abstract representation of system, process, or product that focuses on the representation of cost / price factors.
Cost of Capital	The amount a firm must pay the owners of capital for the privilege of using it. This includes interest payments on corporate debt, as well as the dividends generated for shareholders. [The Dictionary of Economics by the *Economist*. http://www.economist.com/research/economics/]
Cost of Money	The cost of money refers to the availability of credit and the interest rate at which that credit is available, expressed as present future value; the "cost of money" refers to interest -- either interest paid on an existing loan or unearned interest when money is tied up in material assets or other investments that do not generate income (Wikipedia)
Cost Savings	The budgeted costs not expended as the result of a changed product, system, tool, or process or because of another action

TERM	DEFINITION
	taken.
Commercial-Off-The-Shelf [COTS]	A good that is available in the private sector market, normally at a price established by supply and demand and distributed under proprietary licensing
Criteria	The value of a variable or parameter against which some commensurable measured or observed value relevant to an object or process of interest can be compared for purposes of evaluation (singular, criterion)
Customer	Buyer of some good or service. Sometimes, in prospectus, having bought in the past or considered likely to buy in the future. Customers normally have discretionary choice whether to buy a good or service, but normally do not effect price in public sector markets. Customers in government economic transactions normally negotiate with seller to control price, rate, quality, and risk. Influence of customers in private sector markets seldom persists beyond the sales event except insofar as warranty or goodwill considerations pertain. Customers in government procurements are commonly deeply involved in the development of the good or the delivery of the service.
Decision	A clear and concise statement of the line of action intended to be followed by the commander as the one most favorable to the successful accomplishment of the assigned mission. (Department of Defense Dictionary of Military and Associated Terms: Joint Publication 1-02, 12 April 2001 (As Amended Through 04 March 2008).
	The act or process of deciding / a determination arrived at after consideration (Merriam-Webster Online Dictionary. 2008.)
Depreciated Cost or Value	The depreciated cost method of asset valuation is an accounting tool used by both corporations and individuals. It allows for the books to always be carrying an asset at its current worth, and allows cash flows based on that asset to be measured in proportion to the value of the asset itself. It also allows for even tax treatment of large capital assets like homes, factories, and equipment (Investopedia).
Digital Capital	Embodied knowledge, in digital form, developed and captured within a computer and/or software based tool, process, or procedure, and made available as input to further production of goods and/or services. It is knowledge digitally captured, packaged, and stored, in a form ready to apply to some productive use. In this form it is a type of asset that can have definite value to DoD, a value which can be maintained and extended when managed effectively. (note: adapted from "Economics", 7th Edition, Paul A. Samuelson, McGraw-Hill, 1967,

TERM	DEFINITION
	pages 48- 50, 570-571)
Discount Rate	The rate of interest charged by a Central Bank when lending to other financial institutions. It also refers to a rate of interest used when calculating discounted cash flow.
Discounting	Finding the present value of a single sum or series of sums
	The process of determining the present value of a payment or a stream of payments that is to be received in the future. Given the time value of money, a dollar is worth more today than it would be worth tomorrow given its capacity to earn interest. Discounting is the method used to figure out how much these future payments are worth today. Discounting is one of the core principals of finance and is the primary factor used in pricing a stream of cash flows, such as those found in a traditional bond or annuity. For example, the succession of coupon payments found in a regular bond is discounted by a certain interest rate and summed together with the discounted par value to determine the bond's current value (Investopedia).
Economic Ecosystems	An economic community supported by a foundation of interacting organizations and individuals--the organisms of the business world. This economic community produces goods and services of value to customers, who are themselves members of the ecosystem. The member organizations also include suppliers, lead producers, competitors, and other stakeholders. Over time, they co-evolve their capabilities and roles, and tend to align themselves with the directions set by one or more central companies. Those companies holding leadership roles may change over time, but the function of ecosystem leader is valued by the community because it enables members to move toward shared visions to align their investments and to find mutually supportive roles. (source: Predators and Prey: A New Ecology of Competition, by James F. Moore, Harvard Business Review, May/June 1993)
Economies of Scope	The generating cost savings or increased value by actively managing a portfolio to intentionally develop groups of assets of similar kind. Also known as economies of scale.
Enterprise	One or more firms under common ownership or control. Generally refers to the broadest scope of organization and operational process relevant to the subject discussion rather than to individual components thereof. E.g. “The subject analysis takes the DoD enterprise-wide perspective whenever possible.”
Equity	"Assets less liabilities; the residual interest in the assets after subtracting the liabilities." (CFA Institute)
Equity Debt	A measure of a company’s financial leverage (Dept/Equity Ratio)

TERM	DEFINITION
	calculated by dividing its total liabilities by stockholders' equity. (Investopedia)
Estimator	A type of indicator that uses one measure to predict the value of another. (Practical Software Measurement, McGarry et all, 2002)
Expend	To pay out. (http://www.merriam-webster.com/ dictionary/expending)
Expenditure	The act or process of expending. (http://www.merriam-webster.com/dictionary/expenditure)
Expense(s)	Generally used in finance to mean: "an item of business outlay chargeable against revenue for a specific period"; or "financial burden or outlay" "the cause or occasion of expenditure" (http://www.merriam-webster.com/dictionary/expense)
	In accounting: an event in which an asset is used up (or consumed) or a liability is incurred; in strict terms: decreases in economic benefits during the accounting period in the form of outflows or depletions of assets or incurrence of liabilities that result in decreases in equity, other than those relating to distributions to equity participants
	An event where a consumable is purchased in exchange for a current asset
Experience	Behaviors exhibited or performed in the past by the subject. Any body of relevant behavior suggesting persistent competency or capability.
Expertise	Competency, accumulated knowledge of a subject or capability to perform acts of a certain type.
Externalities	"An economic side-effect. Externalities are costs or benefits arising from an economic activity that affect somebody other than the people engaged in the economic activity and are not reflected fully in prices." (http://www.economist.com/research/economics)
Fixed Capital	Any kind of real or physical capital (fixed asset) that is not used up in the production of a product and is contrasted with circulating capital such as raw materials, operating expenses and the like. Fixed capital is that portion of the total capital that is invested in fixed assets (such as land, buildings, vehicles and equipment) that stay in the business almost permanently. [Wikipedia]
Free Rider Problem	"Free-riders" are individuals/entities/groups that consume more than their fair share of a resource, or pay/contribute less than their fair share to costs to costs of production (but still receive full benefits) (http://plato.stanford.edu/entries/free-rider/)
	Arguably the first documented reference to this issue is in Plato's Republic (Bk 2, 360b-c) during Socrates discussion w/ Glaucon (http://plato.stanford.edu/entries/ prisoner-dilemma/)

TERM	DEFINITION
	n. 1. In economics, the free rider problem refers to a situation where some individuals in a population either consume more than their fair share of a common resource, or pay less than their fair share of the cost of a common resource. A commonly used example of the economic notion of the free rider problem is found in national defense. All citizens of a country benefit from being defended; however, individuals who evade taxes are still protected by the same common resource of national defense, even though they did not pay for their fair share of the resource. (sources: Answers.com; Wikipedia.com) Within a DoD investment context, a situation in which some agencies/ organizations obtain the benefits/value of an investment without sharing (paying a share of the cost of creating the products of the investment).
	A circumstance when an individual is unwilling to contribute toward the cost of something (especially a 'public good') when he/she believes someone else will bear the cost instead and the individual will nevertheless enjoy the benefit of the investment. - Bannock
Funder(s)	The one who provides the fiscal or monetary resources for in support of a process or activity or the purchasing of a product.
Government-Off-The-Shelf [GOTS]	Software typically developed by the technical staff of the government agency, often for which it was created. Because the government controls all aspects of development and distribution, generally preferred for government purposes
Hardware-In-The-Loop [HWIL]	A (simulation) system in which hardware components are included within the 'loop of simulation causality. Often operational hardware (or software) are employed for increased realism, or in order to subject the hardware to a synthetic environment for purposes of design, test, or evaluation.
Incentive(s)	Any factor (financial or non-financial) that provides a motive for a particular course of action, or counts as a reason for preferring one choice to the alternatives. [Wikipedia]
	Incentive system: "A method of organizing production that uses a market-like mechanism inside the firm." (CFA Institute)
Indicator	A measure that provides an estimate or evaluation of specified attributes derived from an analysis model with respect to defined information needs. (Practical Software Measurement, McGarry et all, 2002)
Infrastructure	Roads, airports, sewage lines, water systems, railways, telecommunications and other similar public utilities. Likely also to include buildings, research and development assets, and common services owned by an enterprise and used as public

TERM	DEFINITION
	goods.
Internal Rate of Return	Discount rate that equates future inflows to future outflows (so it is the rate of return that results in the Net Present Value being zero). Also, the discount rate often used in capital budgeting that makes the net present value of all cash flows from a particular project equal to zero. Generally speaking, the higher a project's internal rate of return, the more desirable it is to undertake the project. As such, IRR can be used to rank several prospective projects a firm is considering. Assuming all other factors are equal among the various projects, the project with the highest IRR would probably be considered the best and undertaken first. You can think of IRR as the rate of growth a project is expected to generate. While the actual rate of return that a given project ends up generating will often differ from its estimated IRR rate, a project with a substantially higher IRR value than other available options would still provide a much better chance of strong growth. IRRs can also be compared against prevailing rates of return in the securities market. If a firm can't find any projects with IRRs greater than the returns that can be generated in the financial markets, it may simply choose to invest its retained earnings into the market (Investopedia).
Investment	The process of expending money by a/an organization /individual/department/entity/project that results in an increase of assets.
	Costs that result in the acquisition of, or addition to, end items. Such costs benefit future periods and generally are of a long-term character. Costs budgeted in the procurement and Military Construction appropriations are considered investment costs. Costs budgeted in the Research, Development, Test and Evaluation appropriation can be considered investment costs or expenses, depending on the circumstances. (Glossary of Defense Acquisition Acronyms & Terms, Defense Acquisition University Press, 12th Edition, July 2005)
	The process of adding to stocks of real productive assets. This may mean acquiring fixed assets, such as buildings, plan, or equipment, or adding to stocks and work in progress.
	Incurring costs in the present - for the right to receive future benefits / with the expectation of achieving an increased benefit in the future
Liability / Liabilities	The sum total of all expenses incurred, either implicitly or explicitly, by a/an organization / individual / department / entity /project related / relevant to a specific project / activity.
	"Present obligations of an enterprise arising from past events, the settlement of which is expected to result in an outflow of

TERM	DEFINITION
	resources embodying economic benefits; creditor's claims on the resources of a company." (CFA Institute)
Logistics	"The aspect of military science dealing with the procurement, maintenance, and transportation of military materiel, facilities, and personnel" "the handling of the details of an operation" (http://www.merriam-webster.com/dictionary/logistics)
M&S Asset	An asset or assets used in the science, practice, development, or use of M&S
M&S Investment	The process of investing (as defined) in or for M&S (as defined) assets (as defined) by an organization / individual / department / entity / project.
M&S Resource(s)	A source of relevant supply – in the case of M&S, resources normally include: models, simulations, databases, scenarios, threat libraries, V&V histories, accreditation pedigrees, environmental representations, architectures, and interfaces; but they may also include: interfaces, simulation federations, games, plans and policies, personnel, facilities and equipment, information sources, behaviors, system information and documentation, organizational knowledge, procedural knowledge, operational knowledge, mappings and translations, conceptual models, transaction protocols, software components, execution outputs, and analysis results and reports.
Management Process(es)	The procedures that seek to orchestrate an activity and guide it towards a common end.
Market	Any place where the sellers of a particular good or service can meet with the buyers of that goods and service where there is a potential for a transaction to take place" Economic Definition, (http://economics.about.com/cs/economicsglossary/g/market.htm)
	"The means through which buyers and sellers are brought together to aid in the transfer of goods and/or services." (CFA Institute)
	Marketing definition: in general, a market is defined as the group of individuals/organizations/entities that has the need for, and can afford, a product/service.
	A market exists whenever potential sellers of a good or service are brought into contact with potential sellers and a means of exchange is available - Bannock
Measurement	The dimensional or quantitative assignment of that which is being assessed (e.g., five inches long). A set of operations having the object of determining a value of a measure. (Practical Software Measurement, McGarry et all, 2002)
Metadata	Data on a process, event, or system that is fundamentally abstract in nature. A set of "data about data" that characterizes the referent in a more theoretical manner than first order descriptors.

TERM	DEFINITION
Metric(s)	Describe a system of measurement that includes: the item or object being measured; units to be measured, also referred to as “standard units”; and the value of a unit as compared to other units of reference. (The Metrics of Science and Technology, Geisler, 2000).
Microeconomics	The study of economics at the level of individual consumers, groups, or firms. …focus(es) on the choices facing, and the reasoning of, individual economic decision-makers. The general concern of microeconomics is the efficient allocation of scarce resources between alternative uses. - Bannock
Modeling and Simulation [M&S]	The use of models, including emulators, prototypes, simulators, and stimulators, either statically or over time, to develop data as a basis for making managerial or technical decisions. The terms "modeling" and "simulation" are often used interchangeably. (MSETT NAWC-TSD Glossary (reference (p)).) (DoD M&S Glossary, DoD 5000.59-M, January 1998).
Model(s)	An abstract, or simplified, representation of an item, system, or phenomenon.
Monetary	Relating to money or to the mechanisms by which it is supplied to and circulates in the economy” (http://www.merriam-webster.com/dictionary/monetary)
	Money: "Any commodity or token that is generally acceptable as the means of payment." (CFA Institute)
	The process of converting or establishing something into legal tender. It usually refers to the printing of banknotes by central banks, but things such as gold, silver, and diamonds can also be monetized. Monetization may also refer to exchanging securities for currency, selling a possession, charging for something that used to be free or making money on a goods and services that were previously unprofitable. Also, the process of converting some benefit received in non-monetary form (such as readiness) into a monetary form. The term is used when converting in-kind value (the output of many DoD investments) into some "equivalent" cash payment.
Multi-Attribute	The property of an object or system being described by more than one attribute
Net Present Value [NPV]	Present value of the future inflows and outflows discounted at the appropriate cost of capital. The difference between the present value of cash inflows and the present value of cash outflows. NPV is used in capital budgeting to analyze the profitability of an investment or project. NPV compares the value of a dollar today to the value of that same dollar in the future, taking inflation and returns into account. If the NPV of a prospective project is positive, it should be accepted. However, if NPV is negative, the

TERM	DEFINITION
	project should probably be rejected because cash flows will also be negative. NPV analysis is sensitive to the reliability of future cash inflows that an investment or project will yield (Investopedia).
Oligopsony	A market in which there are only a few large buyers for a product or service. This allows the buyers to exert a great deal of control over the sellers and can effectively drive down prices. Comparable to an oligopoly (few sellers). http://www.investopedia.com/terms/o/oligopsony.asp
Open Source	A development methodology, which offers complete accessibility to a product's source (goods and knowledge). Some consider it as one possible design approaches, while others consider it a critical strategic element of their operations. Before *open source* became widely adopted, developers and producers used a variety of phrases to describe the concept; the term *open source* gained popularity with the rise of the Internet, which provided access to diverse production models, communication paths, and interactive communities. The open source model of operation and decision making allows concurrent input of different agendas, approaches and priorities, and differs from the more closed, centralized models of development. The principles and practices are commonly applied to the development of source code for software that is made available for public collaboration, and it is usually released as open-source software. (Wikipedia)
Opportunity Cost	Cash flow that must be forgone in order to accept and expense now. The cost of an alternative that must be forgone in order to pursue a certain action. Put another way, the benefits you could have received by taking an alternative action. The difference in return between a chosen investment and one that is necessarily passed up. A choice between two options must be made. It would be an easy decision if one knew the end outcome; however, the risk that one could achieve greater "benefits" (be they monetary or otherwise) with another option is the opportunity cost (Investopedia).
Opportunity Cost Rate	Rate of return available on the best alternative investment of similar risk
Physical Model(s)	A actual / material representation that has the relevant features of the original
Planning	"The act or process of making or carrying out plans ; specifically : the establishment of goals, policies, and procedures for a social or economic unit" (http://www.merriam-webster.com/dictionary/Planning)

TERM	DEFINITION
Policies	A deliberate plan of action to guide decisions and achieve rational outcomes. [Wikipedia]
Private Sector	The part of the economy in which economic activity is carried on by private enterprise as distinct from public sector. The private sector includes the personal sector and the corporate sector.
Producer	Someone or something that creates economic value or generates goods and services.
Promoter / Advocate	Independent provider of encouragement to the development of the M&S market.
Public Good(s)	Goods which are non-rivalrous (one person's consumption or use of them does not deprive others from using them); non-excludable (if one person uses a good, it is impossible from excluding others from using them also); and non-rejectable (individuals cannot abstain from using the good or service even if they want to). - Bannock
Public Sector	Comprises central government and local authorities (general government) together with the nationalized industries or public corporations. Central government includes all those departments and other bodies for whose activities an official responsible to the executive authority is accountable.
Purchase	A transaction by which one party transfers something of value to another party in exchange for something else of value.
Purchase Price	The price one pays for an asset. This price is important as it is the main component in calculating the returns achieved by the investor. Essentially, it can be thought of as the price that is paid for anything that is bought. (Investopedia)
Qualitative	Descriptions or distinctions based on some quality rather than on some quantity. The term qualitative is used to describe certain types of information. Qualitative data are described in terms of quality (that is, 'informal' or relative characteristics such as warmth and flavor). This is the converse of quantitative, which more precisely describes data in terms of quantity (that is, using formal numerical measurement).
Qualitative Attribute (factor in decision algorithm)	An attribute of an object that is described using qualitative means.
Quantitative	Having to do with quantity. Capable of being naturally / easily measured. An attribute that exists in a range of magnitudes, and can therefore be measured. Measurements of any particular quantitative property are expressed as a specific quantity, referred to as a unit, multiplied by a number. Examples of physical quantities are distance, mass, and time.
Quantitative Attribute	An attribute of an object that is described using quantitative means

TERM	DEFINITION
Rate of Return	Usually net profit after depreciation as a percentage of average capital employed in business – i.e. rate of return on capital.
Repository	A place where data or specimens are stored and maintained for future retrieval. [Wikipedia]
Resource / Resources	A substance or item that is considered valuable because it can be used or exchanged to obtain capital.
Result(s)	Something that follows as a consequence of another action, condition, or event; an outcome. Used in this report as a synonym for value or benefit.
Return	The benefit derived from an investment
Revenue	Income that a company receives from its normal business activities, usually from the sale of goods and/or services to customers [Wikipedia]
Reviewer(s)	Provider of advise and consent of M&S issues
Risk	A measure of the inability to achieve program objectives within defined cost and schedule constraints. It has two components: the probability of failing to achieve a particular outcome, and the consequences of failing to achieve that outcome. (Glossary of Defense Acquisition Acronyms & Terms, Defense Acquisition University Press, 12th Edition, July 2005)
	"The chance of things not turning out as expected. Risk taking lies at the heart of capitalism and is responsible for a large part of the growth of an economy. In general, economists assume that people are willing to be exposed to increased risks only if, on average, they can expect to earn higher returns than if they had less exposure to risk." (http://www.economist.com/research/economics)
	Possibility that actual outcomes will vary from what is expected.
Role(s)	The named designation of a relationship that may be assigned-to or assumed-by an individual or organization with respect to some function or organizational entity. Role is intended to imply requisite authority and concomitant responsibility to execute the associated functions or to act successfully in relation to the designated organizational entity. [Webster..."a part or character assumed by anyone."]
Role (Functional) Authority	Those functions (including decisions) that the individual person or organization assigned to a role class or instance may perform. …what the role holder may do…
Role (Functional) Responsibility	Those functions that must be performed by the person or organization assigned to any particular role class or instance. Performance of functional responsibilities is a necessary condition of satisfactory role-position execution. …what the role holder

TERM	DEFINITION
	must do…
Scale	A specified, graduated reference used to measure the value of an item to a decision maker or user.
Seller(s)	Provider of M&S tools, data, or services
Simulation	A dynamic model
Stakeholder(s)	An individual or organization that sponsors measurement, provides data, is a user of the measurement results, or otherwise participates in the measurement process. (Practical Software Measurement, McGarry et all, 2002)
	Those functions (including decisions) that the individual person or organization assigned to a role class or instance may perform. …what the role holder may do…
Time Value of Money	The idea that a dollar today is worth more than a dollar in the future, because the dollar in the hand today can earn interest during the time until the future dollar is received. (http://www.economist.com/research/Economics/alphabetic.cfm?letter=T#timevalueofmoney)
Units of Cost	The cost of an item or service expressed in a common currency; for this report, expressed in United States' dollars.
Universe of Stakeholders	All of the participants with an abiding interest (types or individuals) relevant to a specific use case or instance of investment management.
Use Case(s)	A description of a system's behavior as it responds to a request that originates from outside of that system. The use case technique is used in software and systems engineering to capture the functional requirements of a system. Use cases describe the interaction between a primary Actor (the initiator of the interaction) and the system itself, represented as a sequence of simple steps. Actors are something or someone which exist outside the system under study, and that take part in a sequence of activities in a dialogue with the system to achieve some goal. They may be end users, other systems, or hardware devices. Each use case is a complete series of events, described from the point of view of the Actor. In this case the system is the proffered Investment decision practice and ROI computation algorithm. http://en.wikipedia.org/wiki/Use_case
Useful or Serviceable Life	The length of time that a depreciable asset is expected to be useable (Investorwords). Also, the time an asset will provide benefit to the business. The depreciation expense calculation requires an estimate of years of usefulness. The service life of an asset may be less than its physical life due to obsolescence or future lack of need (Answers.com).
Utility	The "utility" of something is one factor that is taken into consideration when determining things of "value."

TERM	DEFINITION
	The (relative) importance of items in a class to an agent. (Choices: An Introduction to Decision Theory, Resnik, 1987).
	The state or quality of being useful militarily or operationally. Designed for or possessing a number of useful or practical purposes rather than a single, specialized one. (Glossary of Defense Acquisition Acronyms & Terms, Defense Acquisition University Press, 12th Edition, July 2005)
	Economist-speak for a good thing; a measure of satisfaction. Underlying most economic theory is the assumption that people do things because doing so gives them utility. Individuals strive to achieve as much utility as possible. However, the more they have, the less difference an additional unit of utility will make – there is diminishing marginal utility. Utility is not the same as utilitarianism, a political philosophy based on achieving the greatest happiness of the greatest number.
Utility Function	A representation of a consumer's preferences that maps potential and actual items and outcomes and the value preferences of a consumer or decision maker.
Utility Scales	A specified, graduated reference used to measure the value of an item or process to a decision maker or user.
Value	Relative worth" or "utility" that can change over time, and is, inherently, a relative concept. However, neither one of the aforementioned features makes something's value either less "real" or less "tangible."
	"The monetary worth of something" "relative worth, utility, or importance" or "a numerical quantity that is assigned or is determined by calculation or measurement" (http://www.merriam-webster.com/dictionary/value)
	A numerical or categorical result assigned to a base measure, derived measure, or indicator. (Practical Software Measurement, McGarry et all, 2002)
	That commodity can be exchanged for generates for its owner or user. Value in exchange is the quantity of other or more usually money worth of something to its owner or recipient, That which makes a product or service desirable. Value in use refers to the pleasure a commodity actually has. See utility
Working Capital	Raw materials or intermediate goods, or goods in process. These are the goods that get incorporated into products and become part of them. [In an office context, the word processor, spreadsheet and database management software are fixed capital, and a company's texts and financial data are working capital. They may be processed by the word processors and spreadsheets into financial reports.]
Yield	To generate a return, as for labor expended. The act of producing – often through the interaction of two or more substances or processes.

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APPENDIX D - EXCERPTS FROM: FINAL TECHNICAL REPORT OF SIMSUMMIT SURVEY ON US DOD M&S MANAGEMENT / LEADERSHIP

1 August 2007

Prepared by:
***SimSummit* Round Table**
Prepared for:
US DoD Modeling and Simulation
Steering Committee Tri-Chairs

D.1 Business Practice

D.1.1 M&S Investment and ROI

Considerable attention has been paid to the subjects of the economics of M&S and ROI. "The advent of more and more visible and expensive modeling and simulation enterprises invites explicit consideration of cost and of value of return-on-investment (ROI) in the narrowest terms and, more broadly, of the economics of modeling and simulation as a market sector.", see Appendix ___ for article appearing in SISO Simulation Technology webzine, Volume 2 issue. Much of this effort, its consequential results, and the fact of its stakeholders interests and potential collaborative participation is relevant to the intention of the survey, although not necessarily familiar to survey participants. While these activities are not strictly within scope of survey results analysis, they are cited in order to establish a broader context for the reader of interpretation of particular survey response contents. Particulars include the following:

- Collegial Initiative on the Economics of M&S – begun in 1999, this effort has included collaborative workshops at more than 25 events sponsored by professional, technical and industrial development organizations, see Appendix __ for an abstract of the program.
- Presence as component of *SimSummit* topical agenda since its inception in 2002.[86]
- Subject of SISO study groups and current Standing Study Group, see Appendix __ for terms of reference.
- Subject of NATO MSG 031 Study, see Appendix __ for terms of reference.
- Emphatically present in proceedings of Congressional Caucus M&S Leadership Workshops in 2005 and 2006.[87]
- Subject of a one-day Workshop held on Tuesday, 26 June at AFAMS in Orlando, Florida
- Documented via an annotated bibliography compiled pursuant to SISO and *SimSummit* activities[88]

D.1.2 Determinations and Findings

DD1-1 - ‘Intention and strategy’ for M&S investment and ROI whereby DoD enterprise-scope needs are to be met are not evident, authoritative, or effectively socialized across the DoD M&S community-of-practice.

DD1-2 - Several ‘market attributes’ exist that are considered significant contextual circumstances for any viable program of DoD M&S investment and value recovery.

DD1-3 - Existing ‘management organization’ lacks central vision, authority, and unity of action necessary to lead and control a successful DoD M&S investment program.

DD1-4 - Existing practices for ‘management process’ are apparently fragmented, expedient, and unmotivated.

DD1-5 - Supporting infrastructure necessary to manage DoD M&S investment does not exist.

D.1.3 Recommendations

RD1-1 - Establish explicit, authoritative ‘intention and strategy’ for M&S investment and ROI addressing particularly DoD enterprise-scope perspectives.

RD1-2 - Identify and account for significant effective ‘market attributes’ in reducing DoD strategic intention to practice.

RD1-3 - Existing structure for ‘management organization’ lacks sufficient central vision, authority, and unity of intention to lead and control any coherent program of M&S investment and value-recovery.

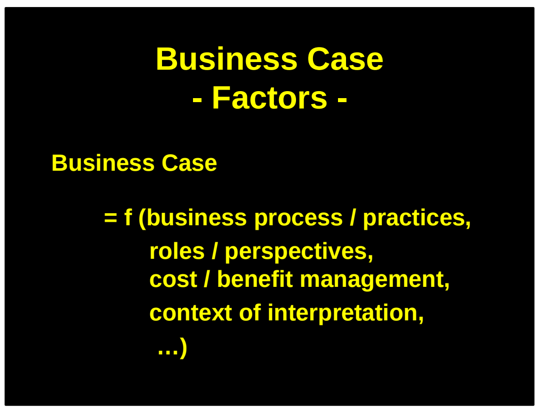
RD1-4 - Establish robust process for M&S resource allocation necessary and sufficient to meet DoD strategic objectives.

RD1-5 - Provide supporting infrastructure necessary to establish explicit, public, authoritative and persistent information base of necessary for investment resource allocation.

APPENDIX E - BUSINESS CASE

A Business Case is a form of expression of the plausibility of one or another business practice, action, or transaction. Naturally, the successful business case requires that the anticipated process or course-of-action be clearly appreciated by the variety of stakeholders. The business case then provides the basis of expression and communication, of advocacy, of deliberation, of perception and judgment, and, last and not least, of the establishment of the *commitment-to-act* by SBA stakeholders. A business case is by its nature hypothetical, and it is contingent for its success on its the validity of its premises, the relevance of its implications, and the effectiveness of its expression

Any given business case is dependent for its effectiveness on a variety of factors.



The business case must be expressed in terms of the business processes and practices which characterize the domain of application. Its elements must correlate to the everyday behaviors, 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 SBA practices. Government and private industry 'players'… system 'users', 'developers', and 'evaluators' … technologists, systems analysts, program managers, contract specialists, financiers, and procurement executives alike must be considered.

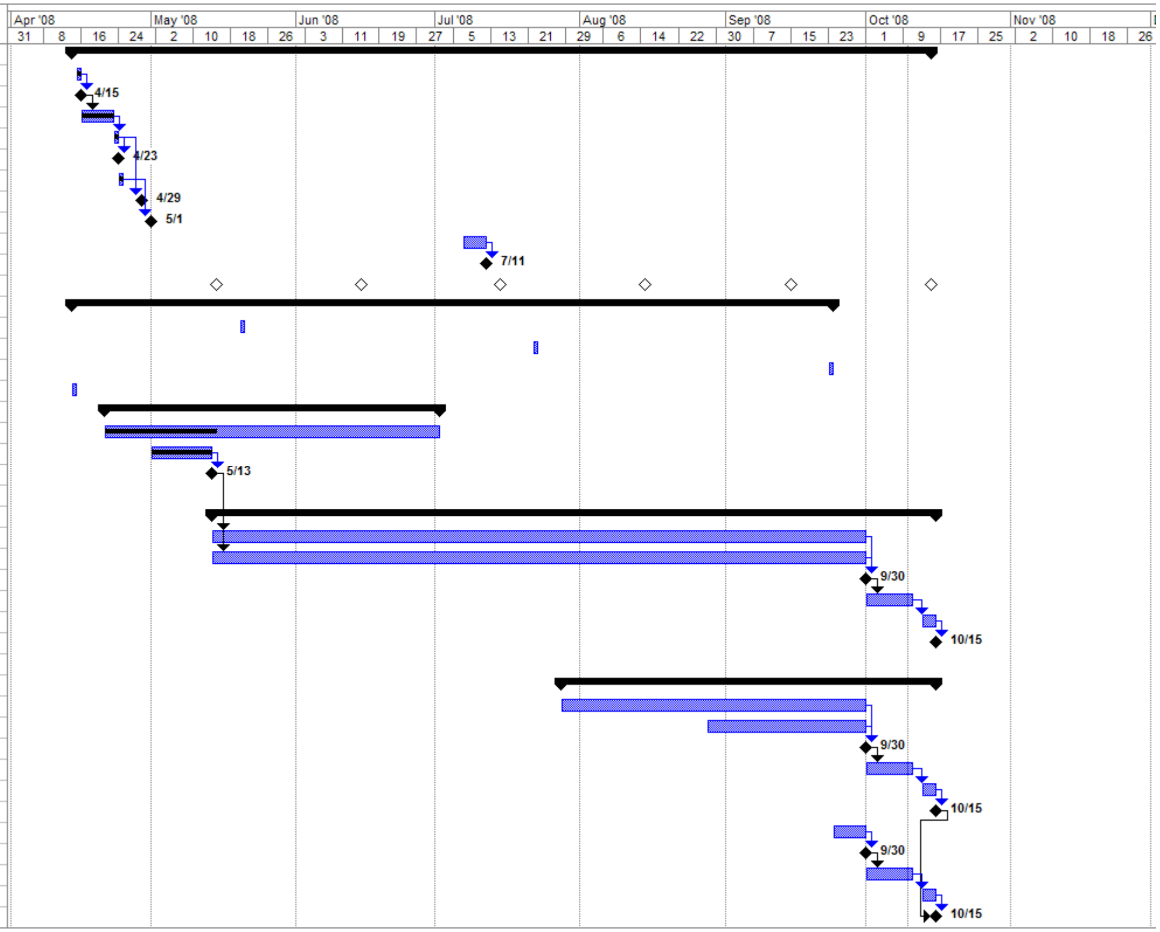
Appreciation of various sorts of costs and benefits must be reflected in an effective business case. Direct cost and cost-avoidance must be accounted. Quantitative benefits such as cost savings and qualitative benefits such as risk avoidance, product quality and time-to-field must be accounted. Dependencies of cost and benefit upon extenuating circumstances must be identified and collectively appreciated. In particular, the dependencies of cost and benefit upon the complements to simulation in an SBA operational environment (i.e. data and collaboration infrastructure) may need to be separately accounted. Visibility of cost and benefit metrics and aggregate merit functions will be required. Causal relationships between investment and recovery of investment must be evident …even (or especially) across the boundaries of stakeholder tenure or domain of authority and responsibility.

Finally, the context of the expression and interpretation of the business case must be clearly established.

The business case for modeling and simulation *now* will certainly be different from the business case for M&S *after* we have achieved SBA-like operations. Similarly, the business case for getting *from* the present *to* the SBA-future is different from (but dependent upon) both. And, since business cases may come to be established which are valid for alternative levels of generality / abstraction, the particularization which is necessary to move from a 'generic' business case to the 'specific instance' appropriate for a given system must be *learned, taught and practiced*.

APPENDIX F - TIME PHASED PLAN

ID	Task Name
1	**Program Management**
2	Develop Project Charter
3	Project Charter
4	Task Execution Planning (SOW 3.2)
5	Develop Project Plan & Checklists
6	AEgis Project Plan & Checklists
7	Start of Work Telecon (SOW 4.2.1)
8	Gov. Task Execution Plan (SOW 4.2.2)
9	Start of Work Telecon Minutes (SOW 4.2.1)
10	IPR Planning (SOW 4.2.5)
11	IPR Inputs (SOW 4.2.5)
12	**Monthly Status Reports (SOW 4.2.4)**
19	**Working / Coordination Meetings**
20	Meeting #1
21	Meeting #2
22	Meeting #3
23	...
24	***Study Approach & Methodolgy***
25	*Conduct Literature Search (SOW 3.1.1)*
26	*Develop Description & Rationale for Technial Approach (SOW 3.1.1)*
27	*Approach & Methodology Report (SOW 4.1.1)*
28	
29	**M&S ROI Criteria & Metrics**
30	Define M&S ROI Criteria Set (SOW 3.1.3)
31	Per Criteria - Determine Measurement Metric (SOW 3.1.4)
32	Draft Criteria & Metrics Report
33	Customer Review of Draft Report
34	Update Criteria & Metrics Report
35	Final Criteria & Metrics Report (SOW 4.1.2)
36	
37	**Decision Process for Application of ROI Criteria & Metrics**
38	Develop Decision Process (SOW 3.1.5)
39	Determine Scope & Types of M&S Subject to Metrics (SOW 3.1.6)
40	Draft Decision & Application Report
41	Customer Review of Draft Report
42	Update Decision & Application Report
43	Final Decision & Application Report (SOW 4.1.3)
44	Develop Draft Briefing Package - Application of ROI Criteria & Metrics
45	Draft Briefing Package - Application of ROI Criteria & Metrics
46	Customer Review of Briefing Package
47	Update Briefing Package - Application of ROI Criteria & Metrics
48	Final Briefing Package - Application of ROI Criteria & Metrics (SOW 4.1.4)



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APPENDIX G - ROI REQUIREMENTS OVERVIEW

SOURCE	NEEDS	REQUIREMENTS	CRITERIA (rec.)
CONTRACT TASKING			
ACTIVITY			
	Decision Support (3.1)	Define a set of metrics to support modeling and simulation (M&S) decisions by the DoD	• Set of metrics • Metrics defined • Metrics support decision process
		Decision process for the application of the criteria and metrics (cited below)	• Decision process • Employs metrics • Decision dependent on criteria
	Investment utility / value (3.1)	Recommended, uniform set of measures (metrics) to assess the effectiveness and benefits of actions implementing the "DoD M&S Vision."	• Metrics set consistent / systematic for alternative (classes of) use and variety of investment categories • Cover scope of topics indicated in Vision Document (e.g. as 'kinds of investment')
	Literature Search (3.1.1)	Conduct a literature search	• Compiled bibliography • Published as report APPENDIX • Citations linked as footnotes or endnotes in report • Most significant bibliographic citations annotated, indicating: intent, cope, relevance to study, influence on study
	Study motivation report (3.1.1)	Description and rationale for the study's technical approach.	• Indicate for Study introduction in report: Background, Context, Need, Intention, Strategy
	Understanding (3.1.2)	Develop the needed understandings	• Indicate results of study analysis, including: fundamental precepts, current status, lessons-learned, issues and challenges, tactical

SOURCE	NEEDS	REQUIREMENTS	CRITERIA (rec.)
			ameliorative, and derived guidance for: generation of investment decision process, ROI metrics, and ROI criteria, and process implementation.
	ROI criteria (3.1.3)	Define a set of criteria by which the return on invest-ment (ROI) of an M&S investment may be determined.	• Explicit ROI metric algorithm. provided • Factors upon which execution of algorithm depends explicitly identified
	Criteria metric (3.1.4)	For each criterion, determine the applicable metric and the means by which it may be objectively measured	• Factor scale defined and measurement or value determination process prescribed.
	Metric Scope of Relevance (3.1.4.1)	metrics and sup-porting information shall describe the total DoD Invest-ment in a M&S project or initiative	• Process steps and algorithms prescribed with sufficient generality or with instructions for specialization to alternative application domain.
	Metrics correlated to value (3.1.4.2)	metrics and supporting data shall describe the Return in Value to the DoD from an investment.	• Results metric components demonstrably correlated to positive value recoverable pursuant and consequent the subject investment
	Decision Process (3.1.5)	Develop a decision process for the application of the criteria and metrics	• Decision process fully specified in algorithmic detail including for each process step specification of entrance criteria, necessary input, intention, activity, execution agent, consequent result product, and exit or completing criteria.
	M&S investment asset identification (3.1.6)	Recommend the scope and type of M&S that should be subject to return on investment (ROI)	• OBE on grounds that practically any M&S investment should be practically subject to consideration of use of the

SOURCE	NEEDS	REQUIREMENTS	CRITERIA (rec.)
		assessment	recommended ROI investment and associated decision process.
REPORTS			
	Report (3.1)		• IAW Paragraph 3.1 of the contract SOW
	Task Execution Plan (3.2)		• IAW Paragraph 3.2 of the contract SOW
	Quarterly In Process Reviews (IPRs) (3.3)		• IAW Paragraph 3.3 of the contract SOW
	Monthly Progress Reports (3.4)		• IAW Paragraph 3.4 of the contract SOW
DELIVERABLES			
	Technical Reports (4.1)		• IAW Paragraph 4.1 of the contract SOW
	Preliminary Report (4.1.1)	Preliminary report detailing the study approach and methodology	• IAW Paragraph 4.1.1 of the contract SOW and CDRL A001.
	Study Report (4.1.2)	Study report detailing criteria and metrics for the assessment of the ROI of M&S investments; their associated rationale; and the means by which they may be objectively measured	• IAW Paragraph 4.1.2 of the contract SOW and CDRL A002.
	Study Report (4.1.3)	Study report detailing a decision process for the application of the criteria and metrics and the scope and type of M&S that should be subject to return on investment (ROI)	• IAW Paragraph 4.1.3 of the contract SOW and CDRL A003.

SOURCE	NEEDS	REQUIREMENTS	CRITERIA (rec.)
		assessment	
	Briefing (4.1.4)	Briefing package detailing application of the ROI assessment criteria and metrics	• IAW Paragraph 4.1.4 of the contract SOW and CDRL A004.
	Administrative Reports (4.2)		• IAW Paragraph 4.2 of the contract SOW
	Minutes (4.2.1)	Start of Work Teleconference Minutes	• IAW Paragraph 4.2.1 of the contract SOW and CDRL A005.
	Plan (4.2.2)	Task Execution Plan	• IAW Paragraph 4.2.2 of the contract SOW and CDRL A006.
	Trip Report (4.2.3)	Trip reports	• IAW Paragraph 4.2.3 of the contract SOW and CDRL A007.
	Monthly status (4.2.4)	Monthly Project Status Reports	• IAW Paragraph 4.2.4 of the contract SOW and CDRL A008.
	IPR (4.2.5)	Inputs to In-Process Reviews	• IAW Paragraph 4.2.5 of the contract SOW and CDRL A009.

APPENDIX H - DERIVED REQUIREMENTS

SOURCE	NEEDS	REQUIREMENTS	CRITERIA (rec.)
'DERIVED' TOPICAL ANALYSIS			
	01 - Stakeholder		• Identify important stakeholder types • Characterize stakeholders, indicating motivation, operational proclivities and preferences, roles, and responsibilities • Indicate the likely posture of stakeholder classes to M&S investment, systematic decision processes, criteria, metrics, and systematic investment in M&S • Identify needs for cultivation of stakeholder community in order to facilitate recommended M&S investment practice.
	02 – (Requirements)		• (Meta topic, see herein)
	03 - Market Context and Business Analysis		• Define investment and distinguish investment from consumption • Establish normal investment market structure and dynamics. Characterize normal investment with roles, motivations and incentives, transaction types and behaviors • Indicate typical measures of investment success and decision processes supporting normal market investment practice. • Identify characteristic desiderata of such markets and investment decision processes and success-measurement practice. • Distinguish DoD budget and acquisition (investment) market and differentiate from normal investment markets • Cite DoD business practice characteristics likely to

SOURCE	NEEDS	REQUIREMENTS	CRITERIA (rec.)
			influence efficacy of M&S investment process • indicate necessary ameliorative particularly wrt investment decision practice and ROI measurement that will preserve desiderata of normal market investment
	04 - Investment Decision Process		• Identify alternative investment decision process candidates. • Include accommodation for participation of stakeholder communities in collective decision-making • Characterize alternative decision making processes and correlated their attributes to the relevant circumstances. • Indicate which processes are best suited to DoD M&S investment market environments
	05 - Asset Identification		• Identify and classify M&S assets or capabilities in which investment may be considered • Characterize alternative classes indicating distinctive features upon which investment cost factors or investment benefit factors may depend.
	06 – Asset Investment Cost		• Identify elements of cost for M&S investments identified above. • Characterize cost factors and indicate typical parametric dependencies • Identify differential stakeholder sensitivity to alternative M&S investment costs
	07 – Asset Investment Results		• Identify elements of results / benefit / return for M&S investments identified above. • Characterize benefit factors and indicate typical parametric dependencies • Identify differential stakeholder sensitivity to alternative M&S investment benefits
	08 - ROI Algorithm Options		• Identify alternative expressions indicating normalized benefit of investment transactions

SOURCE	NEEDS	REQUIREMENTS	CRITERIA (rec.)
			(e.g. benefit cost ratio or ROI equivalent) • Specify computational or qualitative algorithms for valuation… address particularly mixed mode quantitative / qualitative metrics and those whose components are variably uncertain. • Evaluate alternative ROI algorithm options for suitability in context of government M&S investment decision and effectiveness comparison
	10 – Use Cases		• Identify a few cases in which M&S investment may be described in concrete terms, including: stakeholders participation, motives and intentions of all role-player participants, transaction activity among stakeholders constituting investment and value recovery process, use of investment decision processes and associated ROI metrics and criteria in support of investment decision (a priori) or in support of appreciation of relative cost-utility of one of more investments (ex posteriori) • Illustrate typical transactions among representative stakeholders, investing in assets cited in M&S vision. • Illustrate recommended investment decision process(es) and educe positive and potentially negative consequences of their employment.
GENERAL ANALYSIS			
	11 – Literature Search Bibliography		• Completion of bibliographic search • Classification of references by topic • Compilation of bibliographic citations for publication • Generation of annotation of

SOURCE	NEEDS	REQUIREMENTS	CRITERIA (rec.)
			most significant references
	12 - Lexicon - Glossary		• Identification of critical vocabulary and acronyms • Definition of critical terminology • Explication of terms which are overloaded, ambiguous, unusual, equivocal as used in normal economic analysis and DoD government budgeting and procurement process environments • Compilation of dictionary / glossary for report appendix.
BEST PRACTICE SYNTHESIS			
	09 - Conjoin Decision Process and ROI Metrics		• Incorporation of ROI calculation and associated metrics calculation into macro-decision process are prescribed .
	13 – Best Practice Documentation		• M&S investment decision process and associated metric calculations constitute core of recommended best practice. • Best practice guidance document DRAFT provided at IPR indicating subject document content recommendation.
PURSUIT RECOMMENDATIONS			
	14 – Best Practice Deployment		• Recommendations for deployment of best practice to be identified, and included in determinations, findings. And recommendations of the Final Technical Report. • Actual process 'hardening' and deployment for use in the DoD M&S community-of-practice are recommended to be addressed in follow-on phases of the effort.

APPENDIX I - SOFTWARE AND SIMULATION AS CAPITAL ASSETS

I.1 Capital

For the purposes of this report, the result of DoD investment in M&S is an addition to capital. What is "capital" in this context? The concept, concisely stated, is this: **Capital is embodied knowledge.** What does that mean? Simply, that when resources are marshaled and applied to build new tools, the builders of those new tools draw on the existing knowledge and expertise of those who have gone before to pull together a new set of functionality and capability, which is essentially the capture and embodiment of knowledge. The end result, executed properly, is a new capability, providing more and better capability. *The new piece of capital – an asset − captures and embeds within itself some amount of knowledge accumulated over time and space.* Once in place, users freely make use of this tool – without having, or needing to know, all the knowledge that has been captured. Examples include: a hammer, or a safety razor, or the Microsoft Office Suite - just try building one from scratch your self.

For this report, when the M&S investment involves specific software products, that "software" is treated as *digital capital*[89], embodied knowledge, in digital form, developed and captured within a computer and/or software based tool, process, or procedure. "Digital capital" in this context is *software having enduring value* for DoD users. Digital capital, and all other forms of capital (training infrastructure, T&E ranges, R&D laboratories, etc.), are forms of assets, having and providing ongoing value to DoD.

I.2 Capital Structure

This concept of capital as an asset is best stated by Baetjer and Lewin: "Understanding of the nature of capital and of capital development requires a clear appreciation that *capital goods work and have value in particular relationships with one another* (emphasis added) in the capital structure (Lachmann 1978/1956, Hayek 1941). New tools contribute to the economy not by being thrown, as it were, into a bubbling economic pot, where one ingredient adds as much to the amorphous stew as another. Rather they each must fit into a structure, or, more aptly, they must play a particular role in a particular niche in a kind of economic "ecosystem." If they are ill adapted to their niches, they make no contribution, fail to sustain themselves, and are selected out. Capital exists and works within a structure. It is *an ever-evolving structure* to be sure - it is never static - but throughout its evolution the relationships among capital goods, and among capital goods and human capital, are essential. Contra the picture painted by orthodox neoclassical economics, capital is neither static nor homogeneous. In its aggregate manifestation it is best understood as a *structure* rather than as a *stock*. A structural approach to capital is one better suited to an understanding of business institutions than is a stock-based approach (Lewin 2005)."[90]

Figure I.2-1 illustrates the concepts discussed. Over time, knowledge is captured and embedded in capital, which is then available for productive use. The value thus created is a combination of all three elements. As time unfolds, knowledge and capital (as an asset having specific uses) change, impacting and changing the value provided. The value received will erode over time unless action is taken to maintain the value of the capital asset. The mechanism by which value is maintained is called capital maintenance, and is discussed below. Seen from this perspective, it is easy to visualize each developed capital asset as having some ascribed value, *and* a rate of change in value over time, either positive or negative. These two characteristics of capital are important in assessing and assigning value, as will be seen later in this report.

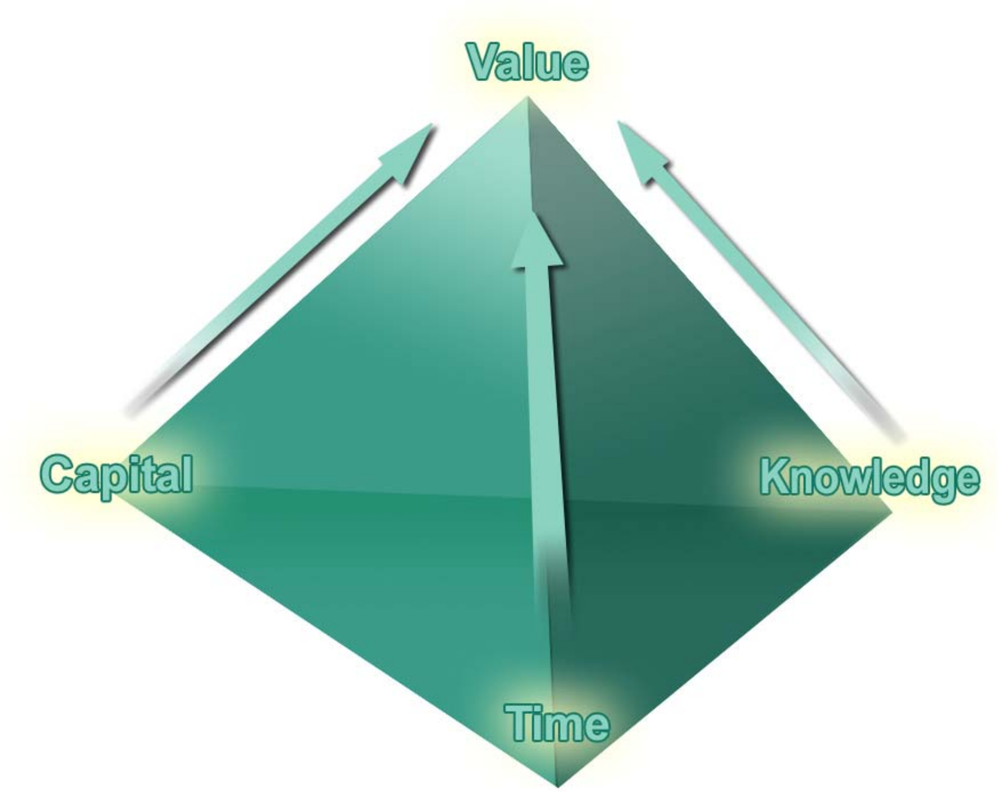


Figure I.2-1. The Investment Triangle - The Building Blocks Of Creating Value.

Essential to this core concept is a related characterization of capital. In traditional financial analysis, there are two forms, fixed and working. To use an example, think of a completed house as one item of fixed capital – a physical item, designed to serve some purpose, with expectation that various components of the house will be modified over the useful life of the house. Working capital is used to construct and maintain the house - the 2x4s, nails, paint, plumbing, etc., collected and applied to the house design. This working capital is 'reuse' material – readily, cheaply available in the marketplace.

Traditional forms of capital – a new intelligence center building, a new network infrastructure, or a new satellite system – are easily understood, as are forms of working capital – the tools, equipment, and materials that go into development of final products. Specifically for M&S software, however, there are 2 kinds of *digital working capital* to recognize, 'classes' and 'design patterns'. Both contribute in essential ways to building and extending a digital capital structure.

> "**Classes**", in terms of software engineering, are mostly worked out solutions, or ways of doing things, that embody knowledge of how to represent effectively certain kinds of concepts and their behavior, …that "provide … largely worked out solutions."[91] SISO's Base Object Model (BOM's) are an example (e.g., a largely worked out solution to represent some captured "thing"; in essence, a form of encapsulation and packaging of knowledge).
>
> "**Design patterns**", in terms of software engineering, are known and accepted ways to do things. "Patterns embody verbal descriptions of the accumulated wisdom and experience of skilled practitioners with respect to how to approach certain kinds of design challenges."[92] Microsoft Office is an extensive set of 'patterns' we all use (e.g., a widely accepted approach for generation and distribution of knowledge).

[Note: regarding software, *digital working capital* is scare – standardized components that all might use. Markets for 'digital working capital' are what DoD has come to characterize as 'reuse' materials and 'middleware' – and markets for such products do not exist as they to for such material as is used in building construction].

I.3 Capital Maintenance

With regard to the concepts of capital and capital structure, one corollary is important to recognize – that of 'capital maintenance'. Simply stated, "capital exists and functions in a capital structure that evolves over time as old tools and processes are supplanted by new. Consequently, for any particular (kind of) capital good, [capital] maintenance is very much a matter of maintaining its complementarity[93] to the rest of the changing capital structure. Hence maintenance may have to do not so much with preventing any change through deterioration, as with actually changing that (kind of) good directly, in a manner that adapts it to the changing capital structure around it, and thereby delays obsolescence."[94]

To economists the concept of complementarity is that as new capital is produced, its value and usefulness is tied to how well it combines with, complements and extends the functionality and value of existing capital, to affect increased productivity among users of the capital. To DoD, this concept is generally characterized variously as 'reuse', 'leveraging existing software', and 'interoperability', without much recognition of the need for, *from an enterprise view*, methods and approaches for generating valid opportunities to effect complementarity among two or more existing M&S products or processes.

I.4 Articulate and Inarticulate Knowledge

It is also useful and instructive to note and recognize differences between articulate and inarticulate knowledge. As tools, M&S products have huge amounts of knowledge – of both types - embedded/embodied within them. Seen in this light, M&S resource allocation represents a significant commitment to capture both in M&S products. *It is this knowledge* that maintains the *value* of the M&S tools and products that DoD has paid for. Simply stated, articulate knowledge is that which can be clearly expressed and conveyed to others. Inarticulate knowledge is that which is not easily conveyed or explained; typically, 'in process' knowledge is in this category (e.g., the in-game move analysis of chess players, the instinctive decisions of those in command in tight situations). In software development, inarticulate knowledge is that which is 'buried' in the completed code, with only the developer able to explain (if he remembers) the why's, how's, or advantages of why it was coded a certain way.

[Note: - this is not the way it's done in creating physical goods – in DoD acquisition, it is hard to conceive of contracting for a ship, aircraft, or spacecraft without including the blueprints, wiring diagrams, etc., complete with technical notes (this is the 'metadata' for the physical product) as part of the deliverables. Yet in M&S investment, software delivery is routinely completed without delivery of the equivalent – metadata about the crafting of the software – the knowledge, both articulate and inarticulate – needed to affect reuse and extensibility. Yet this is *not* delivery of 'source code' – the intellectual property behind the developed software. How to address 'source code' is addressed below.]

Both are essential for maintaining the value of a completed project. In DoD software practice, the term 'metadata' is widely in use, as 'data about data'. But, the real usefulness of metadata in an M&S investment is in capturing as much articulate and inarticulate knowledge as possible in an accessible and understandable manner. Essentially, such capture of metadata is what makes software useful – meaning valuable - over time. Without it, reuse is a non-workable concept.

I.5 Software as Capital

Sam Adams, writing in 1992 stated, software "should be treated as a corporate asset that can *appreciate* though investment in its quality and reusability". [95] Integral to the approach advocated in this study is the concept of treating M&S investment as capital investment. Again, "Almost every software package is a kind of *capital good*. Capital goods are "the produced means of production," the tools, raw materials and intermediate goods used in production processes."[96] As eluded to above, in terms of M&S investment, software projects result in tools, processes, and capabilities which do not deteriorate by themselves over time. They exist and can be used over and over again – an essential characteristic of a capital good.

I.6 Software Maintenance

Seen as an activity for maintaining value, software maintenance becomes any activity that prevents software from losing its value (as distinct from losing functionality, capability, etc.) to the intended User community. Thus, software – a form of M&S investment – is a digital capital asset whose value must be maintained, requiring resources to do so (analogous to maintaining your house – roof, paint, etc.). Organizations can be well served by creating a mindset that spending M&S dollars is an investment; and maintenance of that investment is both important and worth commitment of resources. This is difficult to implement unless there is organizational consensus and belief that the M&S invested in will be there in the future to use again (e.g., we all "KNOW" that we'll be using Office and Adobe for years into the future – and that its software will be maintained/enhanced, etc., and that 'everyone else' will be using it. Hence, individually, and organizationally, updates to those commercial software products are routine, and simply part of the cost of doing business. This is a form of an ecosystem view benefiting DoD's enterprise – "investment" in Office and Adobe is returned time and again by the efficiency provided by enterprise-wide information dissemination, storage, retrieval, and reuse.)

I.7 Approach

I.7.1 Software Development: Buy – Lease – Develop Issues

It costs real, and significant, dollars to discover and embed knowledge – so if there are alternatives to an M&S investment (e.g., use of 'live' equipment and forces, or choosing among buy-lease-develop choices.); there are tradeoff analyses to be conducted. In software development, 'requirements discovery' is a significant cost driver in M&S investment. Typically, it is an ongoing process, one in which the development starts with an initial 'software requirements specification' (SRS), which is later modified as the software's capabilities and features are worked out in detail. User and developer both 'learn as they go' about what is, and is not, possible. As they learn, they modify functional the capabilities/features they are building, and so modify the SRS. All of this effort costs money; and the more ambitious the project, the higher the costs become. There is good reason for this. "Software development is not so much a process of translating knowledge as of discovering and articulating knowledge."[97] As such, the process is an iterative one, as illustrated in Figure I.7.1-1.

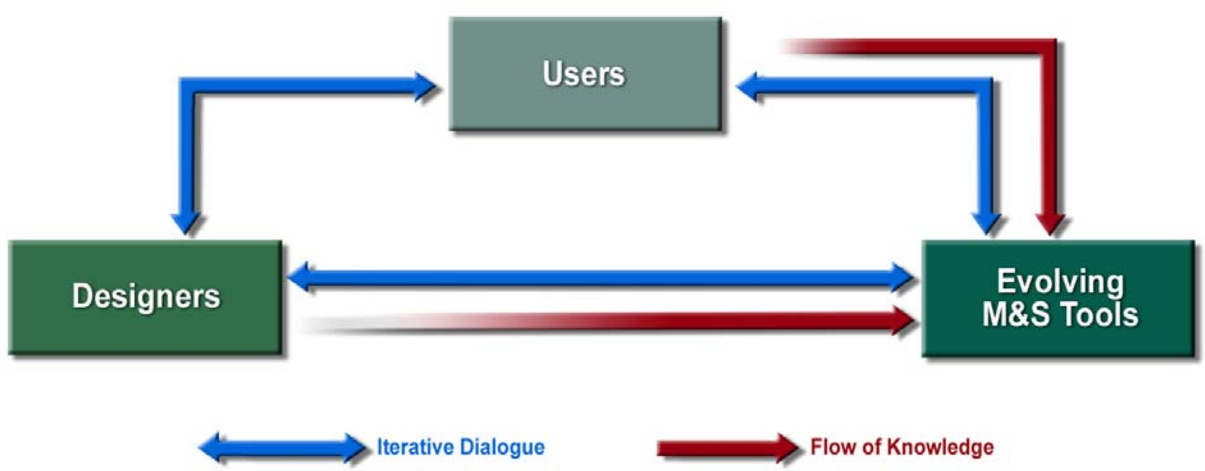


Figure I.7.1-1. The Iterative Software Creation Process.

Iteration costs money, and it is driven by the fact that the "*fundamental challenge in software development is to make sense of the complex systems we are trying to build.*"[98] Evaluation of candidate investment in M&S must recognize this, and somehow recognize the cost implications of choices among buy, lease, and government development options. Following sections of this report address methodologies for cost identification, asset analysis, and assignment of value to project outputs.

The point to make here is that finding and recognizing all the explicit, latent, and hidden costs *of an M&S development effort* is a wise investment of time and resources. Understanding the full cost and value impacts of various choices requires an enterprise perspective, one in which metrics much beyond time, cost, and schedule are considered integral to trade-off analyses. Some of the metrics will be non-financial. Other sections of this report address these issues in more detail. But, as an example here, consider contemplation of large investment in a new, classified, and complex M&S project, with an objective of creating a tool to support both operational planning and some aspects of operations analysis. It may be that, due to classification issues, it seems the best choice is for the government to use its own people (government development) to discover, organize, and encapsulate the knowledge required to develop the entire end product, as the best means to ensure the knowledge remains 'private'. But, as an alternative, it might be discovered that most of the desired capability could be obtained via commercial product (buy, or lease), with additional software modules designed by government staff and interfaced to the commercial product. It might be found that the overall costs could be reduced, and yet yield a more valuable product, by combining two or more buy-lease-build options, and specifying appropriate modular design and flexibility criteria in the SRS governing the acquisition. From an enterprise perspective, achieving such an outcome could have significant value implications for the government by extending the capability, and value, of the end product.

I.7.2 Industry Trends – COTS, GOTS, and Open Source

Related to buy-lease-build issues, both DoD acquisition practice and DoD's M&S Vision address, explicitly or implicitly, need to implement consistent methods for valuation of GOTS, COTS, and Open Source Software ("OSS") in making M&S investment decisions. Use of GOTS implies costs to the government for development, maintenance, upgrade, and modification of produced software over its lifecycle. Use of COTS avoids development costs, but may entail costs to the government for maintenance, upgrade, and modification for reuse. COTS uses also requires valuation and assessment of licensing costs, judgments regards future availability of the product, and judgments regards expected obsolescence of the COTS product.

Open Source Software, on the other hand, represents a growing segment of the M&S community, and is of much interest to DoD (and industry) as a potential way to reduce acquisition and life cycle costs. Measures, metrics, and criteria for assessing true costs of OSS use, or for calculation of NPV as part of an analysis of alternatives for a specific investment, are scarce. However, at an enterprise level, three business cases (acquisition methods) can be identified under which M&S investment decisions can be considered. These are:

- Government chooses to develop M&S products in-house, using OSS obtained 'in the open market'.

- Government chooses vendors who develop M&S products using combinations of OSS obtained 'in the open market' and vendor-conducted integration into completed products.

1. Government chooses vendors whose business model is to develop and make available, via license or buy-out, specific M&S products.

For each of these, appropriate measures, metrics, and criteria, *and costs* (both initial and lifecycle) must be developed and available-risk assessments completed, to fully understand the cost and value implications of using each acquisition method. There is always an option for the government to choose "do nothing" as a course of action, upon completion of assessment of all three acquisition alternatives.

The core benefit to DoD in adopting the concepts described above as the underpinning of its M&S activities is that it sets a mental picture for how M&S resource applications can add to the total accumulation of expertise embedded and made available to DoD organizations. Thought of in this manner, it makes more sense to view M&S resource decisions in the larger context of 'value received' (as opposed to 'cost to obtain'). It is worth restating that software's value depends greatly on how well it fits with both existing digital capital and the human capital with which it must work.

Total potential *value* to a *government* organization from a given software package acquisition is the sum of the value that a procured software product might provide to all possible users of it. It is difficult, if not non-sensical, to speak of "revenue" derived from a government investment in M&S, as the 'return' to the government is the *value* the government receives from making use of its resource allocation. And it often makes little sense to speak about an investment's "free market value", when the only users of the investment are within the government. The components of value to be considered include the total value (or, benefit) accruing to all users of the investment, *and* the additional capability accruing to the government by the M&S investment adding to and extending the total M&S capability owned. In equation terms, broadly speaking,

$$B = (\sum_{i=1}^{N}(\Delta User_i\ Value/benefit_i - \Delta Developer\ \mathrm{Cost})) + \Delta OrganizationalCapital$$

where
B = total Benefit to the intended users of the software
User = the total user base
N represents the *entire* potential User group
Developer cost = the cost to the government to acquire and put in hands of Users of the M&S investment.
Organizational Capital = the additional benefit, beyond that enjoyed by User, of having the M&S capability available for use in conjunction with other M&S assets.

(Example: a vessel hull design benefits the designer and shipbuilder in constructing the vessel, and an ocean wave action modeling effort and/or modeling basin effort benefits analysis of ship stability and propulsion capability analysis. But together, the 2 separate models, properly aligned/interfaced, can provide additional value to T&E efforts later in the design process. This represents additional value to the government over and above that enjoyed by the original user of the two separate M&S investments. The trick is of course, to attend to the details of software project design to allow the alignment and interfacing referred to.)

From this total value, of course, the cost of the M&S investment must be subtracted.

In contrast, a traditional economic valuation of return is normally calculated in terms of a single organization or customer, and expressed in terms of the return in one (or more) of three ways. These are addressed in Section 3.9, ROI Algorithms. It will be seen there that commercial business ROI calculations require data in terms of *Revenue* – in the form of money from sales of product or services for which the investment was made. This does not apply to many DoD M&S acquisition programs.

[Example: significant DoD investment was made in creating and maintaining the Global Command & Control System (GCCS) in various Service variants for distribution to Service Users. The government acquisition machinery does not 'sell' GCCS to those Users, rather, it distributes systems to Users. There may well be real costs to those Users for obtaining and using GCCS systems, but the accounting machinery is not set up in terms of counting *Revenue* for GCCS systems 'sold' to Users.]

APPENDIX J - DECISION SUPPORT METHODS

This appendix is based upon material drawn from the textbooks *Introduction to Operations Research, 8th Ed.* by Hillier and Lieberman and *Management Decision Modeling with Spreadsheets* by Render, Stair, and Balakrishnan. Further explanation on most of these methods can be found in these references. Other references are footnoted.

J.1 Background

Decision Support Systems are methods or models, typically computerized, that assist decision makers in selecting the best choice from amongst multiple possibilities in a given situation. Examples of these situations include: choosing the best information technology system from amongst several to meet the needs of your growing business, deciding the minimum number of people to hire to be security guards at a shopping mall when the number required changes by time of day, where is the best place amongst several possibilities to explore for a new oil find, and determining the maximum amount of compounds available to be made from multiple raw materials. Each one of these situations requires some decision and having a method or system to evaluate all the data at one's disposal can make the difference between a bad decision and a good one.

Additionally, there are many different environments in which decisions are made. In some cases, there are no uncertainties in the outcomes. For example, you are faced with the choice of investing in a bank certificate of deposit from Bank A or Bank B. Bank A pays 4.5% annual percentage yield and Bank B pays 4.3% annual percentage yield. In this case, if your desire is to maximize your return, you would choose Bank A since it gives the higher yield, assuming the stability of both banks is relatively the same. These decisions are relatively easy. However, many, if not most, decisions have uncertainty associated with them. Suppose you are given three areas in which you can drill for oil. Initial testing shows that Area A appears to have the potential to produce 1.5 million barrels of oil each day, however, due to the underlying unstable seismic structure, there is a possibility that it may only produce 100,000 barrels each day. Initial testing in Area B shows that it could produce 800,000 barrels of oil daily and the underground structure in this area is more stable; however, it could only give 225,000 barrels each day. Area C has the kind of makeup that is very good and stable. However, Area C's production estimate is only 500,000 barrels of oil per day. Given all this data where do you choose to explore for oil? Area A has the highest potential payoff, but Area C has the least amount of uncertainty. Note that in this situation, we do not know the likelihood of each situation for a given area. These are the situations where a systematic method to assist the decision maker can be beneficial.

There are also times when additional data can be gathered, for a price. In the above oil exploration scenario if there were a way to put probabilities on the production estimates, then the most advantageous decision might be easier to achieve. For example, if further testing showed Area A had a 90% chance of reaching a production level of 1.5 million barrels each day, then we have quantified the situation, lowered our risk for that option, and it might be the choice that offers the highest return. Similarly, if the testing shows that there is only a 10% chance of reaching the 1.5 million barrel production level, then that option may be rejected as not having the highest return. With information such as this, we have a situation where we are making a decision under risk. This is more beneficial than choosing an alternative under total uncertainty, however, one must assess whether the information, derived from the additional testing potentially required, is worth the cost of that testing. If the estimated benefit of the data gained is less than the cost of gathering the data then it is best to not pay for the data and, therefore, make your decision based upon the information you currently possess. Part of a Decision Support System not only can incorporate risk, but also takes into account the price it costs for the additional data and if that information is worth the price.

J.2 Types / Kinds of Decision Support Methods

There are several kinds or types of Decision Support Methods. In the instance where you are not dealing with uncertainty (decision makers know for sure the outcome/consequences of each decision alternative), techniques such as: Linear Programming (e.g. Simplex Method, Parametric Method, Dual Simplex Method, etc), Game Theory with rational actors and an established strategy, Dynamic Programming (much of the time dealing with sequences of decisions), Non-Linear Programming (e. g. Convex programming, Separable programming, Quadratic programming), Metaheuristic Algorithms (e. g. Genetic Algorithms, Simulated Annealing, etc.), Multi-Attribute Decision Making, and Neural Networks. Short descriptions are listed below:

Linear Programming – a subset of the general category of mathematical programming which also includes integer programming, goal programming, and non-linear programming. Assumptions include that relevant input data and parameters are known with certainty. These decision support systems are used when we have to make decisions about resource (labor, machinery, time, money, material, etc.) allocation. Problems involve optimizing a cost function subject to constraints in which all the applicable functions are linear.

Game Theory – the study of winning strategies for a situation where two entities are vying for the same end state. Assumptions include both players are rational agents and make the best move from their standpoint at every move.

Dynamic Programming – a mathematical technique for making a sequence of interrelated decisions. This technique is suitable for problems that can be divided into stages with some kind of decision required at each stage. Each stage has a number of states that are associated with the beginning of that stage and the effect of the decision at each stage is to move the current state to a state that is at the beginning of the next stage. Finding the solution to the decision process involves finding the optimal decision strategy for moving from the starting stage and state to the final stage/state by formulating a recursive relationship for each problem.

Examples of problems that can be solved by this method are shortest path problems and distribution of effort problems.

Non-Linear Programming – a set of techniques that are used for a very broad class of problems with many different types of algorithms. Problems in their most general form require a potential multivariate function to optimize subject to constraints that can be equalities or inequalities. At least one of these functions is non-linear.

Metaheuristic Algorithms – used for very complex problems when an optimal solution is either very difficult or impossible. They are general solution method which provides a general structure and a strategy for developing a specific method which finds a nearly optimal solution to a problem. Examples of these kind of algorithms are: Tabu search (on graphs), Simulated Annealing (analogous to the physical annealing process), and Genetic Algorithms (based upon the theory of evolution and a form of a neural network).

MADM – a method used to choose from a small, finite, and countable number of alternatives. Falls into the category of Multi-Criteria Decision Analysis which includes methods such as: AHP, Multi-attribute Global Inference of Quality, Goal Programming, and Multi-objective Decision Making. Takes multiple inputs, each one weighted by subject matter experts, multiplies the weights by the inputs and sums them to produce a utility score. These utility scores can be any units or unitless. Very similar to AHP however, MADM evaluates each criterion with respect to a standard not relative to the other choices

Neural Networks – a mathematical or computational model based upon biological neural networks where the nodes of the network are highly interconnected and thus the computations are connected as well. Many different types of algorithms exist with many unique network structures. They have many applications but as a Decision Support System they are most frequently used for pattern recognition to determine where an item of interest fits in a given number of classes. Neural networks can take multiple inputs and typically produce a binary output though they may be used with fuzzy logic and produce a continuous output with values between 0 and 1.

However, if the problem involves uncertainly (decision maker has no information about the various outcomes of a decision, i.e. which political party will control Congress 30 years from now) or risk (decision maker has some knowledge of the probability of each outcome or state of nature), then another class of decision support systems are required. These methods take into account probabilities of a certain "state of nature" (i.e. a good market, a bad market, a moderate market for a new product), or are used when the "states of nature" are known, but their probabilities are unknown. Listed below with a brief description of each are some Decision Support Methods used when the problem contains uncertainty or risk.

Payoff/Decision Tables – a table that lists the decision alternatives on the rows and the states of nature in the columns. The intersection of the row for an alternative and the column for a state of nature is the payoff for that alternative given that state of nature. There are many ways to choose the best decision using payoff tables using different criterion. Some of these algorithms are: Maximax, Maximin, Equally Likely, Expected Opportunity loss, and Minimax regret (both require an opportunity loss table).

Decision Trees – graphical representation of Decision tables showing decision alternatives and states of nature in a sequential manner. Allows for multi-stage decision making (decide this depending upon the outcome of a previous decision) which are not accommodated easily in Decision Tables. Also can incorporate the cost paid for further information (surveys about markets, etc.) into the decision process.

Markov Chains – used when uncertainty exists about not just one future event but about several future events that can possibly change over time. Applied to stochastic processes where the evolution of the events can be modeled in a probabilistic manner. Determines the next state of the system only by using information at the present state (not previous states). Can be used to model and predict weather, inventory systems, financial systems, etc.

There are a few other Decision Support Methods that don't classify well into the above framework. Expert systems, also known as rule-based systems[99], are a way of coding an expert's knowledge on a subject matter into a computerized system. The expert system is then used to feed in data and return an answer. Typical applications involve medical diagnosis, mechanical repair diagnosis, and financial decision making[100].

The Delphi Method was developed in the 1940s and is an exercise in group communication where the group members are geographically separated.[101] It is a technique that allows experts to collaborate and deal systematically with complex problems or tasks. It overcomes the disadvantages of normal committee action by using anonymity as its basis. The interactions amongst team members are controlled by a panel director. The panel director sends out a questionnaire to all panel members and gathers the responses. He then analyzes the responses and filters out the material not related to the group's purpose and sends out another questionnaire. This process repeats until there is some stability in the results. This method is has been shown useful in answering one, specific, single dimension question. It has shown not to be as useful in determining complex forecasts with multiple input factors.[102]

J.3 Choosing a Decision Support System

Choosing the best method to assist in decision making is sometimes as much of an art as a science. However, there are some guidelines to consider. Table J-1 below lists all the methods on the rows and some characteristics of decision methods on the columns. An "X" in the intersection of the method's row and the characteristic's column means that the identified method possesses that characteristic. Similarly, if the intersecting block is blank then that method would not possess that characteristic.

Table J-1. Decision Support Methods vs. Characteristics.

	Multiple Inputs	Repeatable Results	Transparency[103]	Tailorable	Simple Concept	Considers all alternatives	Multiple Data Types
Payoff Tables		X	X		X	X	
Decision Trees		X		X	X	X	
Markov Chains	X			X		X	
MADM	X	X	X	X	X	X	X
AHP	X	X	X	X	X	X	X
Game Theory	X					X	
Linear Programming	X	X		X	X	X	X
Dynamic Programming	X	X		X		X	X
Non-Linear Programming	X	X		X	X	X	X
Metaheuristic Algorithms	X	X		X		X	X
Neural Networks	X	X		X		X	X
Expert Systems		X	X		X	X	
Delphi Method	X			X	X	X	

The choice of method is very much dependent upon the problem you are solving or the type of decision you desire to make. If you desire to minimize the number of people to staff a security gate given that three people are required during some hours, two at others and at least one all the time, then a linear programming technique which optimizes a function subject to constraints would be the method of choice. Each method has its own strengths and types of problems where that method works best. For example, if you are analyzing a problem which evolves over time and there is uncertainty over many future events, then Markov Chains are an excellent choice. In that case, using a payoff table would not be applicable as payoff tables operate on a single event and not over time. In the case of deciding which DoD M&S investments to choose we have some different requirements for a decision support system.

As we study the DoD M&S investment problem we notice that we will have many inputs, so we require a method that can receive multiple inputs. As noted in section 3.8 we desire that the method not be stochastic and that we can get the same result from the same input every time. Additionally, we need to be able to process multiple data types, consider all alternatives, and be able to tailor any method to small tweaks in the DoD M&S investment process. While transparency is desirable, it wouldn't be required, but a method that is able to be easily explained to the decision maker is highly advantageous. As we can see from Table J-1, there are only a few methods that meet these desires.

MADM and AHP fulfill the characteristics listed as well as linear and non-linear programming. However, linear and non-linear programming are not set up to compare amongst choices, they are utilized to optimize a single problem subject to constraints. As noted above, MADM and AHP are very similar. The main difference is that AHP evaluates choices relative to each other and MADM evaluates them with respect to a standard. Because of this and all the other requirements and desired characteristics of the decision support method we chose MADM as the decision support system and its use in this context is further explained in section 3.8.

APPENDIX K – PROCESS SPECIFICATION

A CURSORY APPRAISAL OF TECHNIQUES FOR BUSINESS PROCESS MODELING

K.1 Introduction

Information is key to nearly everything we do. Information is key to operations, be it business operations, technical operations, or even military operations at the strategic or tactical level. .

K.2 Discussion

Several tools and methodologies have been developed to guide and manage information supporting the development of systems, particularly information systems, as illustrated in Table K-1, below.

For convenience, these methodologies have been classified as process / flow models, data models, and object-oriented models. This list is not exclusive, nor exhaustive, but, is suggestive of the large number of methods in use by industry today.

Table K-1. Common Methodologies And Process Documentation.

PROCESS / FLOW MODELS	Business Process Modeling Notation (BPMN)
	IDEF0 Function Modeling
	IDEF3 Process Description Capture
	Data Flow Diagram
	SIPOC
	Program Evaluation and Review Technique
	Gantt Chart
	Flow Chart
	Arrow Diagram
	Diagram
DATA MODELS	IDEF1 Information Modeling
	IDEF1X Data Modeling
OBJECT ORIENTED MODELS	IDEF4 Object-Oriented Design
	Unified Modeling Language (UML)
	System Modeling Language (SML)
	DoD Architecture Framework

These methodologies establish a foundation for collaboration and communication. But these methodologies and tools are not integrated to each other, thus causing inefficiencies in the collaboration process.

Consequently, the best means by which we can capture, use and model information to facilitate communication, nor the rationale for using one technique preferential over another, is completely understood.

However, the AHP, developed by Thomas Saaty[104], provides a proven, effective means to deal with complex decision making. The AHP process can assist with identifying and weighting selection criteria, analyzing the data collected for the criteria, and expediting the decision-making process.

When making complex decisions involving multiple criteria, AHP helps capture both subjective and objective evaluation measures, providing a useful mechanism for checking the consistency of the evaluation measures and alternatives suggested, thus reducing bias and providing structure for decision making.

The AHP Tool can minimize common pitfalls of decision-making process, such as lack of focus, planning, participation, or ownership, which ultimately are costly distractions that can prevent staffs from making the right choice. As illustrated in Figure K-1, below, the first step is for the team to decompose the goal into its constituent parts, progressing from the general to the specific. In its simplest form, this structure comprises a goal, evaluation criteria and alternatives levels. Each set of alternatives may then be further divided into an appropriate level of detail, recognizing that the more criteria included, the less important each individual criterion may become. Next, assign a relative weight to each one. Each criterion has a local (immediate) and global priority. The sum of all the criteria beneath a given parent criterion in each tier of the model must equal one. Its global priority shows its relative importance within the overall model. Finally, after the criteria are weighted and the information is collected, put the information into the model. Scoring is on a relative basis, not an absolute basis, comparing one choice to another. Relative scores for each choice are computed within each leaf of the hierarchy. Scores are then synthesized through the model, yielding a composite score for each choice at every tier, as well as an overall score.

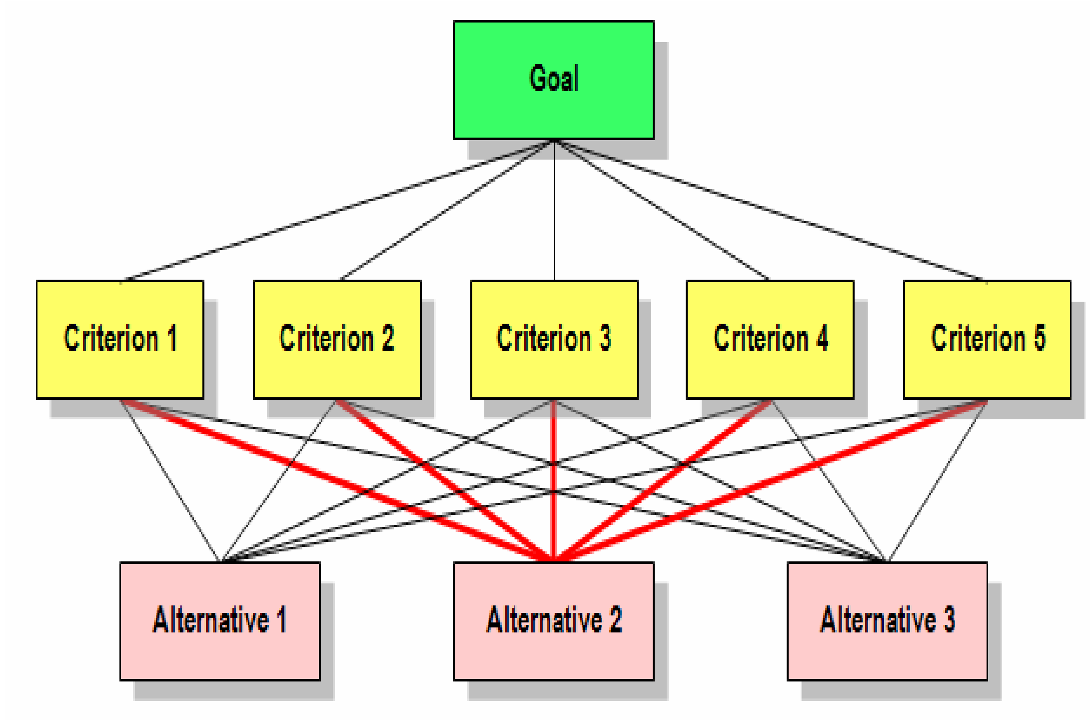


Figure K-1. AHP Process for Decision-Making.

So, let us begin with the specification of desired attributes for any methodology or tool selected for use. A candidate set of criteria are identified in Table K-2, below.

Table K-2. Candidate Evaluation Criteria.

EVALUATION ATTRIBUTES	DEFINITIONS
Levels of Abstraction	This is the ability of the model to describe levels of detail. The ER/EER, IDEF1x, and Object-oriented (OO) data models have the capability to do this via abstraction hierarchies; the other methods have no vehicle to do this.
Hierarchical	This is the ability of the model to break down hierarchically into a more detailed description. For example, IDEF0, IDEF3, and UML all have a hierarchical breakdown from a general level to a more detailed description.
Ease of Use	This is the ease of learning, using, interpreting and communicating the method. For example, IDEF0 is relatively easy to learn, use, and read, while others increase in complexity.
Flexibility	
Events	This is the ability to capture and describe events.
Activities	This is the ability to describe activities.
Aggregation / Deaggregation	This is the ability of the model to aggregate or de-aggregate events or activities to support analysis.
Constraints	This is the ability to describe and incorporate any process and information constraints that exist. IDEF0 incorporates constraints, and IDEF3 has a way of detailing constraints with a language.
Sequence & Interactions	This is the ability to describe the sequence in which events occur, the timing of the events, and the interactions events have with other events. This really does not apply to the data models; all of the process models can do this, except for Data Flow Diagram (DFD), which only shows the flows but not the interactions and sequences.
Scheduling	The ability to describe a time-phased or provide a calendar-based view of events and/or activities.
Resource Allocation	

Using these criteria, we can evaluate common methodologies using AHP. This process is most useful where there are teams of people are working on complex problems, especially those with high stakes, involving human perceptions and judgments, whose resolutions have long-term repercussions. The AHP has unique advantages where important elements of the decision are difficult to quantify or compare, or where communication among team members is impeded by their different specializations, terminologies, or perspectives.

The result of this analysis can compiled as illustrated notionally in Table K-3, which serves to document the criteria, the evaluation of each alternative against the set of criteria, the relative score across all the alternatives, and the summarization of the findings that support tool selection.

Table K-3. Proposed AHP Evaluation Matrix.

COMMON METHODOLOGIES AND PROCESS DOCUMENTATION		EVALUATION ATTRIBUTES[105]: Levels of Abstraction	Hierarchical	Ease of Use	Flexibility	Events	Activities	Aggregation / De-aggregation	Constraints	Sequence & Interactions	Scheduling	Resource Allocation	AHP SCORE
PROCESS / FLOW MODELS	Business Process Modeling Notation (BPMN)												
	IDEF0 Function Modeling												
	IDEF3 Process Description Capture												
	Data Flow Diagram												
	SIPOC												
	Program Evaluation and Review Technique												
	Gantt Chart												
	Flow Chart												
	Arrow Diagram												
	Diagram												
DATA MODELS	IDEF1 Information Modeling												
	IDEF1X Data Modeling												
OBJECT-ORIENTED MODELS	IDEF4 Object-Oriented Design												
	Unified Modeling Language (UML)												
	System Modeling Language (SML)												
	DoD Architecture Framework												
Criteria Weights [%]:		8	8	8	8	10	10	10	10	10	10	10	100

To support the AHP assessment of alternatives, a summary description, link to a Universal Resource Locator (URL) for additional data, identification of the developer / sponsor and an example illustration or graphic is provide for each alternative methodology in the Table L-4 below.

Table K-4. Process Flow and Models Summary.

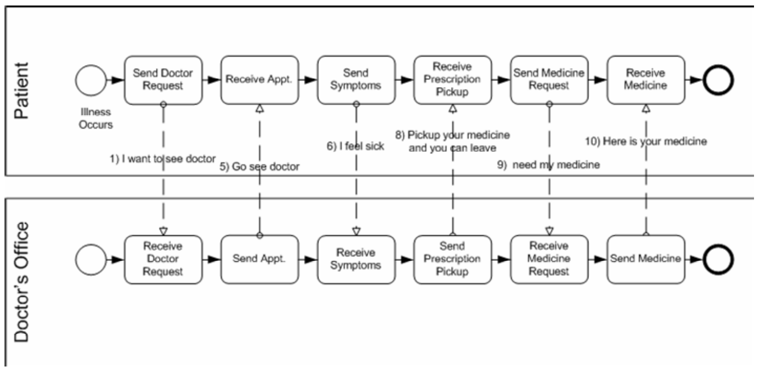
NAME	DESCRIPTION	DEVELOPER/ SPONSOR	EXAMPLE ILLUSTRATION / GRAPHIC
PROCESS / FLOW MODELS			
Business Process Modeling Notation (BPMN) URL: http://www.bpmn.org/	A standardized graphical notation for drawing business processes in a workflow. A BPD is made up of a set of graphical elements that enable the development of diagrams that will look familiar to most business analysts (e.g., a flowchart diagram). The elements were chosen to be distinguishable from each other and to utilize shapes that are familiar to most modelers. For example, activities are rectangles and decisions are diamonds. As illustrated, the four basic elements are: 1) Flow Objects, 2) Connecting Objects, 3) Swimlanes, and 4) Artifacts.	Business Process Management Initiative (BPMI). Now maintained by the Object Management Group (OMG).	

Table K-4. Process Flow and Models Summary.

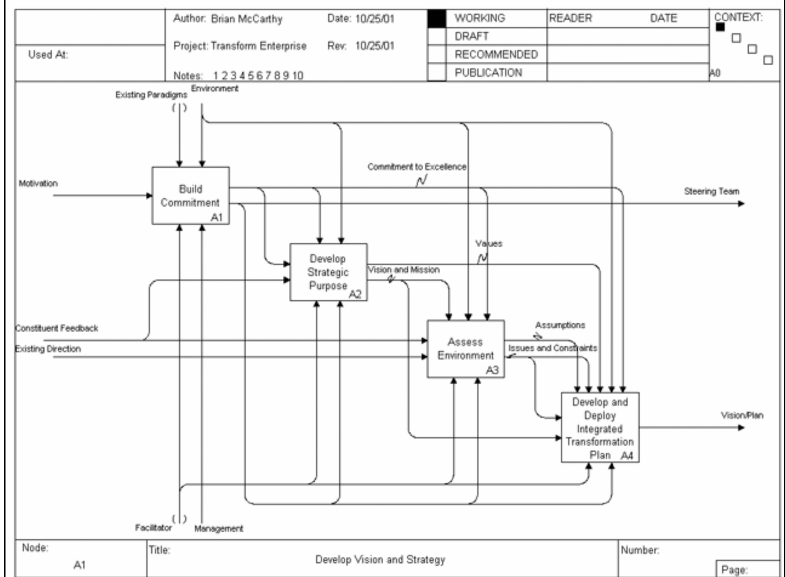
NAME	DESCRIPTION	DEVELOPER/ SPONSOR	EXAMPLE ILLUSTRATION / GRAPHIC
IDEF0 Function Modeling URL: http://www.idef.com/IDEF0.html	IDEFØ is a method designed to model the decisions, actions, and activities of an organization or system. IDEFØ was derived from a well-established graphical language, the Structured Analysis and Design Technique (SADT). Activities can be described by their Inputs, Outputs, Controls, and Mechanisms (ICOMs). As illustrated, the model indicates major activities and the input, control, output, and mechanisms.	Computer Systems Laboratory of the National Institute of Standards and Technology (NIST) released IDEFØ as a standard for Function Modeling in FIPS Publication 183.	

Table K-4. Process Flow and Models Summary.

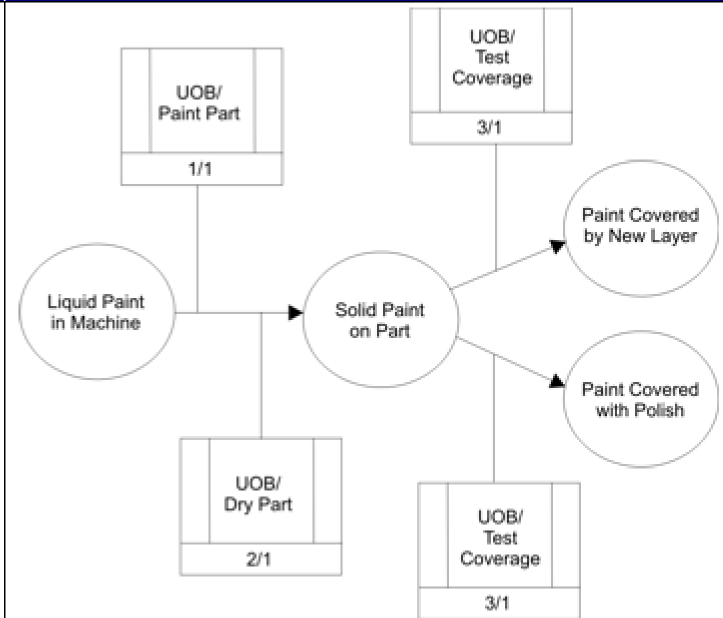
NAME	DESCRIPTION	DEVELOPER/ SPONSOR	EXAMPLE ILLUSTRATION / GRAPHIC
IDEF3 Process Description Capture URL: http://www.idef.com/IDEF1X.html	The IDEF3 Process provides a mechanism for collecting and documenting processes and behavioral aspects of a system. From domain experts, descriptions are captured in which the precedence and causality relationships between activities and events of the process are shown. Thus, IDEF3 is a structured method used to express how a system or an organization works and show different user views of the system. IDEF3 consists of two modeling modes: the Process Flow Description (PFD), which describes how things actually work in the organization, and the Object State Transition Description (OSTD).		

Table K-4. Process Flow and Models Summary.

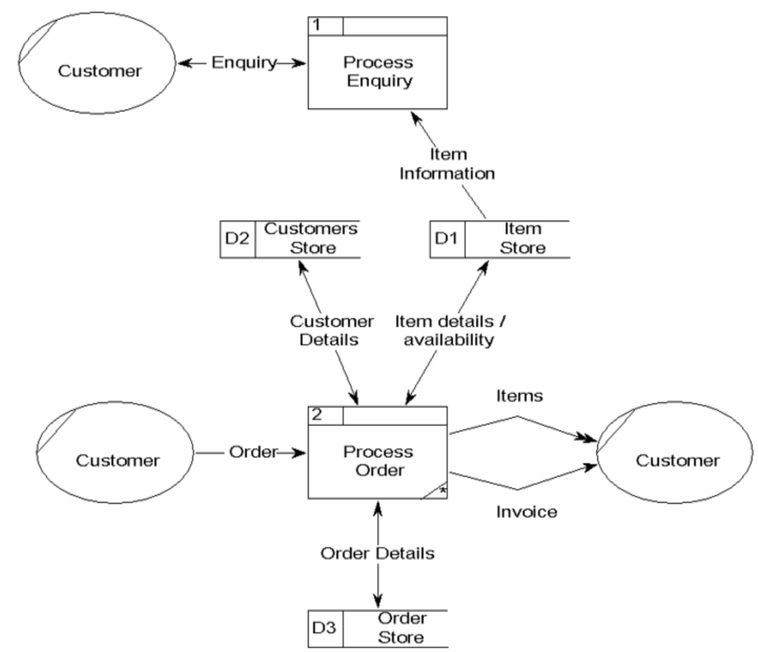
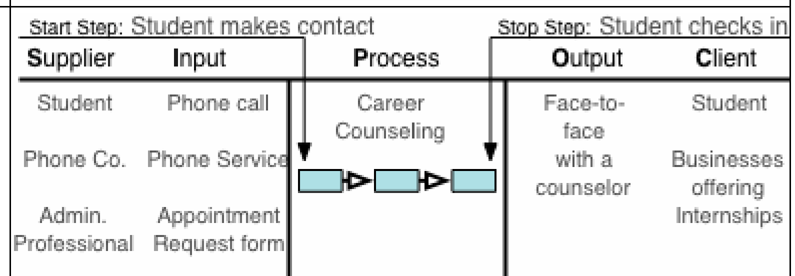
NAME	DESCRIPTION	DEVELOPER/ SPONSOR	EXAMPLE ILLUSTRATION / GRAPHIC
Data Flow Diagram URL: http://en.wikipedia.org/wiki/Data_Flow_Diagram	DFDs are one of the three essential perspectives of Structured Systems Analysis and Design Method SSADM. Data flow diagram help to identify the transaction data in a data model. There are 4 key elements in a Data Flow diagram; Processes, Data Flows, Data Stores & External entities and each element is drawn differently. Another important element which is typically marked with dashed lines is Feedback and Control Data.	Data flow diagrams were invented by Larry Constantine, the original developer of structured design based on Martin and Estrin's "data flow graph" model of computation.	
SIPOC URL: http://www.businessknowledgesource.com/manufacturing/what_is_a_sipoc_diagram_high_level_process_map_and_how_is_it_used_in_six_sigma_021699.html	The name prompts consideration of the Suppliers (the 'S' in SIPOC) of the process, the Inputs (the 'I') to the process, the Process (the 'P'), the Outputs (the 'O') of the process, and the Customers (the 'C') that receive the process outputs. In some cases, Requirements of the Customers can be appended to the end of the SIPOC for further detail		 :

Table K-4. Process Flow and Models Summary.

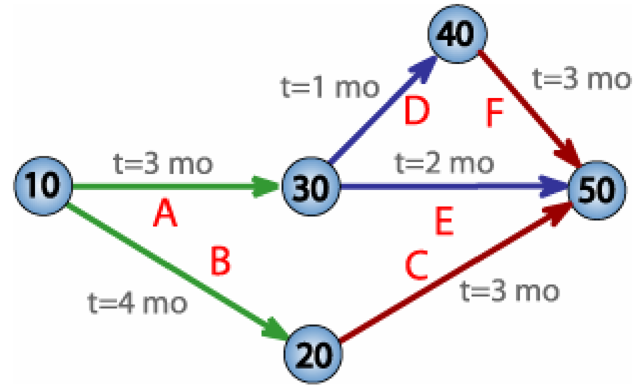
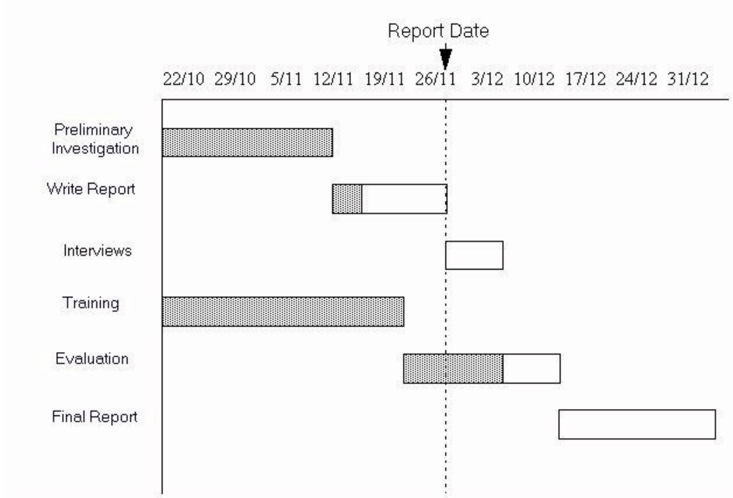
NAME	DESCRIPTION	DEVELOPER/ SPONSOR	EXAMPLE ILLUSTRATION / GRAPHIC
PERT Chart URL: http://en.wikipedia.org/wiki/Network_diagram_(project_management)	The Program (or Project) Evaluation and Review Technique (PERT) is a model for project management designed to analyze and represent the tasks involved in completing a given project. PERT was developed primarily to simplify the planning and scheduling of large and complex projects, identifying slack time and the critical path [zero float].	This technique was invented by Booz Allen Hamilton, Inc. under contract to the United States DoD's US Navy Special Projects Office in 1958 as part of the Polaris mobile submarine-launched ballistic missile project.	
Gantt Chart URL: http://en.wikipedia.org/wiki/Gantt_chart	A Gantt chart is a graphical representation of the duration of tasks against the progression of time, and is routinely depicted as a horizontal bar chart. Frequently used in project management, a Gantt chart provides a graphical illustration of a schedule that helps to plan, coordinate, and track specific tasks in a project.	Gantt chart was developed as a production control tool in 1917 by Henry L. Gantt, an American engineer and social scientist.	

Table K-4. Process Flow and Models Summary.

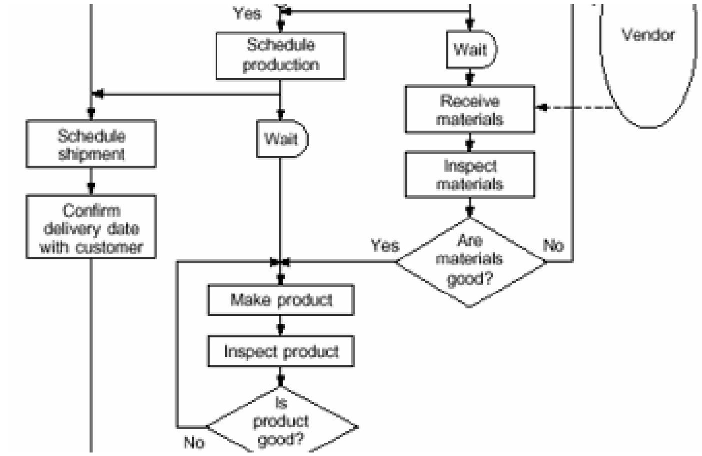
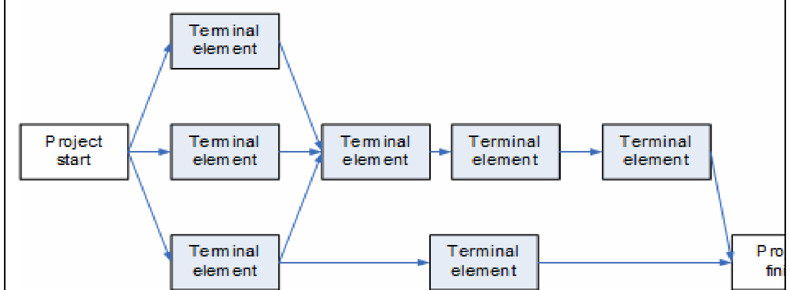
NAME	DESCRIPTION	DEVELOPER/ SPONSOR	EXAMPLE ILLUSTRATION / GRAPHIC
Flowchart (also called Process Flow Diagram) URL: http://en.wikipedia.org/wiki/Flowchart	A flowchart is a picture of the separate steps of a process in sequential order.		
Arrow Diagram (also know as Activity Network Diagram, Network Diagram, Activity Chart, Node Diagram, CPM (critical path method) URL:	An Arrow Diagram is a schematic representation of an algorithm or a process, or the step-by-step solution of a problem, using suitably annotated geometric figures connected by arrows for the purpose of designing or documenting a process or program.		

Table K-4. Process Flow and Models Summary.

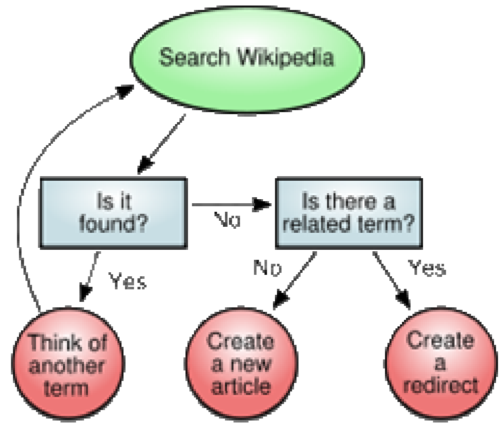
NAME	DESCRIPTION	DEVELOPER/ SPONSOR	EXAMPLE ILLUSTRATION / GRAPHIC
Diagram URL: http://en.wikipedia.org/wiki/Diagram	A Diagram is a 2D geometric symbolic representation of information according to some visualization technique.		

Table K-5. Data Models Summary.

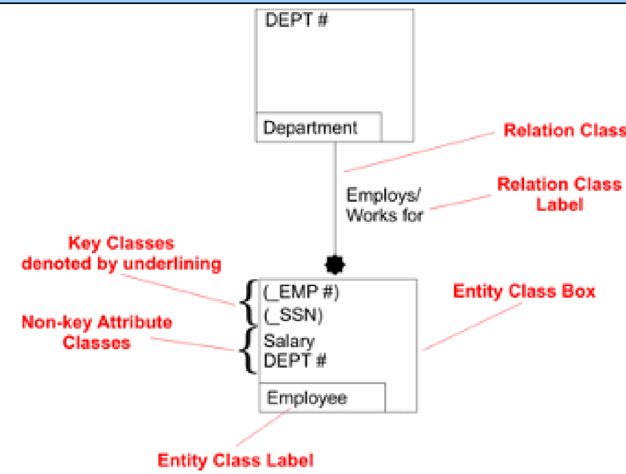
DATA MODELS			
IDEF1 Information Modeling URL: http://www.idef.com/IDEF0.html	IDEF1 was designed as a method for both analysis and communication in the establishment of information requirements, and captures conceptual views of the enterprise's information. The models identify the enterprise's concepts of information such as department and employee and the concept that there is a relationship between the two, such as employee works in a department.	The IDEF1, Information Modeling Method, derives its foundations from three primary sources: The Entity-Link-Key-Attribute (ELKA) method developed by Hughes Aircraft Co., the Entity-Relationship (ER) method proposed by Peter Chen, and Codd's Relational Model.	

Table K-5. Data Models Summary.

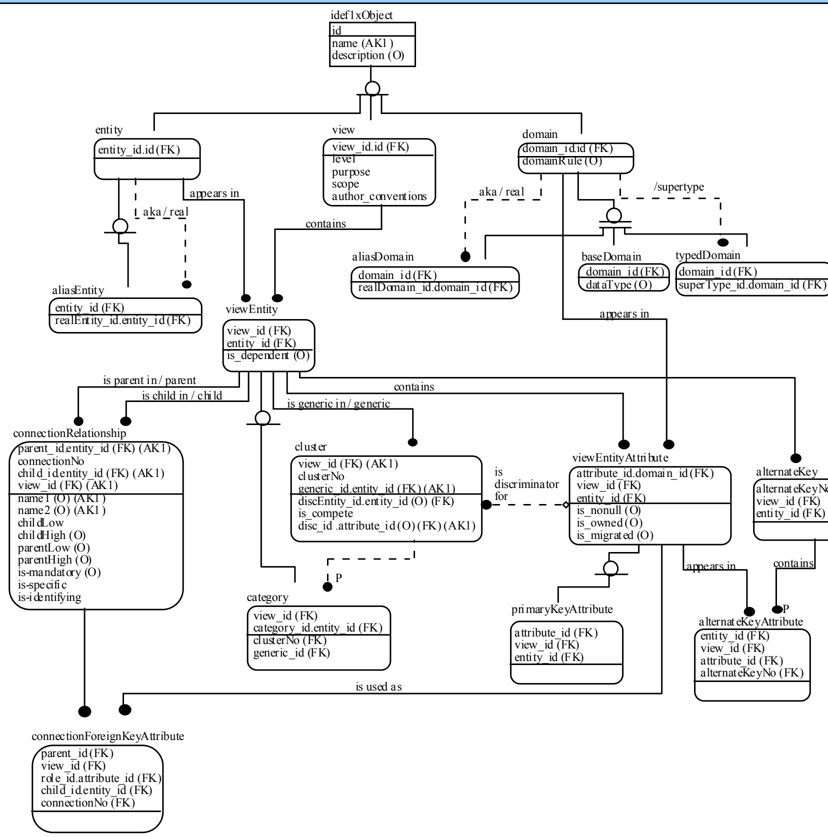
DATA MODELS			
IDEF1X Data Modeling URL: http://www.idef.com/IDEF1X.html	IDEF1X is used for data modeling, which captures the logical view of the enterprise's data and is based on an entity relationship model. It is a design method for logical database design once the information system requirements are known. The focus is on the actual data elements of the information system to be developed.	Computer Systems Laboratory of the NIST released IDEF1X as a standard for Data Modeling in FIPS Publication 184. This standard was superseded by IEEE 1320.2-1998, which is now the national standard for IDEF1X.	
IDEF4 Object-Oriented Design http://www.idef.com/IDEF4.html	IDEF4 is used to design modular object-oriented code that can be easily maintained and re-used. The IDEF4 model has two submodels: the class submodel and method submodel. These structures capture all the information represented in a design model. Due to the size of the class and method submodels,	IDEF 4 was developed by the U.S. Air Force Armstrong Laboratory to facilitate the usage of object-oriented technologies in software development.	

Table K-5. Data Models Summary.

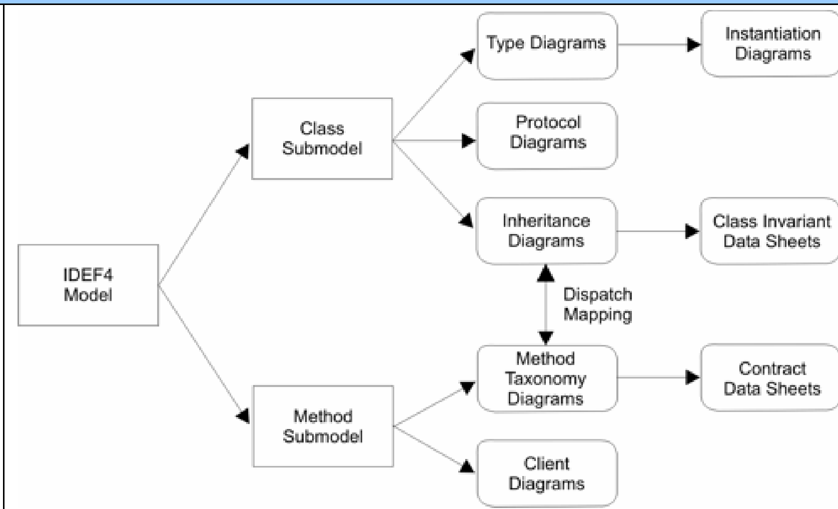
DATA MODELS			
	the IDEF4 object designer never sees these structures in their entirety. Instead, the designer makes use of the collection of smaller diagrams and data sheets that capture the information represented in the class and method submodels.		

Table K-6. System Models Summary.

<table>
<tr><th colspan="4">SYSTEM MODELS</th></tr>
<tr><td>Unified Modeling Language (UML)
URL:
http://www.uml.org/</td><td>Graphical language for visualizing, specifying, constructing, and documenting the artifacts of a software-intensive system. UML offers a standard way to write a system's blueprints, including conceptual things such as business processes and system functions as well as concrete things such as programming language statements, database schemas, and reusable software components.</td><td>Unified Modeling Language is an international standard:

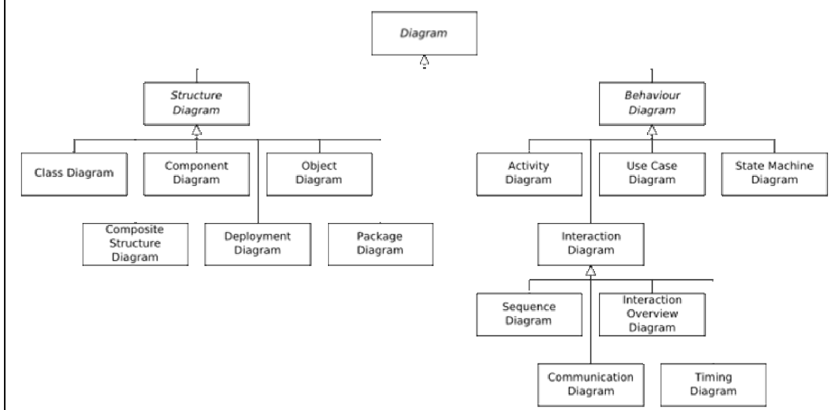
ISO/IEC 19501:2005 Information technology — Open Distributed Processing — Unified Modeling Language (UML)</td><td>UML 2.0 has 13 types of diagrams that can be categorized hierarchically as shown in the following Class diagram:

</td></tr>
<tr><td>System Modeling Language (SysML)
URL:
http://www.omgsysml.org/</td><td>The OMG Systems Modeling Language (OMG SysML is a general-purpose graphical modeling language for specifying, analyzing, designing, and verifying complex systems that may include hardware, software, information, personnel, procedures, and facilities. In particular, the language provides graphical representations with a semantic foundation for modeling system requirements, behavior, structure, and parametrics, which is used to integrate with other engineering analysis models.</td><td>System Modeling Language is an OMG Available Specification.</td><td></td></tr>
</table>

Table K-6. System Models Summary.

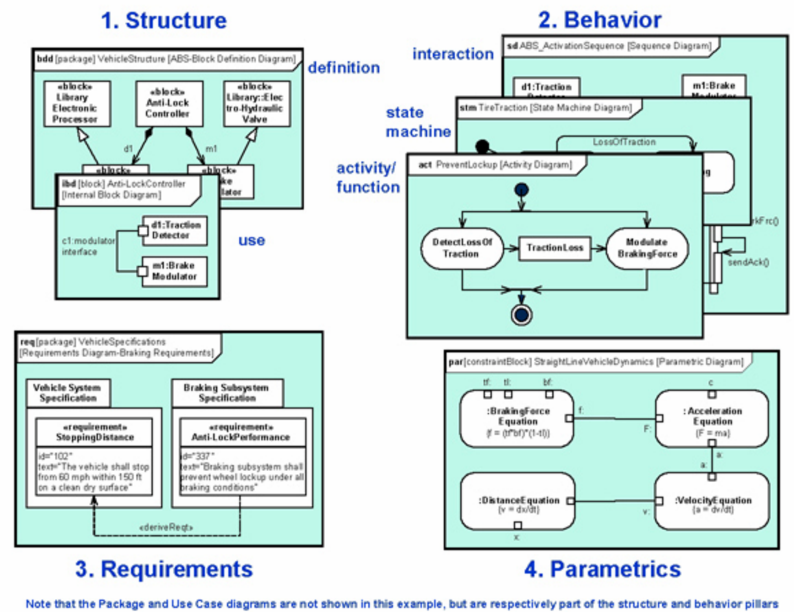
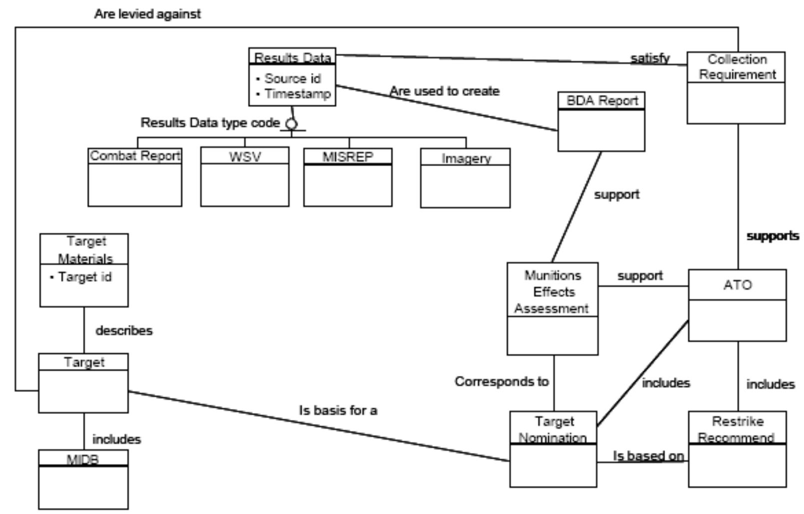
SYSTEM MODELS			
	SysML represents a subset of UML 2 with extensions needed to satisfy the requirements of the UML™ for Systems Engineering.		
DoD Architecture Framework (DoDAF) URL:	The DoDAF defines how to organize the specification of enterprise architectures for U.S. DoD applications. All major DoD weapons and information technology system procurements are required to document their enterprise architectures using the view products prescribed by the DoDAF. DoDAF organizes enterprise architectures into four basic view sets: 1) All View (AV) with two work products; 2) Operational View (OV) with seven work products; 3) Systems View (SV) with 11 work products; and 4) Technical Standards View (TV)	US DoD	The figure below is a notional Logical Data Model (OV-7) depicting data associated with Conduct Joint Force Targeting. This notional product was developed for the based on information in the USCENTCOM Targeting Architecture. This figure represents only a small portion of what a complete data model would look like. Data models usually extend over several pages, each page showing the data entities that are involved in a particular operational activity or mission. Depending on the architecture purpose, a finished OV-7 may or may not have attributes defined for entity types.

Table K-6. System Models Summary.

SYSTEM MODELS			
	with two work products.		

K.3 Resources

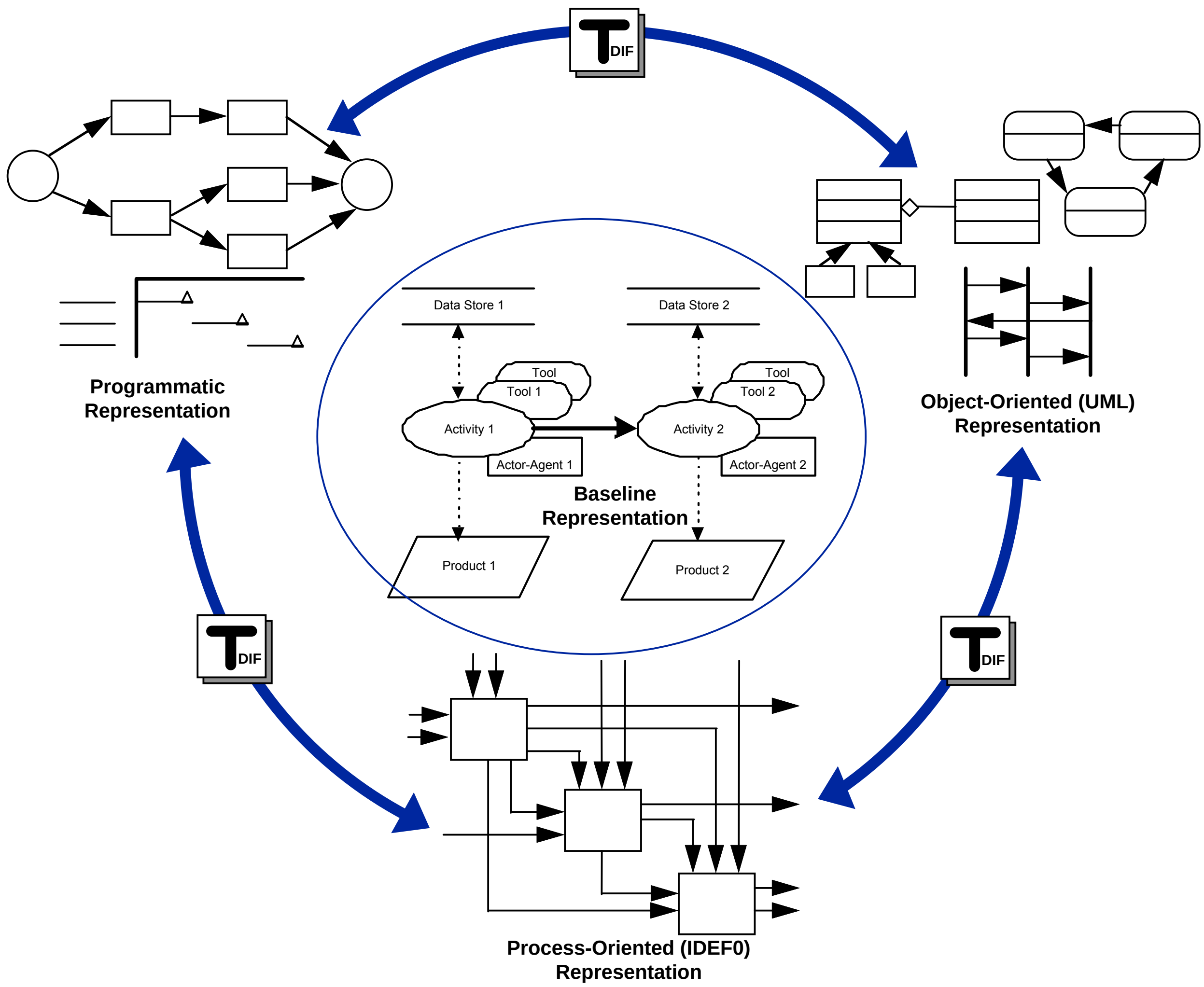


Figure K-2. Alternative Canonical Views with Information-Preserving Transform Operations Are Possible, Facilitating Use of CASE-Supported Native Representations and Guaranteed Information Sharing.

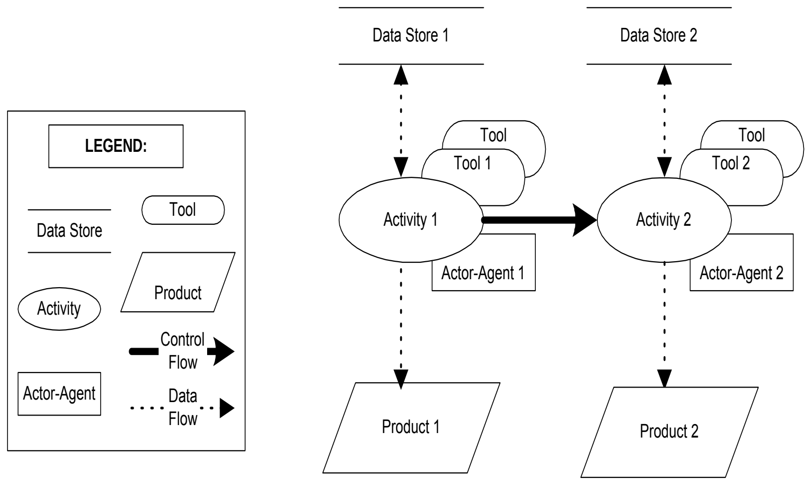
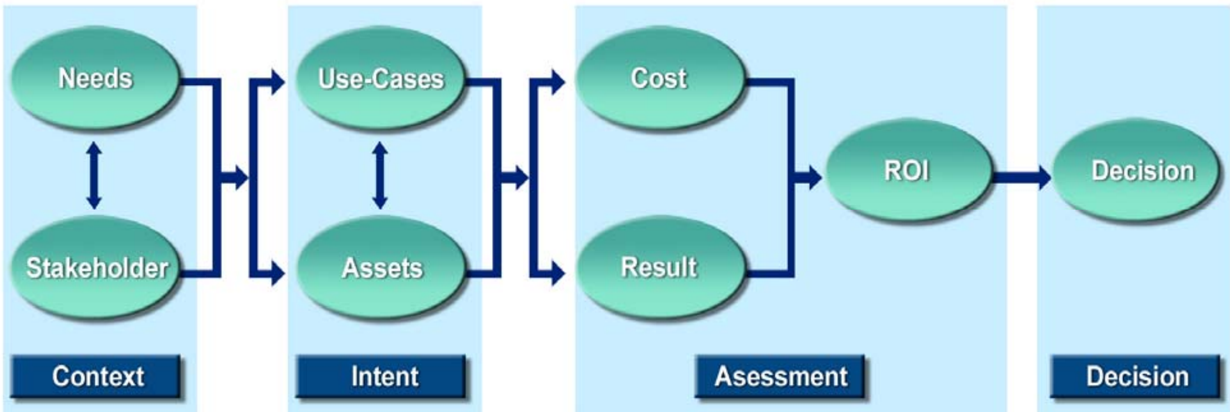


Figure K-3. The Diagrammatic Template Provides a Suggested Baseline Graphical Representation for Indication of Activities and Their Relationship With Other Entities in the FEDEP Model.



APPENDIX L - PROCESS SPECIFICATION DETAILS - ACTIVITY DESCRIPTION

Having indicated in the text and in previous Appendices what schema has been selected for formal specification of the investment decision process resulting from the study analysis and synthesis, we provide in this appendix the detailed description of activities comprising the process and the artifacts associated with those activities (e.g. information pools, products, control flow, tools, and actor-agents.).

The overall process indicated in the text is repeated here:

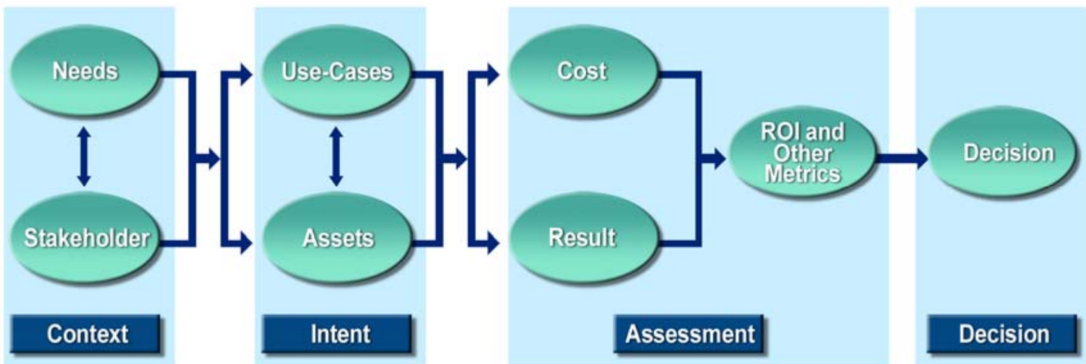


Figure L-1. Investment decision process activities identified with control flow relationships

There follows for each activity a table in which the activity specification is completed to the degree of detail necessary for review, appreciation, improvement, and in some cases execution. The activity in question is identified by the table header, and by the "Activity Identity" field value, and it is indicated graphically in relation to the overall process in each case by the iconic image in which the subject activity is high-lighted.

The Activity Description that follows comprises the full investment process generated by the subject study and is considered an appropriate basis for further analysis, synthesis, and proof of principle exercise, in anticipation of deployment and use by the DoD in managing investment decisions. Naturally, this prescriptive guidance is intended to be consistent with commentary in the text and to be complimentary to process specification components contained elsewhere in the appendices.

Table M1, which follows immediately, is a detailed generic activity description template. In this template, each of the fields constituting attributes of an activity are identified and commentary is provided (in italic and bracketed< > in order to distinguish meta-guidance from the instance information provided for each particular activity chart that follows) to serve as guidance as to the kind of information necessary and sufficient to populate those data fields in such a way that the table in its entirety comprises a record-template defining the activity and identifying its relationships both with other activities but also with collateral agents, assets, and artifacts.

In each of the populated forms that follow, Investment Decision process activities are detailed.

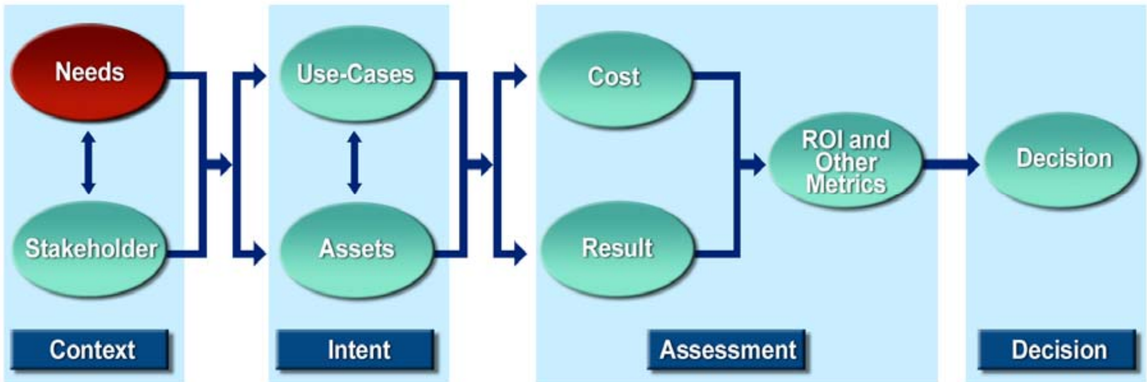
L.1 Generic (META) Activity Specification Template

ACTIVITY CHARACTERISTIC	
Activity Identity	
• Activity Name and Aliases	*<Denotative name of process activity step appears here>*
Activity Description	
• Activity Rationale / Need / Motivation	*<Here an account of the motivation of the subject activity is provided, in order that the investment agent executing the activity can have explicit record of his expected intention in executing the subject activity>*
• Activity Classification	*><In case the activity is typically classified or considered*
Activity Initiation	
• Entrance Criteria	*<This field specifies component values of the state of the decision problem in its entirety that are necessary and sufficient for the subject activity to be begun with high probability of successful completion*
Activity Method	
• Activity Procedure	*<In this field, the investment evaluation agent is provided procedural guidance for the execution of the subject activity. Note that relationships to other activities, needs for tools or information, and expected work-products are specified in other form records. Activity step procedure should be as nearly as possible algorithmically prescriptive. Note however that any procedure may entail almost arbitrary complexity and that the procedure step in question may be replaced with defining notation other than text.>*
Activity Uses	
• Previous Uses	*<Identification of other activities or steps in the overall process where the subject activity has been used, relative this stage in the overall process>*
• Prospective Applications	*<Identification of other activities or steps in the overall process where the subject activity has been used, relative this stage in the overall process>*
Inter Activity Relationships	
• Activity Sequence and Control-Flow	*<Instruction cites relationships among activities. These may be composition (is a part of) relationship in which one activity is executed as one of several components of a composite activity. Otherwise, activity precedence*

ACTIVITY CHARACTERISTIC	
	(comes-before-relationship) and activity successor (comes-after-relationship) may be designated. This latter relationship specification may be contingent allowing programmatic branching, loop recursion, or self repetition.>
• Activity Information Flow	*<Typically information from: a) inside the process (endogenous) - perhaps having been developed by means of the execution of one or another of the activities; or b) information from outside the decision process (exogenous) may be identified as necessary input to an activity. Alternatively information may flow out of the activity having been generated by execution of the activity. In either case it is prudent to indicate the information pool involved as container, and the information type specification needed or generated.>*
Associated Entities	
• Tools	*<Identify tools such as hardware or software necessary and sufficient to complete the activity. In the case of M&S investment activity, algorithms are likely tool-types.>*
• Actor-agents	*<Indicate the actor agent (individual member of one or another stakeholder class) responsible for completion of the activity. Clearly teams or anonymous agents may be designated. If the responsibility of members of the team need to be differentiated, it may be prudent to decompose the activity into its component parts in order to reduce the cardinality of agents to activities from N-to-1 to 1-to-1.>*
• Information Pools	*<Data stores of any type containing information used as input or generated as output from a particular process activity. May contain intermediate information re-used by successor activities, or components of the process result compiled as residual product documentation.>*
• Product-object-artifacts	*<the principle intended output in any form consequent execution of the subject process activity. Ultimately an investment decision, but meanwhile, information artifacts, qualifications to be associated with the decision, or guidance as to how the resulting decision should be pursued.>*
Problem Management	
• Problem Identification	*<Identification, explication and potential consequences associated with the execution of any subject process action. May include problem proximate cause, relevant*

ACTIVITY CHARACTERISTIC	
	contextual circumstances, or qualification / quantification of the problem, useful in understanding the problem mechanism and educing suitable amelioratives.>
• Problem Amelioration	*<Action alternatives suitable to avoid, reduce or ameliorate the pejorative impacts of the problem. Necessary and conditions for employing candidate ameliorative, and expected cost, benefit, and identification of any possible unintended consequences.>*
Activity Completion	
• Exit Criteria	*<This field specifies component values of the state of the decision problem in its entirety that are necessary and sufficient for the subject activity to be considered finished with high probability of successful completion>*

L.2 Needs and Requirements Analysis Activity



ACTIVITY CHARACTERISTIC	INFORMATION
Activity Identity	
• Activity Name and Aliases	Needs and Requirements Analysis
Activity Description	
• Activity Rationale / Need / Motivation	Specify explicitly the conditions, needs and interests in which subsequent context may be executed, in order that the investment agent executing the activity can have explicit record of his expected intention in executing the subject activity. Requirements analysis should provide necessary and sufficient conditions for completing the investment evaluation activity, reflecting the likely concerns of relevant stakeholders.
• Activity Classification	Activity is a management effort, relating to the control and executive influence on the execution of the core investment decision task.
Activity Initiation	
• Entrance Criteria	Component values of the state of the decision problem in its entirety that are necessary and sufficient for the subject activity to be begun with high probability of successful completion include at least the following: • Appreciation of the recommended investment decision process by the requirements analyst • Preconception of the intended application of the investment decision process • Preconception of the stakeholders likely to be interested in the decision, and their particular concerns. • Appreciation of circumstantial conditions associated

ACTIVITY CHARACTERISTIC	INFORMATION
	with the investment decision – calendar, budget, quality constraints • Commitment to discriminate between wants and 'needs' allocable to stakeholders and 'technical requirements of the decision to which compliance / conformance must be achieved by way of constraints on either the execution of the process or the attributes of the result or of its expression.
Activity Method	
• Activity Procedure	Procedural guidance for the execution of the needs / requirements analysis activity by its designated action agent is provided in the list that follows. For each procedural or algorithmic step, identify: relationships to other activities, needs for tools or information, and expected work-products in order to be defined in detail below. Step 1: Identify investment decision problem Step 2: List known stakeholders Step 3: Capture and document stakeholder needs for subject decision, citing constraints, preferences, risk sensitivities. Step 4: Educe problem requirements from comprehensive analysis of needs, indicating necessary and sufficient conditions for requirements satisfactions. Specify test or evaluation method and exit criteria. Step 5: Document and justify any needs or interests likely to remain unmet upon completion of requirements compliance testing. Step 6: Document needs and requirements analysis in suitable memorandum or report, and archive requirements analysis data for reference.
Activity Uses	
• Previous Uses	None
• Prospective Applications	None
Inter Activity Relationships	
• Activity Sequence and Control-Flow	The following relationships pertain to other investment management process activities:

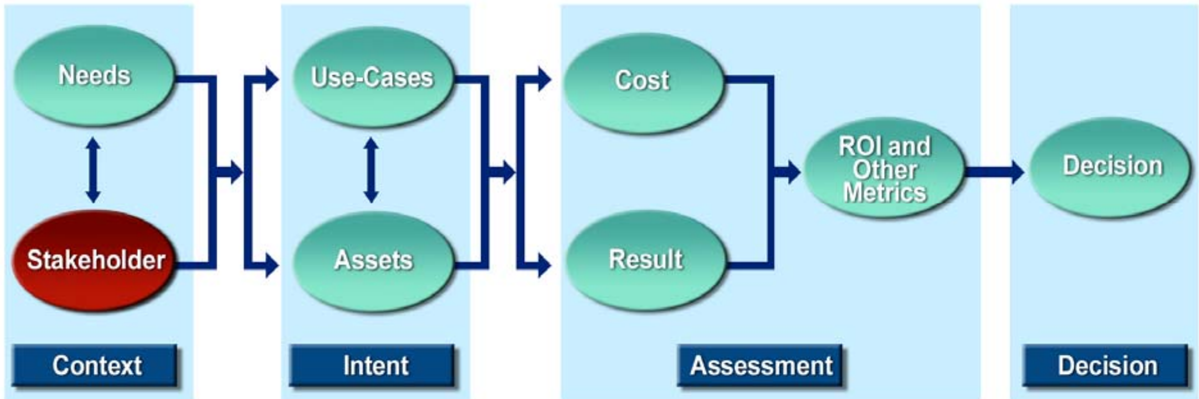
ACTIVITY CHARACTERISTIC	INFORMATION
	R1: This activity is to be conducted concurrent to the Stakeholder analysis task activity. And it is potentially contingent upon the results of Stakeholder coordination results. Together these activities constitute the "Context" phase of the full process. Information generated during the stakeholder analysis and coordination activity should be made available to this task in order to establish the most complete and best understood expression of stakeholder needs possible. Similarly, results of the needs capture and requirements generation component of this task should be revealed to significant stakeholders identified in the Stakeholder Analysis and Coordination task for preliminary confirmation of completeness of identification of needs and interests, reasonable devolution of needs to requirements, and acceptability of exit criteria for requirements evaluation. R2: The subject activity, together with the Stakeholder analysis and Coordination activity, is predecessor to both the tasks constituting the "Intent" phase of the investment management effort, namely Use-Case Specification and Investment Asset Identification. R3: This activity may be reprised after Use Case Specification if a significant number of needs or requirements are found to be addressed, or if stakeholders request review upon examination of Use Case activity results. This activity has no looping, branching or self-
• Activity Information Flow	Information from outside the decision process (exogenous) identified as necessary input to this activity includes: I1: Statement of investment problem. Problem statement should indicate initial perceived need, apparent stakeholders, and type of decision to be made (e.g. marginal alternative, go-no-go, or predictor-corrector analysis of ROI). I2: Constraints on investment decision timeframe, scope of control, and budgetary background.

ACTIVITY CHARACTERISTIC	INFORMATION
	Information from inside the process (endogenous) - having been developed by means of the execution of one or another of the efforts' activities identified as necessary input to an activity includes: I3: Stakeholder identity and preferences and expectations for investment decision criteria, evaluation, and confirmation. Information expected to flow out of the activity having been generated by execution of the activity includes: I4: Requirements necessary and sufficient for confirmation of appropriateness of desired investment decision. This information will be used in the "Investment" phase of the effort.
Associated Entities	
• Tools	Requirements analysis tools such as relational databases, COTS products such as DOORS, or other assets may prove useful in capturing user needs, generation and maintaining audit traceability of derived requirements, and documentary reporting and archiving of needs and requirements analysis results.
• Actor-agents	Indicates the actor agent (individual member of one or another stakeholder class) responsible for completion of the activity. Clearly teams or anonymous agents may be designated. If the responsibility of members of the team need to be differentiated, it may be prudent to decompose the activity into its component parts in order to reduce the cardinality of agents to activities from N-to-1 to 1-to-1.
• Information Pools	Data stores appropriate for use in association with this activity include the following: D1: Stakeholder identification list and characterization or personal or institutional identification. This information is generally provided with the problem specification, but needs to be captured and included in a task activity data product. D2: Stakeholder needs specification, preserving audit traceability to source. This information may be

ACTIVITY CHARACTERISTIC	INFORMATION
	provided with the task specification or may need to be educed during process execution by means of research or interviews with relevant stakeholders, either as principals or as surrogates. Information needs to be captured and included in a task activity data product D3: Requirements list derived from needs, maintaining audit traceability. Requirements are usually generated during task activity, unless technical requirements are expressly called out in tasking. The distinction between user wants and needs and requirements is significant; the former relating to stakeholder preferences, the latter incorporating the judgment of the task team as to the relevance, influence and concreteness for use in process execution and results evaluation. It is essential that this information needs to be captured and included in a task activity data product. D4: Gap analysis results, indicating needs or requirements likely to remain unmet during process execution. This information is generated during task execution and is likely appreciated only be task team. On that account, it is essential that this information be captured and included in a task activity data product. Note that any or all of the data pool input sets or work-products may be maintained in cots or ad hoc information-management tools; but all such information should be referenced, included in the task activity and total effort report.
• Product-object-artifacts	In addition to the information artifacts indicated above, and such technical reports as may be needed for compliance the task / effort, no other work-product artifacts are necessary to be identified or delivered pursuant to the execution of this task.
Problem Management	
• Problem Identification	Typical requirements analysis problem areas include the following: P1: Insufficient or ambiguous specification of the problem tasking for investment decision at large – this circumstance inhibits identification of relevant stakeholders and establishment of requirements fully

ACTIVITY CHARACTERISTIC	INFORMATION
	sufficient for investment decision results evaluation. P2: Notwithstanding the best of intentions, the most frequent and egregious problem is lack of commitment of the executions team or willingness of the customer tasking agent to invest effort into systematic requirements analysis P3: The potential exists that within the available effort of requirements analysis, gaps may nevertheless exist whereby investment decision activity is inappropriately guided in execution or evaluated upon completion
• Problem Amelioration	In response to the potential problems cited above, corresponding recommended amelioratives or risk management strategies are recommended: A1: Effective communication with tasking authorities is a first step in mitigating risk associated with problem specification. Often, however, desired information is not available even to the tasking agent, in which case, information needs should be documented immediately, pursued throughout the task activity, and cited as qualifications in results reports. A2: Commitment of the execution to all necessary civilities including requirements analysis is a proper basis for reducing risk of P2. In addition, however, including requirements analysis explicitly in task program plans, budgets and schedules provides at least the opportunity t negotiate with tasking customer for this activity to be completed successfully.
Activity Completion	
• Exit Criteria	• Requirements analysis is completed when: - Requirements have been confirmed with significant stakeholders - Requirements have been accepted by process execution team as sufficient for operational guidance and results evaluation Requirements analysis work products have been archived (and/or) documented as directed by sponsor.

L.3 Stakeholder Analysis and Coordination Activity



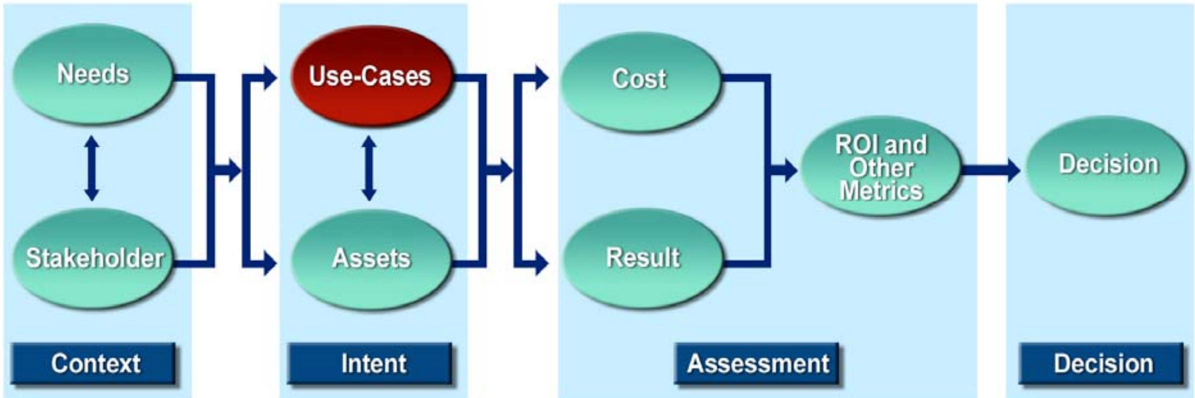
ACTIVITY CHARACTERISTIC	INFORMATION
Activity Identity	
• Activity Name and Aliases	Stakeholder Analysis and Coordination
Activity Description	
• Activity Rationale / Need / Motivation	Understanding the stakeholders and their role-dependent sensitivities within the M&S community of practice is a key step to developing an effective process for determining the metrics for M&S.
• Activity Classification	Conducting the stakeholder analysis is an analyst activity with management oversight. The analyst will identify and characterize the various stakeholders/communities potentially impacted by the investment decision under consideration. Management will confirm the results from the analysis and ensure appropriate coordination with all identified stakeholder.
Activity Initiation	
• Entrance Criteria	Prior to identifying the stakeholders, it is important to first establish a clear description and understanding of the needs and requirements prompting a possible investment in an M&S asset.
Activity Method	
• Activity Procedure	1. From the M&S Stakeholder Category table provided in section 3.3.2 identify the categories of stakeholders impacted by the M&S investment under consideration. 2. Identify specific information about the specific stakeholders within these categories, including the office/roles they hold.

ACTIVITY CHARACTERISTIC	INFORMATION
	3. From the M&S Stakeholder Perspectives table provided in section 3.3.3 identify the perspectives of each of the stakeholders identified in Step 2. 4. Where possible, identify the timelines for each identified stakeholders' decision/return process (see section 3.3.3) 5. For each identified stakeholder conduct analysis to determine their specific concerns relevant to the M&S investment under consideration. Show each stakeholder the preliminary results of the needs capture and requirements generation activity and seek a preliminary confirmation of completeness of identification of needs and interests, reasonable devolution of needs to requirements, and acceptability of exit criteria for requirements evaluation. 6. Consider developing a plot of the stakeholder space as shown by the example in Figure 3.3.6-1.
Activity Uses	
• Previous Uses	None.
• Prospective Applications	None.
Inter Activity Relationships	
• Activity Sequence and Control-Flow	The following relationships exist between the Stakeholder Analysis and Coordination activity and other decision process activities: R1: This activity is conducted concurrent with the Needs and Requirements Analysis activity. Results of the needs capture and requirements generation component of should be revealed to the significant stakeholders identified for preliminary confirmation of completeness of identification of needs and interests, reasonable devolution of needs to requirements, and acceptability of exit criteria for requirements evaluation. Similarly the results of this Stakeholder analysis should be referenced as part of the Needs & Requirements Analysis activity in order to ensure a complete and accurate capture of needs/requirements. R2: This activity, together with the Needs and

ACTIVITY CHARACTERISTIC	INFORMATION
	Requirements activity, is predecessor to both the tasks constituting the "Intent" phase of the investment management effort, namely Use-Case Specification and Investment Asset Identification.
• Activity Information Flow	Information from outside the decision process (exogenous) identified as necessary input to this activity includes: I1: Statement of investment problem. Problem statement should indicate initial perceived need, apparent stakeholders, and type of decision to be made (e.g. marginal alternative, go-no-go, or predictor-corrector analysis of ROI). I2: Constraints on investment decision timeframe, scope of control, and budgetary background. Information from inside the process (endogenous) - having been developed by means of the execution of one or another of the efforts' activities identified as necessary input to an activity includes: I3: Requirements necessary and sufficient for confirmation of appropriateness of desired investment decision. This information will be used in the "Investment" phase of the effort. Information expected to flow out of the activity having been generated by execution of the activity includes: I4: Stakeholder identity and preferences and expectations for investment decision criteria, evaluation, and confirmation.
Associated Entities	
• Tools	None required.
• Actor-agents	Indicate the actor agent (individual member of one or another stakeholder class) responsible for completion of the activity. Clearly teams or anonymous agents may be designated. If the responsibility of members of the team need to be differentiated, it may be prudent to decompose the activity into its component parts in order to reduce the cardinality of agents to activities from N-

ACTIVITY CHARACTERISTIC	INFORMATION
	to-1 to 1-to-1.
• Information Pools	D1: Needs/Requirement specification document for the M&S investment under consideration. D2: Any domain or community analyses which may provide insight into types and characteristics of various stakeholders likely to be impacted by the investment decision under consideration.
• Product-object-artifacts	The interim product is a stakeholder analysis and coordination report.
Problem Management	
• Problem Identification	P1: There is a potential for identified stakeholders not perceiving the potential impact of the investment decision under consideration as important to them and not wanting to, or having time to, support the required analysis. This could result in less robust analysis results.
• Problem Amelioration	Work with identified potential stakeholders to explain the importance of a robust decision process and make clear the impact the decision could have on them.
Activity Completion	
• Exit Criteria	• Stakeholder analysis and coordination is completed when: - Stakeholders have been identified and characterized. - Stakeholder concerns have been captured - Proper coordination with all stakeholders has been established and stakeholders have confirmed needs and requirements analysis reflect their concerns. • Stakeholder analysis and coordination work products have been archived (and/or) documented as directed by sponsor.

L.4 Use Case Analysis Activity



ACTIVITY CHARACTERISTIC	INFORMATION
Activity Identity	
• Activity Name and Aliases	Use Case Development
Activity Description	
• Activity Rationale / Need / Motivation	Developing and understanding Use Cases including stakeholder needs and requirements is an important step in determining, refining, and evaluating the process for investment metrics for M&S. Use Cases illustrate stakeholder issues and role-dependent sensitivities together with investment decision processes. Use Cases also serve to support and guide the definition, explanation, and evaluation of process and metric alternatives.
• Activity Classification	Developing Use Cases in support of the analysis need before making an investment decision is an analyst activity with management oversight. The analyst would work with management to identify the specifics of a Use Case and aide in executing the process steps captured by the Use Case. Management should ensure the Use Case is representative of the investment decision to be made and participate in executing the process steps as part of the Use Case.
Activity Initiation	
• Entrance Criteria	Prior to the development of relevant Use Cases the context for the M&S investment decision under consideration has to be established via the Needs & Requirements Analysis activity and the Stakeholder & Community of Practice Analysis activity. With a clear

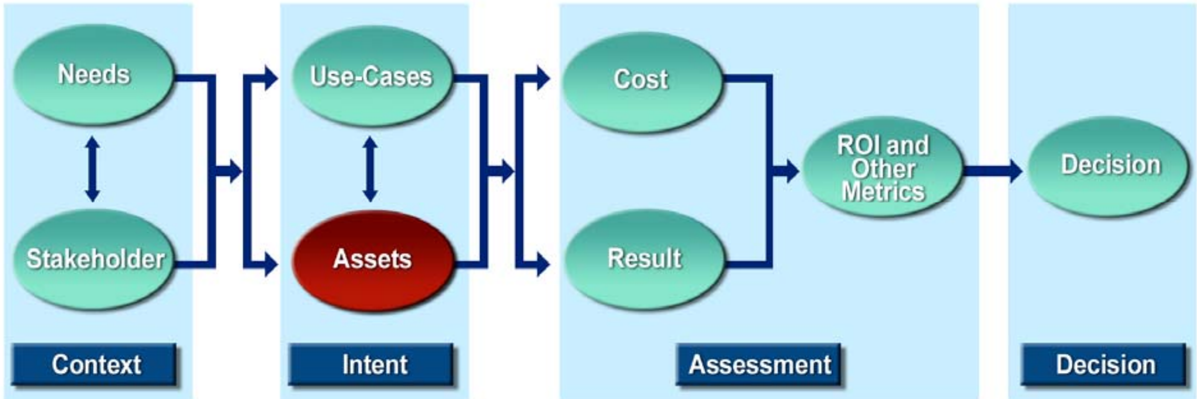
ACTIVITY CHARACTERISTIC	INFORMATION
	understanding of the results of these analyses in conjunction with the results of the Asset Identification activity which is conducted concurrent with this activity, valid and relevant Use Cases can be established.
Activity Method	
• Activity Procedure	1. Postulates a relevant situation/decision involving an M&S investment of the class under consideration. Use this to “sets the stage” for developing the parameters in the use case framework. 2. Determining the primary M&S market *categories* involved with the situation/decision (these should be restricted to the primary categories since many might be involved). 3. Identifying the specific (generic) stakeholders in the primary market *categories* and their *perspectives* (placing them in the stakeholder space) for the situation/decision. 4. Delineate the generic issues or concerns of these stakeholders for the situation/decision. 5. Specify the types of M&S investment metrics that are available and applicable for the situation/decision, and elucidates the *data support* issues involved with these metrics. For example, if the data needed for an investment metric is very difficult, expensive, or time consuming to develop for the postulated situation/decision, then that metric is not useful and should be discarded for another (for that situation/decision). 6. Execute the Use Case by executing the relevant steps of the Investment Decision Process.
Activity Uses	
• Previous Uses	None.
• Prospective Applications	None.
Inter Activity Relationships	
• Activity Sequence and Control-Flow	The following relationships exist between Use Case Development and other decision process activities:

ACTIVITY CHARACTERISTIC	INFORMATION
	R1: This activity is conducted subsequent to the "Context" activities (Needs & Requirements Analysis and Stakeholder Analysis and Coordination). The results of both of those activities are important input to this activity. R2: This activity is conducted concurrent with the Investment Asset Identification activity. Results of the Asset Identification analysis will be used by this activity in establishing a valid Use Case. Similarly the results of this Use Case activity should be referenced as part of the Investment Asset Identification activity in order to ensure a complete and accurate capture of assets relevant to the investment decision under consideration. R2: This activity, together with the Investment Asset Identification activity, is predecessor to the tasks constituting the "Assessment" phase of the investment management effort.
• Activity Information Flow	Information from outside the decision process (exogenous) identified as necessary input to this activity includes: I1: Statement of investment problem. Problem statement should indicate initial perceived need, apparent stakeholders, and type of decision to be made (e.g. marginal alternative, go-no-go, or predictor-corrector analysis of ROI). I2: Constraints on investment decision timeframe, scope of control, and budgetary background. Information from inside the process (endogenous) - having been developed by means of the execution of one or another of the efforts' activities identified as necessary input to an activity includes: I3: Requirements necessary and sufficient for confirmation of appropriateness of desired investment decision. This information will be used in the "Investment" phase of the effort. I4: Stakeholder identity and preferences and

ACTIVITY CHARACTERISTIC	INFORMATION
	expectations for investment decision criteria, evaluation, and confirmation. I5: Identified investment asset types that satisfy the identified need and requirements of all stakeholders. Information expected to flow out of the activity having been generated by execution of the activity includes: I6: Use Case analysis results.
Associated Entities	
• Tools	None required.
• Actor-agents	*<Indicate the actor agent (individual member of one or another stakeholder class) responsible for completion of the activity. Clearly teams or anonymous agents may be designated. If the responsibility of members of the team need to be differentiated, it may be prudent to decompose the activity into its component parts in order to reduce the cardinality of agents to activities from N-to-1 to 1-to-1.>*
• Information Pools	D1: Needs/Requirement specification document for the M&S investment under consideration. D2: Stakeholder Analysis and Coordination report. D3: Identified investment asset type list.
• Product-object-artifacts	The interim product is a Use Case analysis report.
Problem Management	
• Problem Identification	*<Identification, explication and potential consequences associated with the execution of any subject process action. May include problem proximate cause, relevant contextual circumstances, or qualification / quantification of the problem, useful in understanding the problem mechanism and educing suitable amelioratives.>*
• Problem Amelioration	*<Action alternatives suitable to avoid, reduce or ameliorate the pejorative impacts of the problem. Necessary and conditions for employing candidate ameliorative, and expected cost, benefit, and identification of any possible unintended consequences.>*
Activity Completion	
• Exit Criteria	Common practice in writing effective use

ACTIVITY CHARACTERISTIC	INFORMATION
	cases[106] include the following injunction – "You are 'done' when: • You have named *all the primary actors and all the user goals* with respect to the [process] • You have captured *all trigger conditions* to the [process] either as use case triggers or as extension triggers. • You have written all the user-goal use cases, along with the *summary and sub-function use cases* needed to support them. • Each use case is written clearly enough that - The sponsors *agree* that they will be able to tell whether or not [the process / the investment decision] is actually delivered - The [process] *users* agree that [the process] is what they can or accept…. - The developers *agree* that they can actually develop [/execute] the [process] - The sponsors *agree* that the use case set covers all they want (for now)."

L.5 Investment Asset Identification Activity



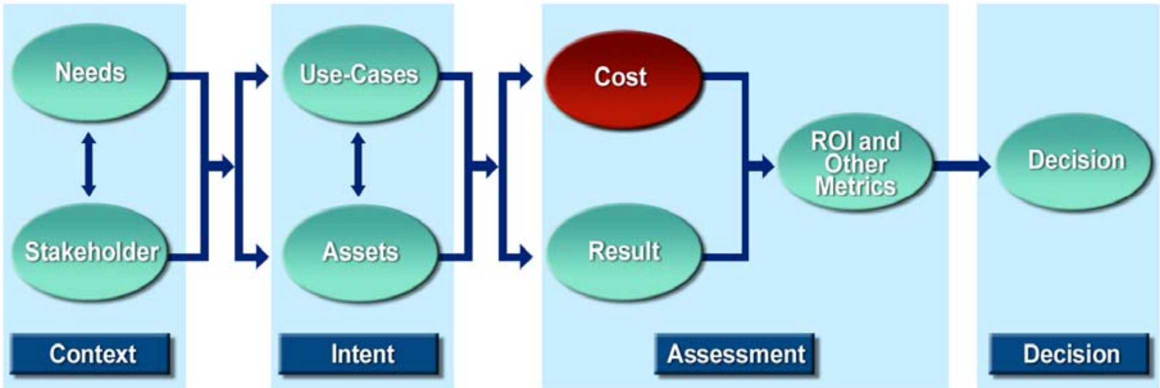
ACTIVITY CHARACTERISTIC	INFORMATION
Activity Identity	
• Activity Name and Aliases	Investment Asset Identification (Assets)
Activity Description	
• Activity Rationale / Need / Motivation	It is useful to identify the type or class of investment asset under consideration in order to better understand the metrics and measures needed to feed into the decision method. Additionally, using the cross-correlation matrices in section 3.5 one can identify other potential stakeholders by determining the asset type under consideration.
• Activity Classification	Determining the asset type is an analyst activity with management oversight. The analyst would determine the asset category in the process of identifying the applicable cost and result metrics to use in the decision method. Management would ensure all stakeholders were considered once the asset category was established.
Activity Initiation	
• Entrance Criteria	Prior to identifying the asset type it is necessary to determine the requirement and need that the investment must fulfill. Without the requirements analysis it is impossible to determine the category of assets that are necessary to meet the need.
Activity Method	
• Activity Procedure	Identifying the investment asset types is a subjective process, but one that is easily repeatable.

ACTIVITY CHARACTERISTIC	INFORMATION
	1. From the asset list given in section 3.5 use the needs and requirements analysis to determine what asset type satisfies the requirement. 2. Using the cross-correlation tables given in section 3.5 verify that all potential interested stakeholders for that asset type have been considered. 3. The investment asset type is then used to determine applicable cost and result metrics.
Activity Uses	
• Previous Uses	Investment Asset Identification has not been previously used. Stakeholder identification was performed in the prior step and is performed here as a verification.
• Prospective Applications	None. Once the asset category is determined it will not be necessary to repeat the process.
Inter Activity Relationships	
• Activity Sequence and Control-Flow	The following relationships exist between investment asset identification and other decision process activities: R1: Investment asset identification follows the investment needs and requirements analysis. R2: Investment asset identification can be performed simultaneously with the use case process. R3: Investment asset identification precedes the selection of the appropriate cost and result metrics for use in the decision method.
• Activity Information Flow	Information flow for investment asset identification is only within the process. I1: Information flows from the results of the needs and requirements analysis which allows the asset type to be determined. I2: Once the investment asset type is determined this information is fed to the analyst who will choose the appropriate cost and result metrics which will be measured and then used as input to the decision process.
Associated Entities	
• Tools	None required.
• Actor-agents	While management will review and approve the needs

ACTIVITY CHARACTERISTIC	INFORMATION
	and requirement analysis, the identification of asset(s) required to fulfill the stated requirements will be an analyst activity. Additionally, once the asset(s) are identified then again an analyst will review and verify that all the stakeholders in that type of asset are considered.
• Information Pools	Information regarding previous procurement of the selected asset type may be in a program manager's files, but information regarding an explication of asset types and categories is given in section 3.5.
• Product-object-artifacts	The interim product is the asset type which fulfills the needs and requirements determined in the needs and requirement analysis.
Problem Management	
• Problem Identification	The process of identifying the investment asset types is fairly straightforward. There are two potential, but unlikely and low threat, problem areas. The first potential issue is if the needs and requirements analysis is incorrect or incomplete. This may lead to selecting the wrong asset type. However, given the fact that a team of analysts may perform the analysis and that it would be reviewed and approved, it is unlikely that the needs and requirements analysis would contain totally incorrect conclusions. Secondly, there is the possibility that the list of assets in section 3.5 does not contain an asset type which fulfills the identified needs and requirements. Given that the list was determined by a panel of SMEs this is also unlikely, however, it is possible that a new class of assets could be developed in the future. If that is the case then this class of asset is added to the list and applicable cost and result metrics are developed.
• Problem Amelioration	Measures have been taken to combat the above potential problems. As mentioned above due to multiple people reviewing the needs and requirements analysis it is unlikely that it would miss the mark by enough to cause the investment to consider an entirely different asset type. For the second issue, while one cannot and would not desire to stop progress, if a new asset type is invented/developed the asset list and associated cost and results metrics can be updated with relatively minimal

ACTIVITY CHARACTERISTIC	INFORMATION
	effort.
Activity Completion	
• Exit Criteria	Investment Asset Identification is complete when the asset is categorized as to type and all the potential Stakeholders are identified based upon the asset type.

L.6 Investment Asset Cost Analysis Activity



ACTIVITY CHARACTERISTIC	INFORMATION
Activity Identity	
• Activity Name and Aliases	Investment Asset Cost Analysis (expenses, investment, money)
Activity Description	
• Activity Rationale / Need / Motivation	Provide a consistent measurement to compare alternative investments in M&S versus the status quo or versus no investment in M&S. Cost data using a standard metric such as current year United States dollars is a very useful objective way to compare alternatives. Cost data must also be accompanied with information on the assumptions on which the cost analysis is based.
• Activity Classification	Determining costs is a labor-intensive activity that requires guidance by management before it starts. Cost analysis is an effort to fairly and consistently determine the funding that must be expended by some entity to pay for an M&S tool, use, or event. Part of the decision process must include the perspective or viewpoint because that can make a significant difference in costs. Programs and enterprises may share costs differently. A cost to one program may be good (low) but bad (high) to another program or to the enterprise level. Cost and results (benefits/outcomes) form the primary ways expenditures are judged, and these metrics are coupled. A lower cost for the purchase of M&S may fund poorer results, and a cheaper product may have expensive consequences in use.

ACTIVITY CHARACTERISTIC	INFORMATION
Activity Initiation	
• Entrance Criteria	Management (at the program, enterprise, or intermediate level) directs either a cost analysis of M&S alternative investments or a full (cost and results) return on investment analysis, of which cost is a key component. The workforce/analyst(s) completing the cost analysis must have guidance on the perspectives (program or enterprise) that will be wanted/used in the evaluation. The workforce must also know the timelines required for the analysis (years or number of uses), and the timing (frequency of use) and characteristics of predicted future uses of the M&S. Cost analyses will require the input guidance included above, the discount rate, and the inputs derived from budgetary or programmatic costing data to calculate personnel, systems, and infrastructure costs.
Activity Method	
• Activity Procedure	Management directs that cost data for alternatives be calculated, and management provides the guidance and the information sources needed to complete the calculations. The analyst(s) then complete the following steps: Step 1: Identify the alternatives being compared Step 2: List known stakeholders and identify the program or enterprise perspective to be used Step 3: Document the use cases assumed, time horizon, and frequencies of uses assumed. Document the discount rate that management directs Step 4: Identify the budgetary or programmatic costs to be used for each geographic site to be used in the estimates for personnel, systems, and infrastructure Step 5: Receive the government-reviewed development or purchase costs for each of the M&S alternatives. Verify that hardware, software, infrastructure, and personnel costs are known for each alternative. Each alternative probably needs different levels of control staff, role players, operators, computers, distribution infrastructure, facilities, set-up, and other characteristics

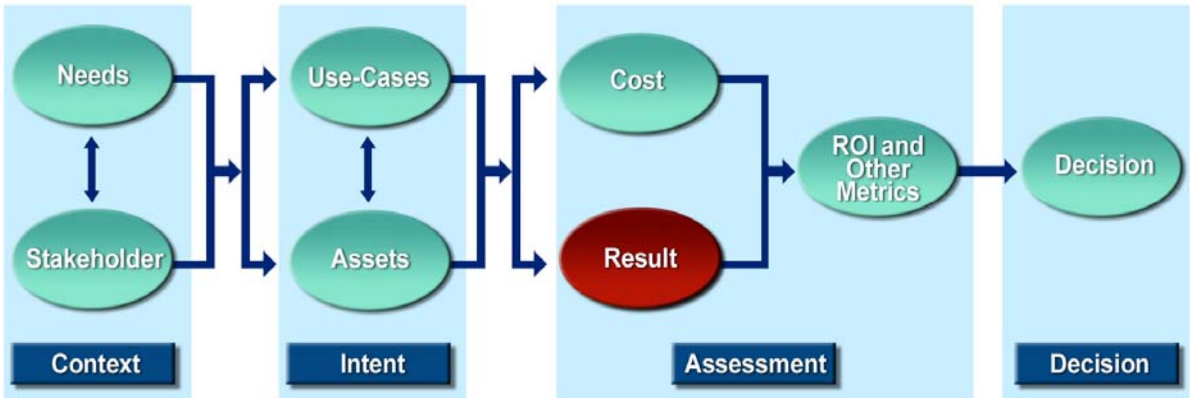
ACTIVITY CHARACTERISTIC	INFORMATION
	that affect cost. Step 6: Compute the costs of each alternative depending on use assumptions, perspective, and time horizon. Discount the costs to determine the NPV Step 7: Compare the costs Step 8: Compare the cost of the alternatives to the cost of doing business as is, and compute cost avoidance return on investment, if appropriate Step 9: Compute the cost of completing the uses or events with all live forces from the same perspective and over the same time window and use-cases used in the previous cost analyses, and compute the cost avoidance return on investment for the alternatives relative to the cost of using all live forces. Comparisons should be completed in current year dollars (discounted and summed to NPV).
Activity Uses	
• Previous Uses	If the government authorized an analysis of alternatives (AoA) or an evaluation of alternatives (EoA), cost data was already developed.
• Prospective Applications	Cost information will be used in AoA, EoA, cost avoidance ROI, and overall results calculations. It will also be retained and used in subsequent evaluations to see whether the cost data was accurately computed (feedback).
Inter Activity Relationships	
• Activity Sequence and Control-Flow	The following relationships pertain to cost analysis activities: R1: This activity is dependent on and will be conducted after the Needs, Stakeholders, Assets, and Use Cases are identified R2: This activity is conducted concurrently with the Investment Asset Results Analysis task activity. R3: This activity will be combined with the Results analysis in order to calculate ROI. The Cost and Results are dependent (related, perhaps inversely), and when

ACTIVITY CHARACTERISTIC	INFORMATION
	combined, they can be used to give a useful idea of an investment's utility R4: The Cost analysis calculation should be updated as more accurate information becomes available. Cost analysis for any given set of alternatives is an iterative process, and cost data from previous studies can be useful to subsequent analyses, as lessons learned or good starting data
• Activity Information Flow	Information from outside the decision process (exogenous) identified as necessary input to this activity includes: I1: Purchase cost data for the M&S alternatives I2: Stakeholder perspective to be used (program or enterprise) I3: Use case data for the M&S alternatives based on management predictions of future uses over a management-specified timeframe. I4: Cost data for personnel salaries and travel costs, cost data for operating weapons and other systems, and cost data for infrastructure. I5: Management-specified discount rate for expressing costs in terms of current year costs. Information from inside the process (endogenous) - having been developed by means of the execution of one or another of the efforts' activities identified as necessary input to an activity includes: I6: Cost data for the M&S assets and cost data for use of the assets over time Information expected to flow out of the activity having been generated by execution of the activity includes: I7: Cost data expressed in current year dollars for each alternative, for the existing system, and for using all live forces, if computed

ACTIVITY CHARACTERISTIC	INFORMATION
Associated Entities	
• Tools	Database search and retrieval tools and spreadsheet tools like Microsoft Excel can be used.
• Actor-agents	Management (a stakeholder at the program, enterprise, or intermediate level) to direct the cost analysis. Analyst(s) to conduct the cost analysis combine the results, and present the results in a meaningful way to decision-makers. Government or government-funded contractor representatives to assist users of the process, at least over the first year or two, and to document lessons learned and process improvement ideas.
• Information Pools	Government databases using Presidential Budget data or Program Objective Memorandum data should be used whenever possible in order to have accurate authoritative cost data for the cost comparisons explained in this document. Databases should be developed from previous uses of the cost estimation tools. Automated methods or tools that allow analysts to locate typical personnel, systems, and infrastructure costs could be developed/accumulated to vastly ease this cost estimation process. A help desk to usher analysts through the process and beta test the system would not only help new users but also build a database of lessons learned and needed system modifications.
• Product-object-artifacts	The process will produce a cost estimate for each of the alternative M&S investments and perhaps cost estimates for the current solution and for using all live forces instead. These cost estimates will include the costs to buy, build, or modify the M&S asset and the cost to use it over a specified time horizon. The cost data can then be separated between initial (purchase) costs and use costs over a specified time frame.
Problem Management	
• Problem Identification	Once management identifies the framework of the problem such as perspectives required, uses, frequency of uses, and timeframe for the M&S asset, the alternatives can be evaluated in terms of cost. The cost data for the uses planned for the assets can be difficult to compute – at least initially. Government databases using Presidential Budget data or Program Objective Memorandum data should be used whenever possible in order to have accurate authoritative cost data for the cost comparisons

ACTIVITY CHARACTERISTIC	INFORMATION
• Problem Amelioration	Once the M&S asset cost analysis has been used a few times, analysts will learn where to find the necessary data and how best to use it. Databases will also be developed from previous uses. Tools that allow analysts to locate typical personnel, systems, and infrastructure costs could be developed / accumulated to vastly ease this cost estimation process. A help desk to usher analysts through the process and beta test the system would not only help new users but also build a database of lessons learned and needed system modifications.
Activity Completion	
• Exit Criteria	• Cost data for all relevant assets for every alternative being considered will be calculated and indicated. The cost data will be combined with the results data to compute ROI measures and other metrics to facilitate decisions. • It is important that the most authoritative data sources available be used to conduct the cost calculations and that equivalent assumptions be used and stated when making the calculations for each alternative. • Cost databases and sources should be declared and made available by the enterprise level stakeholder(s) for cost calculations.

L.7 Investment Asset Result Analysis Activity



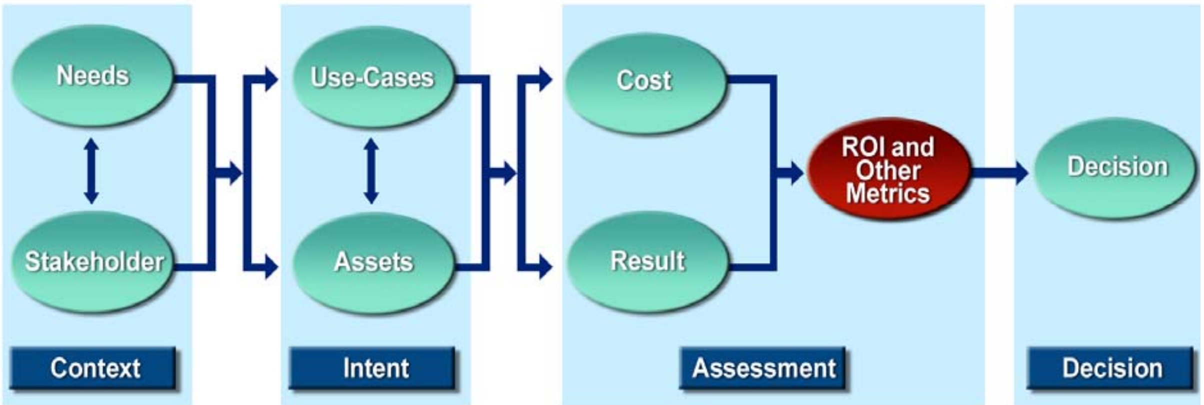
ACTIVITY CHARACTERISTIC	INFORMATION
Activity Identity	
• Activity Name and Aliases	Asset Investment Results Analysis
Activity Description	
• Activity Rationale / Need / Motivation	To understand the utility of M&S it is necessary to characterize the results of its application: the 'return' in 'return on investment.' These results, whether positive or negative, can be rigorously described. This analysis decomposes the three relevant perspectives into results classes, characteristics, and metrics; and for each metric connects applicable quality and monetary dimensions. These metrics reflect the results of M&S investment and measuring each (determining quality and cost savings / avoidance values) provides quantitative inputs to the calculation of M&S investment utility and return on investment. In other words, the intended products of this activity, the values of the results metrics, provide insights in their own right and are inputs to the subsequent utility / ROI calculation algorithm.
• Activity Classification	Results analysis is a management process, guiding the incorporation of M&S investment products into decisions, made by enterprise, application, and program managers.
Activity Initiation	
• Entrance Criteria	Components relative to items needed for results analysis to be successful include: • Commitment to metrics identification and measurement – cost, time, leadership, etc.

ACTIVITY CHARACTERISTIC	INFORMATION
	• Preconception of stakeholder perceptions on anticipated results • Appreciation of circumstantial conditions of results analysis – external perspectives, applications, and programs.
Activity Method	
• Activity Procedure	Procedural guidance for the execution of the results analyses are: Step 1: Establish perspective (enterprise, application, program) Step 2: Identify alternatives being compared Step 3: Define relevant metrics Step 3.1: Select from samples Step 3.2: Expand as required Step 4: Measure metrics Step 4.1: Produce current values Step 4.2: Project and normalize values Step 5: Assess results Step 5.1: Relative to status quo Step 5.2: Relative to each other Step 6: Provide outputs to decision algorithm Step 7: Repeat / iterate as possible Step 8: Document and archive data for reference
Activity Uses	
• Previous Uses	None
• Prospective Applications	M&S Investments relative to Enterprise, Application, and Program Perspectives
Inter Activity Relationships	
• Activity Sequence and Control-Flow	The following relationships pertain to results analysis activities: R1: This activity will be conducted after the Needs, Stakeholders, Assets, and Use Cases are identified R2: This activity is conducted concurrently with the Asset Investment Cost Analysis activity R3: This activity will be combined with the cost analysis in order to calculate M&S utility and/or ROI. R4: The results analysis should be updated as more accurate information becomes available. Results analysis calculation for any given set of alternatives is an iterative process, and data from previous iterations / studies can be useful to subsequent analyses

ACTIVITY CHARACTERISTIC	INFORMATION
• Activity Information Flow	Information from outside the decision process (exogenous) identified as necessary input to this activity includes: I1: Stakeholders and perspectives. The definition of each and their relative considerations. Information from inside the process (endogenous) - having been developed by means of the execution of the efforts' activities identified: I2: Relevant alternatives and associated scales; assessment approaches; metric and measurement assessments. Information expected to flow out of the activity having been generated by execution of the activity includes: I3: Results metrics and specific values necessary as inputs to the M&S Value / ROI calculation process.
Associated Entities	
• Tools	Expert Choice, INPRE and ComPAIRS, PRIME Decisions, HIPRE 3+, HIPRE 3+ GROUP LINK, Criterium, DecisionPlus, Winpre, and Automan. [107]
• Actor-agents	The results analysis can be conducted by an individual analyst or group of analysts familiar with operations research, metrics assessment, and M&S evaluation.
• Information Pools	Results information should include a description of the alternatives assessed, metrics utilized, measurement techniques/quantitative transformations employed, any intermediate steps/derived results, and aggregation methods
• Product-object-artifacts	Assessed metric values are the primary product of results analysis. These values provide inputs, along with cost and risk factors, to the investment decision algorithm that calculates M&S utility and/or return on investment.
Problem Management	
• Problem Identification	The first challenge is relative to the data needed: each of the proposed metrics must be measured in a consistent and accurate manner. The next is relative to implementing the approach is the complexity brought on by the three perspectives and the need to correlate / de conflict the results.
• Problem Amelioration	Two potential ways to remediate these risks are to take

ACTIVITY CHARACTERISTIC	INFORMATION
	an incremental approach and to use the lessons learned from other domain applications.
Activity Completion	
• Exit Criteria	• The Result analysis activity is complete when: - A necessary and sufficient set of results metrics have been chosen at a (given the) relevant perspective(s), - The results metrics have been adequately defined, - The metrics have been rigorously assigned values, - Metric interdependencies have been articulated. • Results analysis work products have been created and/or documented – per direction of the sponsor

L.8 Return-On-Investment Evaluation Activity



ACTIVITY CHARACTERISTIC	INFORMATION
Activity Identity	
• Activity Name and Aliases	Return-On-Investment Evaluation Activity
Activity Description	
• Activity Rationale / Need / Motivation	ROI is an intuitive and suggestive indicator of investment viability. However, ROI is itself sensitive to alternative interpretations in public and private sector environments. Understanding ROI concepts and their application is key to developing an effective process for determining the metrics for M&S.
• Activity Classification	Conducting the Return-On-Investment evaluation is an analyst activity with management oversight.
Activity Initiation	
• Entrance Criteria	Prior to performing the ROI evaluation it is important to first establish a clear description and understanding of the needs and requirements prompting a possible investment in an M&S asset and all relevant stakeholders, understood the intent of the investment via use cases and M&S asset identification and then having conduct analyses of both the associate investment costs and anticipated results.
Activity Method	
• Activity Procedure	There are, broadly speaking, three different methodologies used in Finance to calculate ROI – the "Three Formulations" as they are referred to in the report: (1) as a percentage increase in a holding's value

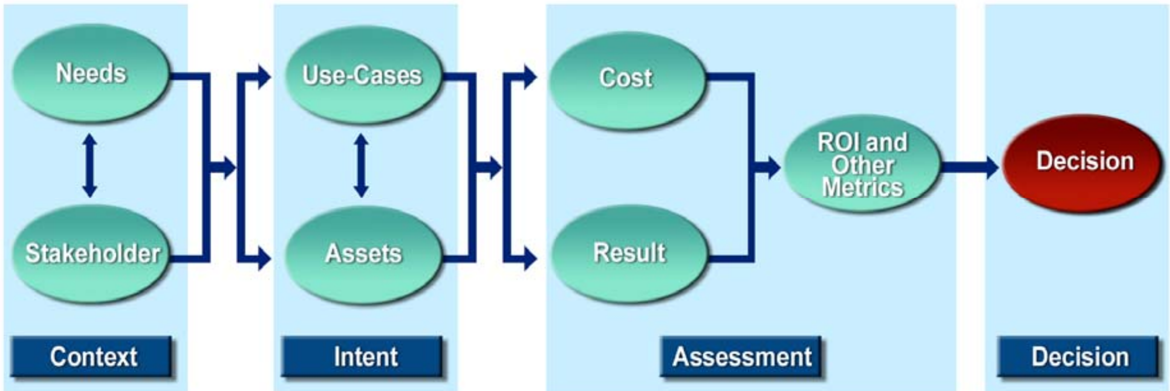
ACTIVITY CHARACTERISTIC	INFORMATION
	between two time periods % Return = [(V_{end} – V_{begin} + CF) / V_{begin}] * 100 Where: V_{end} is the value at the end of a portion of time, V_{begin} is the value at the beginning, and CF is the sum of all cash flows that come about as a direct result of having made the investment. (2) as the amount of cash (or, revenue) generated from a set, fixed asset base[108]. % Return = [(benefit) / (base)] * 100 Where: Benefit is the results (such as net income, revenue, yield, etc.) from a fixed Base of some type (total assets, total equity, total capital expenditure, etc.). (3) as the sum of a series of cash flows, discounted by an appropriate rate. There are, typically, two ways that financial analysts go about these calculations. Net Present Value (NPV): $\sum [CF_t / (1+r)^t]$ – Outlay Where: CF_t = cash flow at time *t* (usually after tax), r = discount rate Outlay = cash required/needed (@ *t*=0) for project to proceed Or Internal Rate of Return (IRR): $\sum [CF_t / (1+r)^t]$ = Outlay Where: CF_t = cash flow at time *t* (usually after tax), r = discount rate Outlay = cash required/needed (@ *t*=0) for project to proceed While the discounting rate can (and is) used to adjust for the time value of money, it can also be employed to

ACTIVITY CHARACTERISTIC	INFORMATION
	adjust for the rsk of an investment. In order to adjust for higher risk, we simply use a greater discounting rate. The discounting rate then becomes the sum of the adjustment needed to compensate for TVM plus an "extra" adjustment for risk. For public (and very large private) corporations, the discount rate generally used is equal to the cost of capital for that firm. As the CFA Institute writes, "The most common way to estimate this required rate of return is to calculate the marginal cost of each of the various sources of capital and then calculate a weighted average cost of capital (WACC)." $WACC = (w_d)(r_d)(1 - t) + (w_p)(r_p) + (w_e)(r_e)$ Where: w_d = proportion of debt that the company uses when it raises new funds, r_d = the before-tax cost of debt, t = marginal tax rate, w_p = the proportion of preferred stock the company uses when it raises new funds, r_p = marginal cost of preferred stock, w_e = proportion of equity that the company uses when it raises new funds, r_e = marginal cost of equity. In the above equation, the cost of equity is usually equivalent to the "rate of return required by a company's common shareholders." (CFA Institute) In order to calculate the cost of equity (or, necessary rate of return on common), typically financial analysts use the Capital Asset Pricing Model (CAPM): $E(Ri) = R_f + ß_i[E(R_M) - R_F]$ Where: R_f = risk free rate (usually the rate of a US Treasury bond with suitable maturity), $ß_i$ = the return sensitivity of stock *i* to changes in the market return, $E(R_M)$ = the expected return on the market, $E(R_M) - R_F$ = the expected market risk premium.
Activity Uses	
• Previous Uses	None.
• Prospective Applications	None.

ACTIVITY CHARACTERISTIC	INFORMATION
Inter Activity Relationships	
• Activity Sequence and Control-Flow	The following relationships exist between the ROI Evaluation and other decision process activities: R1: This activity is conducted concurrent after the M&S Investment Cost and Results analyses. R2: This activity, together with the Cost and Results analysis activities comprise the "Assessment" phase of the investment management effort and precede the "Decision" phase and activity.
• Activity Information Flow	Information from inside the process (endogenous) - having been developed by means of the execution of one or another of the efforts' activities identified as necessary input to an activity includes: I3: Results of the Cost and Results Analyses. Information expected to flow out of the activity having been generated by execution of the activity includes: I4: ROI evaluations for use by the Decision activity.
Associated Entities	
• Tools	None required.
• Actor-agents	*<Indicate the actor agent (individual member of one or another stakeholder class) responsible for completion of the activity. Clearly teams or anonymous agents may be designated. If the responsibility of members of the team need to be differentiated, it may be prudent to decompose the activity into its component parts in order to reduce the cardinality of agents to activities from N-to-1 to 1-to-1.>*
• Information Pools	D1: Cost Analysis Report D2: Results Analysis Report.
• Product-object-artifacts	The interim product is a ROI Evaluation report.
Problem Management	
• Problem Identification	This field specifies component values of the state of the decision problem in its entirety that are necessary and sufficient for the subject activity to be considered finished with high probability of successful completion.
• Problem Amelioration	Action alternatives suitable to avoid, reduce or ameliorate the pejorative impacts of the problem.

ACTIVITY CHARACTERISTIC	INFORMATION
	Necessary and conditions for employing candidate ameliorative, and expected cost, benefit, and identification of any possible unintended consequences.
Activity Completion	
• Exit Criteria	• ROI Evaluations have been completed and presneted for use in the decision activity. • Work products have been archived (and/or) documented as directed by sponsor.

L.9 Investment Decision Activity



ACTIVITY CHARACTERISTIC	INFORMATION
Activity Identity	
• Activity Name and Aliases	Investment Decision (Decision Process, Decision Method, Decision Algorithm)
Activity Description	
• Activity Rationale / Need / Motivation	Once the various M&S investment evaluation metrics and measures of those metrics are obtained and calculated, a method or algorithm to objectively determine the best use of limited dollars and other resources is required. Without an objective decision process that takes into account all the metrics that are of interest there is a high probability that investments will be made that do not lead to the most advantageous results.
• Activity Classification	The decision method is a labor intensive activity that requires management input before it is executed. The measures of costs, results, and other metrics requires a dedicated effort, but can be accomplished by non-management personnel. The determination of the weightings in the recommended decision algorithm is a management process that needs to be completed before the algorithm is executed. A large influence on the values for the weightings will be the shareholder assigning the weights and the viewpoint of that shareholder. A project manager will be most likely concerned with different objectives than an undersecretary of defense and the algorithm weightings will reflect this difference.

ACTIVITY CHARACTERISTIC	INFORMATION
Activity Initiation	
• Entrance Criteria	Before the decision method can be executed the input metrics and measures must be completed. In this situation the main inputs are cost and result measures. Weightings must be assigned to the decision process algorithm, however that process can be done prior to, or in conjunction with, the gathering of the input measures.
Activity Method	
• Activity Procedure	The decision method at a high level is fundamentally simple: 1. Determine the stakeholder/viewpoint by which to evaluate the M&S investment 2. Determine the metrics by which one wishes to evaluate M&S investments. 3. Measure those metrics by some objective means. 4. Determine the relative importance of each metric and potentially group of metrics. 5. Execute the decision process algorithm using the weightings and input data. Each one of these steps may take days or weeks (in the case of the determination of algorithm weights) and may require management direction. More detail on each of these steps can be found in the Decision Process section of the body of the report.
Activity Uses	
• Previous Uses	The decision algorithm is the last step in the overall M&S Investment decision and is not previously used.
• Prospective Applications	The algorithm weightings will be used in other M&S investment decisions at the same stakeholder level.
Inter Activity Relationships	
• Activity Sequence and Control-Flow	The decision algorithm is the last step in the M&S investment process and is, therefore, dependent upon virtually every activity denoted in the process. R1: The weightings for the decision algorithm are dependent upon the stakeholder viewpoint. Weightings will differ depending upon whether the viewpoint is at the DoD/Enterprise level or project level. This is acceptable as long as weightings are consistent across all investments considered from an individual level.

ACTIVITY CHARACTERISTIC	INFORMATION
	R2: The cost and result metrics and measures directly feed into the decision algorithm and, therefore, the decision result is totally dependent upon these inputs. Poor or incomplete metrics or measures will skew the decision process result and may lead to a sub-optimal investment. R3: The cost and result metrics are dependent upon the type of investment asset of interest and, therefore, the decision algorithm indirectly depends upon the type of investment asset under consideration.
• Activity Information Flow	The decision method relies upon information generated throughout the process. Some of the information generated at the various stages of the decision process relies upon external (exogenous) data and information. However, most of the information directly required by the decision method is generated from within the decision process. Information required from within the decision process is: I1: Identification of the stakeholders which serves as the framework for the choice of input metrics and the development of the algorithm weightings. I2: Identification of the asset(s) of interest which determines which input metrics to measure. I3: Measures of the applicable cost and results metrics to use as input to the decision algorithm (this will include risk). Exogenous information required in the decision method is: I4: Measures of applicable metrics used in the decision method that are in addition to cost and results and will be used as input to the decision algorithm. I5: DoD or higher headquarters policy/directives or any other pertinent information that will influence the assignment of weightings in the decision method. Information that is produced by the decision method:

ACTIVITY CHARACTERISTIC	INFORMATION
	I6: The decision method produces a "utility" score which can be used to rank order the investment options and determine the best choice(s).
Associated Entities	
• Tools	The decision algorithm should be automated for ease of use. In many of the potential uses this can be accomplished via Microsoft Excel. In the rare case where Excel is not powerful enough, the algorithm will need to be developed internally or by a DoD contractor, or purchased off-the-shelf if available.
• Actor-agents	Management oversight and approval is required in the process of determining the algorithm weightings as is a team of subject matter experts. Analysts to run/implement (to include measuring the applicable metrics) the algorithm and interpret and present the results would be highly desirable. Then management/executives would make the necessary investment decision(s).
• Information Pools	Information on the implementation of the decision method and in particular the assigning of weights can be found in academic literature. See footnotes in section 3.9 and the Bibliography for examples of these resources.
• Product-object-artifacts	The decision method produces a utility score which may be used to rank order alternatives. Additionally, scores which reflect the utility by community or by the DoD M&S Vision categories can be collected as interim results.
Problem Management	
• Problem Identification	While the multi-attribute decision process recommended in section 3.9 is robust and reasonably transparent, one can see that it is sensitive to the values of the weightings given to each metric as well as those given to the first level aggregation categories (e.g. communities, DoD M&S Vision categories, etc.). Assigning weights which do not adequately reflect given or known priorities may well lead to a sub-optimal or incorrect decision. Additionally, there is risk in incorrectly measuring the metrics, especially those metrics which are subjective in nature. Incorrect measurements can also lead to a sub-optimal decision.

ACTIVITY CHARACTERISTIC	INFORMATION
• Problem Amelioration	As discussed in section 3.9, using a guided team of subject matter experts that understand and represent the view of the stakeholder greatly reduces the risk of assigning weights which do not reflect the priorities of the stakeholder. Subject matter experts may also be used to alleviate incorrect measurements for subjective data. Using a team of experienced and knowledgeable people to evaluate subjective metrics lessen the impact of any one observer and helps to ensure the measurement is as close to correct as possible.
Activity Completion	
• Exit Criteria	The Investment Decision is complete when: a) the process/method is performed on each alternative resulting in a utility score for each. b) the utility scores are ranked and the information prepared and presented to the decision maker(s)

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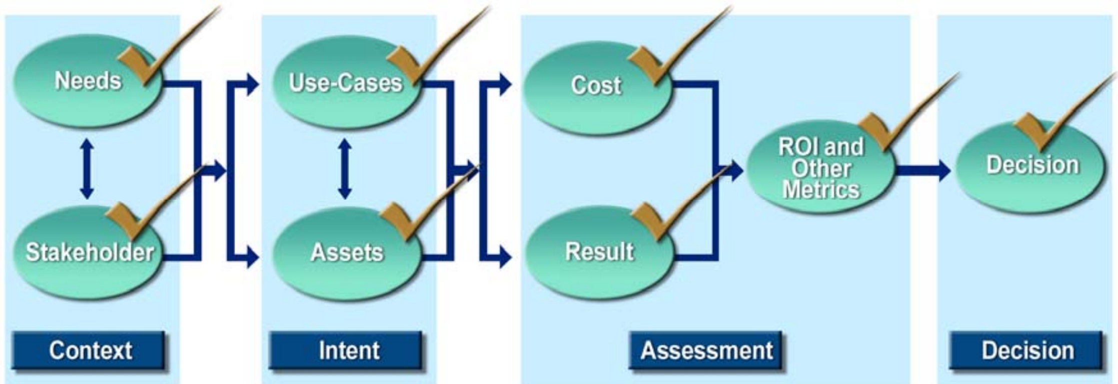
APPENDIX M - USE CASE EXEMPLARS

M.1 Use Case #1 (Alaska) Testing the Combat Benefit of a Position Determination System



I. Context

A simulation professional would like to conduct a small 4-day experiment in Alaska to test the combat benefit of a new system for position determination of friendly ground forces. The simulationist will need to evaluate alternative simulations for use in this experiment. The cadre of simulation operators, even for the most commonly used simulations, is limited in Alaska, so the simulationist must not only compare various simulations but also the need to have distribution of the simulation environment from other locations. Friendly forces could be brought into the experiment live, through a constructive simulation[109], via virtual simulation, or as a combination of all these. The position determination system may need to be simulated or assumed. Databases for Alaska are limited, particularly for semi-automated forces (SAF) simulations that require minimal operators, so databases for geography and other environmental factors may also need to be purchased with lead time. Connectivity and simulation architecture costs will have to be evaluated. The cost element structure developed in this report could be used to compare the costs of the different alternatives, estimate the cost of conducting the experiment using all live forces, and calculate cost avoidance ROI.

A. Needs and Requirements

The scenario selected for an event will affect the costs and results obtained from each of the alternatives. In this case, the simulationist develops an event scenario and force laydown to be the minimum necessary to evaluate the objectives. Here are the basic elements of the scenario:

- Three helicopter crew members acting as downed crew members evading hostile forces in rough terrain. In some trials, the crew members will use current radio and identification systems, and in other trials, the new position determination system will be used. In some cases, these crew members could be represented in a constructive simulation, yet for this event, they will be represented live.
- Hostile, mobile ground forces searching for the evading crew members. These hostile ground forces can be played entirely by live forces or, alternatively, by partly live and partly constructive simulation. A limited number of live forces will be necessary to preserve the reality of the chase.
- Friendly ground command and control forces, in this case a Combat Search and Rescue (CSAR) team from an Air Operations Center augmented with the necessary radar and radio feeds, will be used. While this group and capabilities could be represented with a constructive simulation, they will be conducted live.
- Friendly surveillance forces, in this case an Airborne Warning and Control System (AWACS) aircraft, will be use either live, virtual, or constructive to complete this role
- Friendly CSAR rescue team who will conduct the live rescue and reinsert the 3 evaders for a subsequent trial.
- Friendly combat air patrol (CAP) forces, in this case represented virtually by 3 fighter cockpit simulators.
- Other necessary command and control, surveillance, friendly and enemy forces will be assumed to be functioning as usual in constructive simulation in this event.

B. Stakeholder(s)

The stakeholders include the Commander of Alaska Command, the Program Manager for the position determination system, and the warfighting commands that require the system. While costs are shared across these stakeholders and the T&E community, an overall cost to the enterprise is used to evaluate the alternatives. The stakeholders have designated the discount rate to be 10%. The decision criteria is based on selecting the simulation alternative for this event that is the lowest cost only if the predicted cost avoidance ROI as compared to the traditional simulation support is at least 20%.

II. Intent

The simulationist, in consultation with the stakeholders, develops three alternatives to portray this scenario.

A. Use-Cases (Alternatives)

Alternative A is the traditional M&S solution used for other events in Alaska and that can be distributed to the Alaskan theater from another simulation center. This alternative uses 100 personnel at one or more locations for the simulation operators, control force, white cell, and role players. A larger number of personnel (25) will need to attend two planning conferences in Alaska. No databases will need to be developed, no training of simulation personnel in Alaska will be required, and there will be negligible residual benefit to the Alaskan simulation center. Floor space in two facilities will be required, but no other hardware or software will need to be purchased. Some distribution lines to and within Alaska will have to be reserved and leased.

Alternative B uses a SAF simulation that will reduce the personnel required to run the simulation to two people plus a back-up in Alaska. The 3 operators will double as white cell, control force, and roll players; however, they will need a two-week course on the SAF simulation at a location near Langley AFB. The SAF simulation will also need a database developed at a cost of $50K with a lead time of 60 days. The leave behind for this option is a trained cadre of 3 SAF operators that can conduct similar events using the same database on subsequent occasions. This alternative requires 2 planning conferences for 10 personnel on travel to Alaska. One new laptop with additional memory will have to be purchased, but no software will have to be purchased. Software to link the SAF simulation to the GCCS Common Operational Picture (COP) is GOTS. Distribution lines within Alaska will be reserved and leased.

Alternative C uses all live forces for the transport, rescue, humanitarian relief, and disaster recovery roles. All other secondary roles will be represented in constructive simulations due to the realities of costs and operational tempo. The use of the locator device will be simulated by downed aircrew in the same way for each alternative. Live forces will require planning conferences similar to Alternative A, and the operating cost for the live assets will be computed by using fictional cost figures, but for actual analyses, the current year POM/BES cost per hour figures would be used. Additional communications lines do not need to be rented.

B. Asset Identification

The assets being considered in the case study alternatives are traditionally-used simulations and SAF simulations with all the required hardware, software, data, distribution systems, facilities, and support personnel.

III. Assessment

The cost and results data in this use case will be notional data to illustrate use of the ROI process and is not intended to support any real-world decisions about the alternatives.

A. Cost Analysis

Since the costs for this event will be expended in the current year (even though some planning must take place many months before the event), no discounting of costs is necessary. One could extend the costs avoided into the out-years if the selected simulation environment, as developed, will generate cost avoidance or other results in future events. However, that analysis is not included in this example. Avoided costs in terms of personnel and systems will be expressed in current year costs for this comparison (to avoid appreciating and/or discounting).

Some of the data that the simulationist needs would typically come from or through management. So, whether the simulationist is directed to do the cost element analysis or decides independently to do the analysis, she will need some information on labor and per diem costs for personnel, the number of personnel needed for specific duties, systems' cost data from the BES or POM processes, infrastructure costs, and discount rate(s), if used. Some of this data can be found or calculated by the simulationist, but some or all of the data should be reviewed/approved by management so that the analysis starts with approved data. This prior review/approval reduces the likelihood that decisions will stall on the disagreement of where the data originated.

Here are the average assumed costs used for this comparison (actual, approved cost data would be used for a real-world cost element analysis):

- Travel costs are estimated at $1,500 per trip per person
- Per Diem is estimated at $200 per day per person
- Labor costs per person are estimated at 8 hours per day, 40 hours per trip, and $100 per hour fully burdened
- The cost of the operational assets are estimated at 4 hours of use per day at $20K/hour for the helicopter, $25K/hour for the ground C2, $100K/hour for the AWACS, $150K/hour total for the 3-ship of air-to-ground assets, and $200/day for the truck
- Operational assets are estimated to be used at 4 hours of per day
- Estimated 6 personnel are the ground support for the rescue helicopter
- Estimated 48 ground personnel will be deployed to support the live assets, if used, such as the AWACS and 3 air-to-ground fighters
- Planning conferences are expensed at 40 labor hours, 6 days and 6 nights
- The cost of network connectivity is $1K per hour in Alaska and $2K per hour to and from Alaska. The lines will be used 8 hours per day

- New computer purchase at $2000 per computer, with the cost for use in an event estimated at $200/event
- Facility charges are $5K per day per structure used in Alaska or used as a simulation distribution site elsewhere

These are the costs apportioned to each option for the 4-day, 4-hour/day event:

Cost Element	Alternative A – Traditional Distributed M&S	Alternative B – Semi-Automated M&S	All Live Forces
Hardware/Systems			
Computer for COP ($200.00/Event)		$200	
Truck for Hostile Forces (Same for Each)	$800	$800	$800
Helicopter for Evading Force Insert	$320,000	$320,000	$320,000
AWACS Aircraft			$1,600,000
3 Fighter Aircraft			$2,400,000
1 Control and Reporting Center			$400,000
Software			
Traditional Simulation	0	0	0
SAF Simulation	0	0	0
Networks			
In Alaska ($1K per Hour)	$1,600	$1,600	
To/From Alaska ($2K/Hour/Center)	$8,000		
Facilities ($5K per Day/Structure)			
Alaska Simulation Center	$5,000	$5,000	$5000
Simulation Building #1	$5,000		
Simulation Building #2	$5,000		
Aircrew & Ground Support Building #1	$5,000	$5,000	$5000
Aircrew & Ground Support Building #2			$5000
People (40 Hours & 6Days & Nights/Week)			
3 Evading Crewmembers	$20,100	$20,100	$20,100
6 Hostile Forces	$40,200	$40,200	$40,200
SAF Simulation Training		$40,200	
CSAR Team of 20	$134,000	$134,000	$134,000
AWACS Team of 10	$67,000	$67,000	$67,000
1 Pilot Each in 3 Fighter Sims	$20,100	$20,100	$20,100
Simulation Staff	$670,000	$20,100	
Planning Conference #1	$335,000	$67,000	$335,000
Planning Conference #2	$335,000	$67,000	$335,000
5 Rescue Helicopter Crewmembers	$33,500	$33,500	$33,500
Ground Support for Live Assets	$40,200	$40,200	$321,600
Products and Procedures			
SAF Database		$50,000	
Total Cost (Current Year)	$2,045,500	$932,000	$6,042,300

B. Result

The results of using the proven SAF simulation are lower costs, a trained resident cadre of SAF operators who can run follow-on events, a leave-behind SAF database, added realism on the COP, and much fewer personnel to support (to reduce personnel tempo). Since the SAF simulation is a proven asset that will be run in the simulation center in Alaska, it will reduce risk because of its dependability in prior uses and because of a lack of dependence on long-haul distribution from distance simulation centers. One additional result of having a leave-behind SAF database and cadre of operators is the accelerated reaction time for future needs. A simulation that is ready to support future events will be advantageous to a scenario with all live forces that requires much more planning and lead time.

C. ROI Calculations

All costs are expressed in current year dollars because the analysis was conducted over a single year. The total cost for Alternative A, which is the traditional way simulation environments are distributed to the Alaskan theater, is $2,045,000. The total cost for Alternative B, which is using the SAF simulation in Alaska, is $932,000. The total cost for Alternative C, which is using a limited selection of the assets as live forces, is $6,042,300.

The cost avoidance ROI comparing the best case (Alternative B - SAF) to the Alternative A (traditional distributed simulation) is:

$$ROI_{\text{B to A}} = (\$2,045,500 - \$932,000)/(\$932,000) = 1.19 \text{ or } 119\%.$$

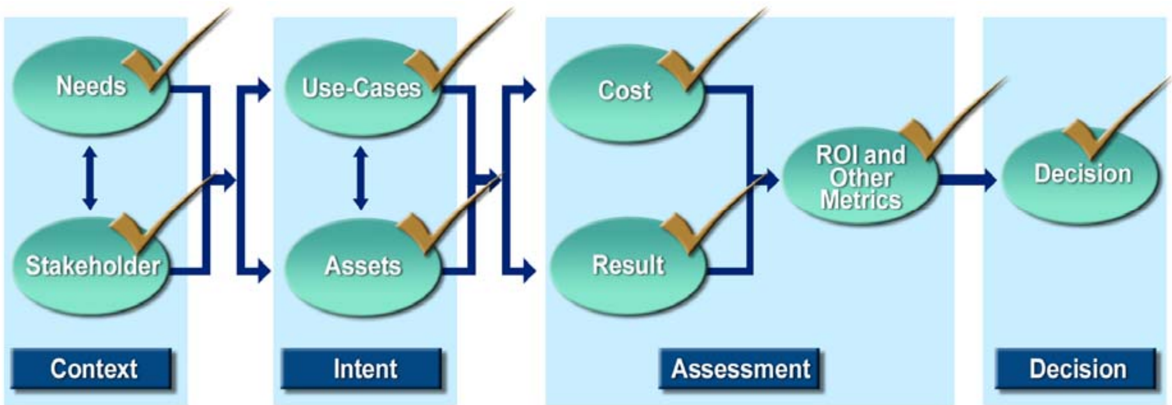
The cost avoidance ROI comparing the best case (Alternative B – SAF) to Alternative C (live forces) is:

$$ROI_{\text{B to C}} = (\$6,042,300 - \$932,000)/(\$932,000) = 5.48 \text{ or } 548\%.$$

IV. Decision

The stakeholders designated 20% as the hurdle rate for the predicted cost avoidance ROI for the best option. In other words, why switch from the traditional (comfortable) alternative for simulation support unless the new alternative is better and has an estimated cost avoidance ROI of at least 20%. Alternative B (SAF simulation) meets the decision criteria and is the best choice.

M.2 Use Case #2 Live Virtual Constructive Simulation Infrastructure Investment



I. Context

Joint Forces Command (JFCOM) is responsible for warfighter training. In order to improve training quality, JFCOM observed that constructive simulation alone was not providing sufficient training effect; and they inferred that the existence and use of a standard, seamless live-virtual-constructive (LVC) practice could significantly improve training quality. Pursuant a gap analysis, and identification of needs and requirements; an LVC study was begun. Observing that integration of LVC components within an architectural schema is difficult, and that integrating simulations across dissimilar architectures is even more difficult; attention has been focused on ways to improve interoperability within and across architectures.

This specific subject is being addressed by an ”LVCAR Study” on behalf of the DoD M&S Steering Committee. Discussions with study participants revealed that study topics include: a) technical issues related to object modeling approach and specific object model specifications, and the reconciliation of simulation federation systems engineering process via SISO’s DSEEP Distributes Simulation Engineering and Execution Process (supplanting the HLA’s FEDEP – Federation Development Process); and b) management concerns. This study may conclude that homogeneous architectures will not be achieved in the near-term, and that no new overarching M&S architectures should be attempted. Nevertheless, in order to pursue LVC technical and management initiatives, investment in simulation federation ‘middleware’ must be made.

A variety of middleware software is required to integrate components compatible with disparate simulation federation architectures (“flavors”), for instance Common Training Instrumentation Architecture (CTIA), Test and Training Enabling Architecture (TENA), and High Level Architecture (HLA). Middleware assets that are sufficient to support the requisite diversity are available; but no single middleware artifact will “do it all” for users, and these assets are provided under variable procurement, custody, and distribution business models. For instance, in order to distribute the subject LVC practice across DoD and to share it with coalition partners, the need is perceived for more flexibility in licensing, commercial versus GOTS acquisition, cost of use in federation development, and middleware bill-payer distribution and dissociation with user/benefit recipient. For instance, JFCOM uses middleware, but so might NATO; some middleware is commercial with fixed-site licenses while others are GOTS; middleware development is distributed among several commercial and government agencies with no single set of standards or guarantees of full compliance with existing standards.

Based on the prevailing circumstances, which is the preferred investment:

(a) DoD-wide licensing of commercial products, all other things being equal,
(b) Develop a fully supported certified GOTS middleware solution,
(c) Do nothing (maintain the status quo),
(d) In addition to (c), move existing government middleware code to open source, or
(e) Develop and enforce middleware standards for LVC across DoD.

A. Needs & Requirements

Performing the prescribed process on this use case we start with identifying the needs and requirements. Based upon the scenario given the need is to improve interoperability within and across LVC architectures. The requirement is to invest in simulation federation 'middleware'. The use case lists four possible investment alternatives along with maintaining the status quo (no investment), for a total of five options.

B. Stakeholders

The scenario lists the stakeholder as the DoD M&S Steering Committee (M&S SC), although Joint Forces Command (JFCOM) and the individual warfighting units stand to benefit from this investment. However, because this is an issue across all services and the M&S SC commissioned the study, we will consider the DoD M&S SC as the stakeholder and apply this process from the enterprise point of view.

II. Intent

A. Asset Identification

Since we are developing this course of action in response to a use case, we will omit that part of the process. As stated in the scenario, the investment asset type is software. In particular if we look at table 3.5.3-1, Assets Listing, we find that under the asset type software, middleware would fall in the category of "Tools (CAD/CAM)". The problem statement lists no other potential acquisitions, and thus, the software tool is the only asset of interest.

III. Assessment

[NOTE: All cost and return numbers and data are used for example only and are in no way meant to represent real values.]

A. Cost Analysis

If costs are to be used as one way to judge the efficacy of these alternatives, then some common or "standard" use pattern for LVC environments would be used in the analysis. In that way, alternatives (a) through (e) could be evaluated in terms of costs and cost avoidance in a standard pattern of use across one or more years. Why? Because maintaining the status quo would surely be the least-cost alternative for the stakeholder contemplating this decision unless they funded LVC events.

For this analysis, we assume the enterprise (DoD) funds an average of 30 major LVC events per year in the T&E, training, and experimentation areas. Across these events, with different types and levels of simulations and simulators required and with different command and control systems that link to the virtual-constructive environments, 8 different middleware assets are used. Three of these are GOTS that require some level of contractor support for modification (tailoring) for the event. The other 5 middleware solutions have a specific use cost that is paid to the owner/provider of the commercial tool. Here are the assumed average use costs and the number of annual uses for these middleware tools:

- GOTS Tool #1: $15K per use, 6 uses
- GOTS Tool #2: $5K per use, 12 uses
- GOTS Tool #3: $3.5K per use, 14 uses
- COTS Tool #1: $20K per use, 5 uses
- COTS Tool #2: $18K per use, 6 uses
- COTS Tool #3: $9K per use, 10 uses
- COTS Tool #4: $25K per use, 4 uses
- COTS Tool #5: $20K per use, 2 uses

The simulationist that is conducting this analysis also gets the estimate for licensing the commercial products for DoD's annual use:

- COTS Tool #1: $40K licensing, $8K per use, and $4K per year maintenance
- COTS Tool #2: $30K licensing, $4K per use, and $3K per year maintenance
- COTS Tool #3: $10K licensing, $2K per use, and $1K per year maintenance
- COTS Tool #4: $50K licensing, $15K per use, and no maintenance fee for 4 years
- COTS Tool #5: $40K licensing, $6K per use, and $4K per year maintenance

She then investigates the cost to develop a fully-funded certified GOTS middleware solution for DoD and support it annually. She determines that these costs are representative:

- Develop the GOTS middleware solution in year 0 at $1.2M
- Field and maintain the GOTS solution year 1 at $300K

- Maintain the GOTS solution year 2 at $250K
- Maintain the GOTS solution year 3 at $300K

For moving the existing government middleware to open source, she estimates that the government will need to pay an estimate $150K upfront and this improvement will reduce the per-use costs to:

- GOTS Tool #1: $10K per use, 6 uses
- GOTS Tool #2: $3K per use, 12 uses
- GOTS Tool #3: $2K per use, 14 uses

The simulationist determines that the establishment of middleware standards for DoD will cost $150K in year 0 for the initial meetings, staffing, and coordinating. Monitoring and maintaining the standards over the subsequent years will cost an estimated $50K per year. The existence of these DoD-wide middleware standards will reduce the estimated cost of use for several of the middleware tools and will reduce the time needed to prepare the tools for a given T&E, training, or experimentation event. Here are the estimated use costs once the standards are implemented and enforced:

- GOTS Tool #1: $15K per use, 6 uses
- GOTS Tool #2: $5K per use, 12 uses
- GOTS Tool #3: $3.5K per use, 14 uses
- COTS Tool #1: $15K per use, 5 uses
- COTS Tool #2: $10K per use, 6 uses
- COTS Tool #3: $5K per use, 10 uses
- COTS Tool #4: $20K per use, 4 uses
- COTS Tool #5: $12K per use, 2 uses

Once these use fees and other costs are calculated and the average use each year is estimated, the simulationist decides that the alternatives will be evaluated based on average costs over 3 years of use. She knows that the costs will vary by year and by options, so she decides to compute the NPV of each option in order to have a standard comparison metric. So, the expenditures and avoided costs over year 1, year 2, and year 3 will be discounted to the current year (year 0) in order to evaluate the alternatives in current-year dollars. The simulationist is told by her stakeholder that a 10% discount rate is appropriate for use in this analysis, and the stakeholder approves the cost figures estimated for all options by the simulationist.

Cost Analysis for Alternative (a): DoD-wide licensing of commercial products, all other things being equal.

Cost Factor	Year 0	Year 1	Year 2	Year 3
GOTS Tool #1		6x$15K = $90K	6x$15K = $90K	6x$15K = $90K
GOTS Tool #2		12x$5K = $60K	12x$5K = $60K	12x$5K = $60K
GOTS Tool #3		14x$3.5K = $49K	14x$3.5K = $49K	14x$3.5K = $49K
COTS Tool #1	$40K	$4K + 5x$8K = $44K	$4K + 5x$8K = $44K	$4K + 5x$8K = $44K
COTS Tool #2	$30K	$3K + 6x$4K = $27K	$3K + 6x$4K = $27K	$3K + 6x$4K = $27K
COTS Tool #3	$10K	$1K+10x$2K = $21K	$1K+10x$2K = $21K	$1K+10x$2K = $21K
COTS Tool #4	$50K	4x$15K = $60K	4x$15K = $60K	4x$15K = $60K
COTS Tool #5	$40K	$4K + 2x$6K = $16K	$4K + 2x$6K = $16K	$4K + 2x$6K = $16K
Totals	$170K	$367K	$367K	$367K
Multiplier	1.0	.90909	.82645	.751315
NPV	$1.083M			

Cost Analysis for Alternative (b): develop a fully supported certified GOTS middleware solution.

Cost Factor	Year 0	Year 1	Year 2	Year 3
GOTS Toolkit	$1.2M	$300K	$250K	$300K
Multiplier	1.0	.90909	.82645	.751315
NPV	$1.905M			

Cost Analysis for Alternative (c): Maintaining the status quo.

Cost Factor	Year 0	Year 1	Year 2	Year 3
GOTS Tool #1		6x$15K = $90K	6x$15K = $90K	6x$15K = $90K
GOTS Tool #2		12x$5K = $60K	12x$5K = $60K	12x$5K = $60K
GOTS Tool #3		14x$3.5K = $49K	14x$3.5K = $49K	14x$3.5K = $49K
COTS Tool #1		5x$20K = $100K	5x$20K = $100K	5x$20K = $100K
COTS Tool #2		6x$18K = $108K	6x$18K = $108K	6x$18K = $108K
COTS Tool #3		10x$9K = $90K	10x$9K = $90K	10x$9K = $90K
COTS Tool #4		4x$25K = $100K	4x$25K = $100K	4x$25K = $100K
COTS Tool #5		2x$20K = $40K	2x$20K = $40K	2x$20K = $40K
Totals		$637K	$637K	$637K
Multiplier	1.0	.90909	.82645	.751315
NPV	$1.584M			

Cost Analysis for Alternative (d): In addition to (c), move existing government middleware code to open source.

Cost Factor	Year 0	Year 1	Year 2	Year 3
GOTS Tool #1		6x$10K = $60K	6x$10K = $60K	6x$10K = $60K
GOTS Tool #2		12x$3K = $36K	12x$3K = $36K	12x$3K = $36K
GOTS Tool #3		14x$2K = $28K	14x$2K = $28K	14x$2K = $28K
COTS Tool #1		5x$20K = $100K	5x$20K = $100K	5x$20K = $100K
COTS Tool #2		6x$18K = $108K	6x$18K = $108K	6x$18K = $108K
COTS Tool #3		10x$9K = $90K	10x$9K = $90K	10x$9K = $90K
COTS Tool #4		4x$25K = $100K	4x$25K = $100K	4x$25K = $100K
COTS Tool #5		2x$20K = $40K	2x$20K = $40K	2x$20K = $40K
Open Source	$150K			
Totals		$562K	$562K	$562K
Multiplier	1.0	.90909	.82645	.751315
NPV	$1.548M			

Cost Analysis for Alternative (e): Develop and enforce middleware standards for LVC across DoD.

Cost Factor	Year 0	Year 1	Year 2	Year 3
GOTS Tool #1		6x$15K = $90K	6x$15K = $90K	6x$15K = $90K
GOTS Tool #2		12x$5K = $60K	12x$5K = $60K	12x$5K = $60K
GOTS Tool #3		14x$3.5K = $49K	14x$3.5K = $49K	14x$3.5K = $49K
COTS Tool #1		5x$15K = $75K	5x$15K = $75K	5x$15K = $75K
COTS Tool #2		6x$10K = $60K	6x$10K = $60K	6x$10K = $60K
COTS Tool #3		10x$5K = $50K	10x$5K = $50K	10x$5K = $50K
COTS Tool #4		4x$20K = $80K	4x$20K = $80K	4x$20K = $80K
COTS Tool #5		2x$12K = $24K	2x$12K = $24K	2x$12K = $24K
Standards	$150K	$50K	$50K	$50K
Totals	$150K	$538K	$538K	$538K
Multiplier	1.0	.90909	.82645	.751315
NPV	$1.487M			

Therefore, on the basis of total costs expressed in current year dollars, the 5 alternatives can be compared as:

Alternative:	Year 0 NPV:
(a) DoD-Wide Licensing	$1.083M
(b) DoD GOTS Middleware Solution	$1.905M
(c) Status Quo	$1.584M
(d) Status Quo Except GOTS to Open Source	$1.548M
(e) DoD Middleware Standards	$1.487M

Hence, on the basis of costs alone over the current year and the 3 subsequent years, alternative (a) for the licensing of the middleware DoD-wide is the most cost effective solution in terms of NPV.

B. Results Analysis

While one way to determine the investment is on costs only, it is more illuminating to consider the value or results received from the investment. There are two major ways to utilize results in this process. One way is to measure the results using metrics like those in section 3.7 and then monetize them so that they are in the same units as the costs. Then using one of the equations in section 3.8 we can calculate the ROI or a ROI-like quantity as discussed in section 3.9. The other way is to measure the applicable metrics and use the decision process discussed in section 3.9 of this report. This may be your only option if the results metrics cannot be monetized or cannot be monetized well. Performing both processes gives more information to the decision maker and will lead to better insight into the best investment.

ROI is discussed below with a what-if example. In this case, the stakeholder has determined that accurate monetization of all the results is not possible, and therefore, use of the MADM decision process in section 3.9 is necessary. The analyst in charge of performing this method chooses four metrics in the spirit of section 3.7 (for example purposes we have limited the number of metrics for clarity, in practice many more metrics may be desired):

i) Amount of flexibility in each option – measures how easy to distribute across the enterprise and how easy to modify each option for new protocols/formats

ii) Long term benefit/life expectancy – how long can I expect this option/solution to meet the requirement

iii) Implementation time – how soon can the solution be in place

iv) Efficiency of proposed solution – measure of perceived effectiveness of an option moving the training to the next level

[Note: it is assumed that all options will meet the *requirement*s and allow the LVC training to be successful.]

In addition to the three metrics above, the analyst sees an area of significant risk that he/she will include in the algorithm:

v) Expertise/Experience risk – which options give a greater probability of success due to the required expertise

These metrics are sent to the decision algorithm for use in computing a utility score for use in the final decision.

C. ROI Calculations

Once the results are measured (in the same units as the costs), ROI or an ROI-like measure can be computed and factored into the decision method. For example, in this scenario suppose we found a way to somehow monetize the results metrics and by converting all the results dollars to NPV we find the values in the following table.

Option	Year 0 NPV Cost	Year 0 NPV result	ROI
(a) DoD-Wide Licensing	$1.083M	$1.21M	11.73%
(b) DoD GOTS Middleware Solution	$1.905M	$2.23M	17.06%
(c) Status Quo	$1.584M	$1.76M	11.11%
(d) Status Quo Except GOTS to Open Source	$1.548M	$1.83M	18.22%
(e) DoD Middleware Standards	$1.487M	$1.68M	12.98%

ROI is calculated using the formula (Results – Cost)/Cost *100 and expressed as a percentage. See section 3.8 of the report for further discussion. Note that in terms of "bang for the buck" or getting the most for the dollars spent option (d), moving GOTS to open source is the best decision for this artificial example, even though option (a) costs the least. Therefore, it is important to consider results in your decisions.

IV. Decision

Having defined the cost and result metrics we now move to determining the utility score of each option and making the decision. As the use cases have shown there are many ways to make investment decisions, sometimes decisions are based upon the cheapest cost (the Alaskan Exercise, use case number 1), other times we use the greatest return on investment (Missile Defense Agency, use case number 3), and other times we require a measure that is more robust and may consider other measures besides cost and return.

Following the steps outlined in the Decision Process Activity matrix from Appendix M we note that it is important to determine the stakeholder and viewpoint of the decision maker. In this case we have identified the M&S SC as the stakeholder and, thus, this is an enterprise view. For this example we will assume that the stakeholder chose to frame the problem from the DoD M&S Vision statement viewpoint and this is the framework for the decision method (see figure 3.9.3.3-2). As noted above, we have defined the applicable cost and result metrics based upon the asset class of Software and the asset being tools (middleware), we now must obtain measures for the metrics. Cost measures are relatively simple as in the vast majority of the time, they are expressed in dollars or equated to dollars (for example, we can express the cost of one man-week in dollars by multiplying 40 hours by the hourly rate for that worker). Results metrics have many different ways of being measured and may be in terms of dollars (i.e. cost savings), or may be in terms of increased readiness, higher level of proficiency on a task, etc. Section 3.7 and 3.9 with applicable appendices discuss these issues and offer ideas on how to measure these types of metrics. Therefore, at this step the analyst determines how to measure the chosen metrics and by some objective or minimally subjective method he or she arrives at quantitative measurements for each cost and result metric. For this case, the analyst chose the following methods to measure the four metrics listed above.

i) Flexibility – this was measured using a linear scale with values ranging from 1 to 10. The analyst developed a rubric for evaluation of flexibility which took into account factors such as: could the option be fielded across the DoD? To coalition partners? Could the option be easily modified to include a new format from a coalition partner if necessary? This rubric was then used by 10-15 members of the project team and their scores averaged to arrive at a measurement.

ii) Long-term benefit/life-expectancy – this was measured by using the number of expected years the option would endure without significant modification or expense with the maximum years being seven. Long-term benefit was measured subjectively on a scale of 1 to 5 with 5 being the best. Guidance on the subjective measurement included issues of extendibility to other training simulation applications, whether the option could be used in a new architecture, etc. Again, this metric was evaluated by 10-15 members of the project team and their scores (based upon a high of 12) were averaged to arrive at a measurement.

iii) Implementation time – this was measured objectively using a scale of months by listing the total months given in the proposal for each option. In this case the maximum was 24 months.

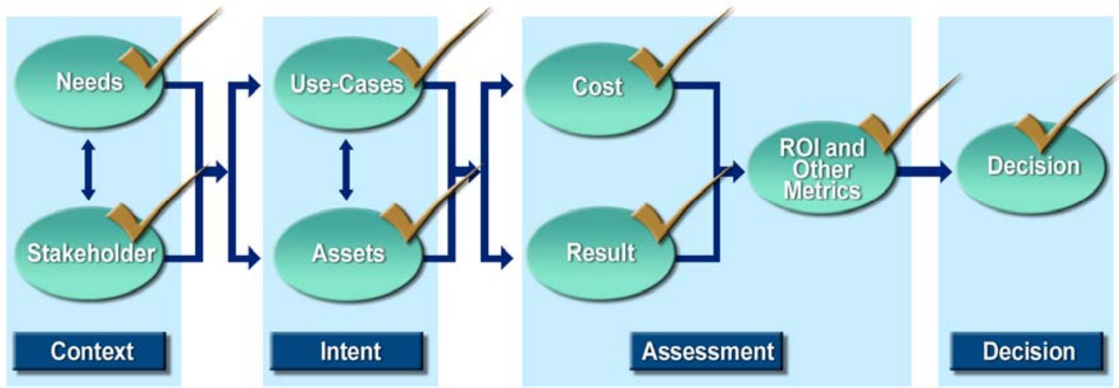
iv) Efficiency of Solution – this was measured by JFCOM training experts upon their evaluation of each proposal. They were given factors to consider that included: would the option allow an increase in the type of training scenarios? Would the option shorten the training time for certain scenarios, etc. They used a scale from 1 to 10 and then their scores were averaged to arrive at a measure.

It is at this stage where, as discussed in section 3.9, any other additional metrics besides cost and results (and risk) will be identified. For example, in this case we have five alternatives as noted in the use case. It may be that the SECDEF has put out a policy saying that he prefers COTS software solutions to GOTS because he feels the on-going maintenance and upgrades are too costly when the government performs them. Therefore, COTS software should be utilized unless there are extenuating circumstances. With that knowledge in mind the analyst would feed a metric into the utility score that would measure whether or not the solution was COTS. It would measure a 1 if it was and a 0 if not (binary measurement). There may be other metrics similar to this example that the analyst will want to consider. They will need to be identified and measured at this step.

At this point, we have quantitative measures and we have weights that were determined by a panel of SMEs for the decision method that uses DoD M&S Vision statement point of view. Each quantitative measure is normalized (divided by it's maximum possible value. For example, the flexibility metric is evaluated on a 1 to 10 scale so its measure is divided by 10 to achieve the normalized score). And an analyst now implements the algorithm. For each option listed, he/she takes the top level measures and multiplies those measures by the weights for each metric. These products are summed for each category from the M&S Vision Statement (in this example). For example, in looking at figure 3.9.3.3-2, the analyst takes the measure of each metric feeding into the "Infrastructure" category and multiplies each measure by the associated weighting. These products are summed and a utility score is calculated for "Infrastructure" category. This process is repeated for the "Policies", "Management", "Tools", and "People" categories and will result in utility scores for each area. Once this level is complete then the utility scores for each category are multiplied by the weightings for each category and those products summed to find the total utility score. As noted in section 3.9.3.5 if a measure of risk is deemed to be pertinent in this evaluation[110], its measure would be included here, multiplied by a weighting and the product added into the total utility score. In this case we do have a risk metric. To measure this risk a team of project members to include the project manager and another senior officer met and discussed each proposal. They assigned a risk value varying from 1 to 5 to each option with 1 being the highest risk and 5 being the lowest (since higher utility scores are better). Each risk score would also be normalized as well before being multiplied by its associated weight.

As mentioned above, this process is repeated for each option ((a) through (e)). The total utility scores are ranked and assuming the weightings have been assigned to reflect the relative worth of the metrics and the categories, the option with the highest utility score is the option the decision maker should choose for investment. However, occasionally, the situation occurs where two options will have reasonably close utility scores, but the costs are relatively different. If this is the case, the decision maker may wish to adopt the option with the lower utility score, but the significantly lower cost (which is an ROI-like measure as discussed in section 3.8 and 3.9). Therefore, taking the utility score, an ROI calculation like that in use case number 3 or discussed above and rendering a decision based upon both data points is most likely prudent.

M.3 Use Case #3 MDA Conceptual Modeling Investment



V. Context

The Missile Defense Agency is proceeding to implement, field, and initialize for operations the nation's only ballistic missile defense capability. The MDA Director specifically reports to the Under Secretary of Defense for Acquisition, Technology and Logistics.

Modeling and simulation is clearly and expressly critical to the MDA program and the successful operation of the evolving Ballistic Missile Defense System (BMDS). The Deputy Director of MDA recently cited that the first of his top three priorities upon assuming duties as the MDA Director is ensuring that M&S accurately reflects the physical BMDS and environments.

A. Needs & Requirements

One factor in establishing such the necessary M&S capability is the creation (and use by all enterprise constituents) of a coherent, evolving, and formally managed simulation conceptual modeling (CM) effort. This task is particularly important and difficult because BMDS is a system-of-systems enterprise, entailing the coordinated development and use of hundreds of models and simulations over the BMDS evolutionary life-cycle.

The CM effort should be based on development and use of effective technical standards and best practices by the disparate BMDS community of interest, and endorsed and provided strategic guidance at the Agency enterprise level. The significance of CM is readily apparent in other such system-of-systems programs such as the NASA Space Exploration Program and the Army's Future Combat System.

Conceptual models serve as the common basis of representation of all entities within models and simulations. They provide support for common appreciation of the mission space by dispersed and differentiated members of the MDA M&S community of practice and anchor the development and qualification of all simulation assets. Failure to conduct a comprehensive and systematic M&S conceptual modeling program virtually guarantees inconsistent simulation representations and inefficiency in system-of-system engineering and system safety assurance.

For this circumstance, what is the relative expected return on investment in CM? Predictive results will be tracked through the program and confirmed at program milestones to ensure efficient investment and results recovery.

In this case, accurate, valid M&S outputs for the BMDS are essential for national security. So models that can be examined and challenged in order to develop more accurate representations, with perhaps faster run times, are essential. An elegantly simple yet complete model can more easily be evaluated through the VV&A process, where we judge readiness to perform accurately for the purposes intended. With hundreds of models and simulations, linked differently depending on the nature of the event, it is vitally important that the current models be evaluated conceptually and that future modeling efforts incorporate CM. Through the discipline of CM, the model that will give the best outcome for the intended purpose can be chosen, and the model performance, confidence in the model, and expected resource use can be understood.

For the proposed CM effort, management is faced with two choices:

(1) Authorize an ongoing CM effort to evaluate, understand, and improve the current and new M&S support to BMDS or
(2) Continue the status quo of limited or no CM after this 3-year trial.

B. Stakeholders

The principle stakeholder is the MDA Director. In this particular example the Director falls into both the *Buyer* and *Consumer/Users* stakeholder categories. The primary concern of the Director is to be able to have consistent simulation representations and efficiency in system-of-system engineering and system safety assurance areas. He wants to look 2 years beyond the current year and evaluate the cost of the CM program versus the cost avoidance and other results of having a vibrant CM program.

Other stakeholders include the various members of the MDA M&S community of practice. They fall into the *Consumer/Users* stakeholder category. Their principle concern is having the ability to gain a common appreciation of the mission space. In this way they can better execute their functions and responsibilities.

Another set of stakeholders are the M&S asset developers. They must deliver simulation representations that meet stated requirements and support the overall MDA BMDS mission. Their principle concern is having a clear and unambiguous specification of requirements based on a common appreciation of the mission space.

VI. Intent

A. Asset Identification

In this case the M&S asset for which an investment decision is being made is falls into the category/type of *Products and Procedures* and the specific M&S asset is a BMDS Conceptual Model.

VII. Assessment

The cost and results data in this use case will be notional data to illustrate use of the ROI process and is not intended to support any decisions about BMDS.

A. Cost Analysis

The cost of hiring a trained CM industry cadre and contracting with industry for CM support is approximately:

- Year 0, $5M;
- Year 1, $4M;
- Year 2, $2M; and
- Year 3, option year.

B. Results Analysis

While the results of the CM will be tracked over the 3-year life of the program, results and cost avoidance metrics can be estimated now and tracked for accuracy as the CM program progresses. The expected results of the CM program include:

- 30% time savings for VV&A of simulations previously processed through CM
- 5% decrease in runtime for the combination of simulations that have been processed through CM
- 2% increase in accuracy of the results for simulations that have been processed through CM
- 10% reduction in downtime for simulation confederations that have been processed through CM

These estimated results are especially significant for BMDS simulation confederations that run on expensive super computer networks, require a large cadre of support personnel, help determine very expensive and critical test engagements, and train thousands of personnel.

C. ROI Calculations

The estimated cost savings through year 2 for each predicted area is:

- Year 0 – None
- Year 1
    - 5 less weeks of VV&A support by a local team of 150 professionals
    - 10 fewer hours of super computer support
    - 1 less week of planned events due to the accuracy and reduced variability of the simulation results (1600 participants)
    - 3 hours saved for 1600 participants due to less down time
- Year 2
    - 3 less weeks of VV&A support by a local team of 120 professionals
    - 6 fewer hours of super computer support
    - 4 less days of planned events due to the improvement in accuracy and the reduction in variability of the results (1590 participants)
    - 2 fewer hours of downtime saved for 1590 participants

The notional costs for these results are based on all participants being local, thus not requiring travel pay. Weeks are assumed to be 5 working days, 8 hours per day. The pay rate is assumed to be $100 per hour fully burdened. The super computer time is estimated to cost $1000 per hour. No other cost savings due to infrastructure, such as communications networks or facilities, are included in this analysis. Results such as fewer wasted test shots could be factored into the analysis, but they are not included here. More information on probabilities would have to be known and the cost avoidance would substantially overwhelm any costs for CM. The training for the estimated 50 government CM cadre is expected to last 6 weeks locally and cost $40K per person for the course; this cost is in addition to the contracted CM support. The government cadre will generally rely on the contracted effort to perform CM but they will spend 4 weeks per year supporting CM or participating in CM currency training ($5K each).

For this case example, cost avoidance is assumed to be a positive number and expenses are indicated as negative within parentheses. The discount rate approved by management is 10%.

Cost Element	Year 0	Year 1	Year 2
Industry CM Cadre	($5M)	($4M)	($2M)
Government Cadre	($2.016M)	($0.266M)	($0.266M)
Avoided VV&A Costs		$3M	$1.44M
Saved Super Computer Time		$0.01M	$0.006M
Duration of Planned Events		$6.4M	$6.36M
Less Downtime		$0.48M	$0.318M
Cost Total	($7.016M)	($4.27M)	($2.27M)
Cost Avoidance Total	0	$9.89M	$8.12M
Net Total	($7.016M)	$5.62M	$5.858M
Discount Factor	1.0	.90909	.82644
NPV	**$2.93M**		

The Cost Avoidance ROI can be estimated by:

NPV/(PV of Costs) = 2.93/12.774 = .23

Hence, the proposed CM program is estimated to cost avoid approximately $2.93M through year 2 for an ROI = 23%, and this predicted cost avoidance by category can be tracked and updated as the program progresses.

VIII. Decision

For this Use Case, it is asserted that the MDA Director has established a set of thresholds to be applied in making an investment decision based on the ROI calculations. The thresholds established are:

ROI > 12% → Invest
ROI < 12% & > 8% → Table, re-look and study some more
ROI < 8% → Do Not Invest

Given these thresholds and the analysis results of an ROI calculation of 23%, then the decision is to invest.

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APPENDIX N - ENDNOTES

[1] "Strategic Vision for DoD Modeling and Simulation", U. S. Department of Defense,

[2] H. Res. 487, In the House of Representatives, U. S., July 16, 2007. "…*Resolved,* That the House of Representatives-- …(4) recognizes modeling and simulation as a National Critical Technology; and (5) affirms the need to study the national economic impact of modeling and simulation…."

[3] Report on Department of Defense Modeling and Simulation Efforts, Office of the Director DDR&E, Washington, DC, June 2008

[4] Cuda, D. and Frieders, M. (2005). Estimating DoD Budgets for Modeling, Simulation, and Wargaming. Institute for Defense Analyses Technical Report to the Defense Modeling and Simulation Office.

[5] Cultivating Communities of Practice, Wenger, et. al. Boston, MA, 1952. "Communities of practice are groups of people who share a concern, set of problems, or a passion about a topic, and who deepen their knowledge and experience in this area by interacting on an ongoing basis."

[6] "Statement of Work For Metrics for M&S Investments", entailed by Contract NAVAIR Prime Contract Number N61339-08-C-0012

[7] "Report on Department of Defense Modeling and Simulation Efforts", Office of the Director, Defense Research and Engineering, Washington DC, June 2008.

[8] Study Approach and Methodology, Technical and Management Work Plan, CDRL A001, Metrics for M&S Investments' NAVAIR Prime Contract Number N61339-08-C-002, Date of Report: 30 May 2008.

[9] Gordon, Steven; Waite, William; Öhlund, Gunner; and Björk, Åsa. "Review and Update of Findings from Economics of Simulation Study Groups", Paper 21, NATO Modeling and Simulation Group Symposium, Warsaw, Poland, October 2005 (Paper presented at the RTO NMSG Symposium on "The Effectiveness of Modeling and Simulation – From Anecdotal to Substantive Evidence", held in Warsaw, Poland, 13-14 October 2005).

[10] *The Cost Effectiveness of Modeling and Simulation (M&S) MSG-031 Final Report - Draft*. 2008, NATO MSWG

[11] *A Road Map for Simulation Based Acquisition*. 1998, Report of the Joint Simulation Based Acquisition Task Force.

[12] Waite, W.F. and D. Smith, *SBA/SeBA - Implementing the Inevitable*. SISO Euro SIW, 1995.

[13] Hillegas, A., *Findings on the Economics of Modeling and Simulation from the DoD&E M&S Survey*. 2001.

[14] Waite, W.F., *High Level Architecture (HLA) for Simulation Based Acquisition (SBA) Systems-Engineering automation*. SISO, 1999.

[15] Oswalt, I., *Navy M&S Value Analysis: Structure, Results & Ongoing Efforts*. 2005

[16] *USAF M&S Investment Analysis*, .

[17] Dunn, W., *Economics of Models and Simulations - Army Perspective*. 1999.

[18] Weatherly, J., *Investigation into Economics of Modeling & Simulation (Navy)*. 1999

[19] Conspicuous recent efforts by the Missile Defense Agency (MDA, National Air and Space Administration (NASA), and Department of Homeland Security (DHS) are evident.

[20] Department of National Defence, Canada, The Joint Simulation and Modelling for Analysis, Requirements, Training, and Support (SMARTS) Initiative: A Vision for enabling Strategy 2020 through the application of Modelling & Simulation in DND, 15 March 2004.

[21] Waite, W.F., *Proposal for Establishment of a Technical CHAPTER within the Society for Computer Simulation (SCS) on "The Economics of Modeling and Simulation"*. 2000.
[22] Waite, W.F., *Terms of Reference (TOR) Revised for the SISO Study Group on The Economics of Simulation*. 2001.
[23] Waite, W.F., Tutorial: *Economics of M&S: Change-Agents or Martyrs for Innovation.* I/ITSEC 05, 2005, Sponsored by NTSA.
[24] Erlandson, M. and S. Gordon, *Economics of Simulation Data Compilation Work Group*. 1995.
[25] Gordon, D.S., *Review and Update of Findings From Economics of Simulation Study Groups*, B. Waite, Editor. 2005, NMSG-035/RSY-005.
[26] Nesselrode, M.C., *Developing a Repeatable and Reliable Methodology to Determine Return-on-Investment*
[27] *SimSummit*, "Final Technical Report of *SimSummit* Survey on US DoD M&S Management / Leadership", 1 August, 2007.
[28] Report on Department of Defense Modeling and Simulation Efforts", Office of the Director, Defense Research and Engineering, Washington DC, June 2008
[29] *Measuring Intangible Assets: A Price on the Priceless.* The Economist, 1999.
[30] Hubbard, D.W., *How to measure anything : finding the value of "intangibles" in business*. 2007, Hoboken, N.J.: John Wiley & Sons
[31] E.g. "A Business Case for Simulation Based Acquisition (SBA)", Session 3, Track on the Economics of Modeling and Simulation Summer Computer Simulation Conference,
July 12, 1999.
[32] Panel: "Enabler Class 9: Business Case Evidence", NDIA SBA Conference, Thursday May 17 2001.
[33] Andrew L. Vallerand, Ph.D., Head DND/CF SECO, CF Exp. Center, National Defence Headquarters (HQ), Ottawa ON K1A 0K2, "*SimSummit 03Business Case & Common M&S/SE "MATRIX"*July 2003.
[34] Guide to GAAP, Practioners Publishing, Ft. Worth, TX, 1996
[35] Marco Iansiti and Roy Levin, "Strategy as Ecology", in Harvard Business Review, March 2004.
[36] "Building a Business Case for Modeling And Simulation", C. David Brown, Ph.D., COL Gordon Grant, Canadian Forces, LTC Donald Kotchman, USA, COL Robert Reyenga, USA, and Lt Col Terence Szanto, USAF, Acquistion Review Quarterly, Fall 2000, p. 315.
[37] Ibid, p. 312
[38] This is a form of addressing complementarity of various digital capital goods, addressed under "Capital Maintenance" above (basically, to be effective, capital works w/ other capital). See Glossary.

[39] "Capital Structure Evolution: Austrian Observations on the Case of Software Development", Howard Baetjer, paper presented at the Southern Economic Association meetings, New Orleans, November 22, 1999.

[40] Implications of proposed changes in business practice within the DoD in general, and need for consideration of additional enabling practices were identified during the 6 November 2008 In-Process-Review (IPR) Briefing to the M&SCO and members of the DoD M&S Steering Committee by Ms. Amy Henninger.
[41] Wall Street Words, Houghton Mifflin Company
[42] Webster's Revised Unabridged Dictionary, MICRA, Inc.
[43] Value Measuring Methodology – How-to-Guide, CIO Council, Best Practices Committee, October 2002, http://www.cio.gov/documents/ValueMeasuring_Methodology_HowToGuide_Oct_2002.pdf, retrieved 15 August 2008

[44] Gordon, Steven C. "Determining The Value Of Simulation" Society for Modeling and Simulation International, Paper 1126, 2002, www.scs.org/getDoc.cfm?id=1126

[45] Gordon, S.C. "The Value of Training" Air Force Agency for Modeling and Simulation, 2001, Summary of Findings from the Battle of 73 Easting

[46] Gordon, Steven; Waite, William; Öhlund, Gunner; and Björk, Åsa. "Review and Update of Findings from Economics of Simulation Study Groups", Paper 21, NATO Modeling and Simulation Group Symposium, Warsaw, Poland, October 2005 (*Paper presented at the RTO NMSG Symposium on "The Effectiveness of Modeling and Simulation – From Anecdotal to Substantive Evidence", held in Warsaw, Poland, 13-14 October 2005)*

[47] M&S Cost Benefit Analysis Lists, AEgis Technology Group Incorporated, 29 September 2006.

[48] For estimating the use cost of live simulation assets, it is recommended that the estimator use current Service Budget data to allocate costs per hour of operation for assets.

[49] For estimating the personnel costs to support simulation events, it is recommended that the cost estimator use current Service Budget documents, payroll figures, and per diem tables to estimate wage and temporary duty costs, as necessary, for the event staff.

[50] Strategic Vision for DoD Modeling and Simulation, http://www.msco.mil/StrategicVision.html, retrieved 15 August 2008.

[51] Note that personnel charges may also be indicated in other areas of the M&S Asset Cost Element Structure, such as in range personnel expenses, simulation facility support personnel expenses, or in help desk staffing costs. However personnel expenses are allocated, given a particular use case and comparison, the user should ensure consistency and guard against double counting of resource needs.

[52] Defense Modeling and Simulation Office: "The Utility of M&S in the Department of Defense: Initial Data Collection, IDA," May 1996.

[53] Gordon, S.: "M&S Reuse Success Stories: Improving Economics & Effectiveness of M&S Support to Warfighting," Society for Modeling and Simulation (SCS), Interservice/Industry Training, Simulation & Education Conference (I/ITSEC), December 2006.

[54] Cost savings are the costs made obsolete and thus potentially not programmed. Cost avoidance is programmed costs that were not expended. Cost reductions are either. See Glossary of Terms for additional detail with regard to definitions.

[55] *Vectors of Navy Simulation: A Compilation of Key Trends or "A Study of Studies"* presentation and article, Spring Simulation Interoperability Workshop, April 2008.

[56] See: *Vectors of Navy Simulation: A Compilation of Key Trends or "A Study of Studies"* presentation and article, Spring Simulation Interoperability Workshop, April 2008.

[57] See: "Navy M&S Value Analysis, Structure, Results & Ongoing Efforts," Ivar Oswalt, Navy Modeling and Simulation Office (NMSO), July 2005 and "ASN(RDA) M&S Business Plan: In Progress Briefing: Draft," Bill Zimmerman, Andrew Malloy, Ivar Oswalt, Bob Tyler, Mark Nesselrode, Hans Kohnle, Draft Briefing, June 2008.

[58] See: *Characterizing Models, Simulations, and Games*, presentation and article, Inter-service/Industry Training, Simulation and Education Conference, December 2006.

[59] The CFA Institute was established in the Summer of 1947, and is arguably the foremost international, professional financial society. The "CFA Institute is the global, not-for-profit association of investment professionals that awards the CFA and CIPM designations. We promote the highest ethical standards and offer a range of educational opportunities online and around the world." (http://www.cfainstitute.org/index.html)

[60] Vol 3, G-17

[61] http://www.fasb.org/

[62] http://www.iasb.org/Home.htm

[63] As Hyman Minsky writes, "In a capitalist economy, assets are priced. The prices reflect the relation between cash flows, or quasi-rents, that capital assets are expected to earn as they are used in production and the payment commitments that have to be agreed upon in order to finance ownership." (*Can "It" Happen Again*, Minsky, p 73) This statement highlights the critical role that revenue – as referred to as "cash flows" – plays in traditional (macro and micro) financial analysis.

[64] "The return consists of the income and the capital gains relative on an investment. It is usually quoted as a percentage." (http://www.investopedia.com/terms/r/return.asp)

[65] Examples of this include Return on Equity (ROE), Return on Assets (ROA), Return on Common Equity (ROCE), Return on Invested Capital (ROIC), etc. While the specifics of how each of the aforementioned ratios is calculated – that is, while each differs in what information/numbers are included in the numerator and the denominator – all calculations such as this fit into the basic model that is herein referred to as The Second Formulation.

[66] These risks include, but are not limited to: Interest Rate, Yield Curve, Call and Repayment (for bonds), Credit, Liquidity, Currency, Purchasing Power, Sovereign, Event, and Systemic. (Vol 5, Reading 61)

[67] "… in an efficient market, the expected returns implicit in the current price of the security should reflect its risk, which means that investors who buy at these informationally efficient prices should receive a rate of return that is consistent with the perceived risk…" (Vol 5, p. 63)

[68] While it is not true that all high risk investments generate high returns, it is the case that all high returns are the result of high risk investments, in an efficient marketplace.

[69] "Money has time value in that individuals value a given amount of money more highly the earlier it is received. Therefore, a smaller amount of money now may be equivalent in value to a larger amount received at a future date. The time value of money as a topic in investment mathematics deals with equivalence relationships between cash flows with different dates." (Vol 1, p. 171-172)

[70] $NPV = \sum [CF_t / (1+r)^t] - \text{Outlay}$

Where: CF_t = cash flow at time t (usually after tax), r = discount rate

Outlay = cash required/needed (@ t=0) for project to proceed

[71] IRR: $\sum [CF_t / (1+r)^t] = \text{Outlay}$

[72] Tompkins, E. L., "Using Stakeholder Preferences in Multi-Attribute Decision Making: Elicitation and Aggregation Issues", CSERGE working paper ECM 03-13, www.uea.ac.uk/env/cserge/pub/wp/ecm/ecm_2003_13.pdf, retrieved in 2003.

[73] de Vries, M. S., *Calculated Choices in Policy Making: The Theory and Practice of Impact Assessment*, MacMillan Press, Ltd., Basingstoke, Hants, 1999.

[74] Tompkins, E. L., "Using Stakeholder Preferences in Multi-Attribute Decision Making: Elicitation and Aggregation Issues", CSERGE working paper ECM 03-13, www.uea.ac.uk/env/cserge/pub/wp/ecm/ecm_2003_13.pdf, 2003.

[75] "Report on Defense Modeling and Simulation Efforts", Office of the Director, Defense Research and Engineering, submitted to Congress June 2008

[76] Fischhoff, B., "Value Elicitation: Is There Anything in There?", *Judgement and Decision Making, An Interdisciplinary Reader*, T Connolly, H. R. Arkes, and K. R. Hammond, Cambridge Press, 2000.

[77] Ibid.

[78] Ibid

[79] Kersten, G. E., "Support for Group Decisions and Negotiations – An Overview", *Multi-Criteria Analysis*, J Climaco, Springer-Verlag, Berlin, 1997.

[80] *William F. Waite*,"HLA Federation Design / Development and Federation Implementation Process Model",SISO, SIW 1997.

[81] "The return consists of the income and the capital gains relative on an investment. It is usually quoted as a percentage." (http://www.investopedia.com/terms/r/return.asp)

[82] Examples of this include Return on Equity (ROE), Return on Assets (ROA), Return on Common Equity (ROCE), Return on Invested Capital (ROIC), etc. While the specifics of how each of the aforementioned ratios is calculated – that is, while each differs in what information/numbers are included in the numerator and the denominator – all calculations such as this fit into the basic model that is herein referred to as The Second Formulation.

[83] A virtual simulation could be someone operating an aircraft simulator, or a similar simulator with human operators, which joins the scenario and "plays" as if it is a live "actor" or participant. A constructive participant or entity is one that is completely played by a computer. Often, live participants in an event cannot tell if the entities are from virtual or constructive simulations or played by live actors if the event interactions are via electronic media, such as the common operational picture.

[84] Challenges attendant to selection by voting of alternatives subject to few simple plausibility conditions were demonstrated to yield pathological values by Kenneth Arrow in his work: ***Social Choice and Individual Values*** (1951, 2nd ed., 1963). This circumstance is believed to pertain generally to the DoD M&S Steering committee decision process. The present concern however is not with voting *per se* so much as with the generation of consensus preference functions (or, equivalently weighting parameters suggested in the M&S investment process herein.

[85] It is interesting and reassuring that "A REQUEST FOR TECHNICAL STUDIES, ANALYSES, OR CONTRACT SUPPORT" on the particular subject of: "M&S Value Determination Methodology" was submitted in previous funding cycles to the M&S Steering committee on behalf of OUSD(A&T)/SSE/DT&E/DiPetto, Many of the activities and much of the rationale and strategic approach cited in that submission are relevant to components of this subject activity. Particularly significant within that proposal are the GOAL: "This study will generate a common methodology for determining the value of M&S assets such that a rigorous and quantitative understanding of M&S asset impact can be gained and applied in developing M&S business cases and efficiently and effectively acquiring and maintaining M&S assets/capability."; IMPORTANCE: "DoD's M&S vision states that DoD M&S shall "facilitate the cost effective and efficient development and use of M&S systems and capabilities." This can only be done if the value of M&S is rigorously and consistently calculated with an approach that can be applied across all DoD M&S communities.", and BENEFICIARIES: : The entire DoD Acquisition enterprise, to include PMs of individual systems; Portfolio Managers; Joint Analysis Teams; Operational Test Agencies (OTAs), and logistics managers. In addition, the Analysis and Training communities as well as all of the Services will benefit from a clear, quantitative understanding of the value of M&S. "

[86] See www.sim-summit.org.

[87] www.simulationprofessional.org

[88] www.sim-summit.org

[89] *Digital Capital*: Embodied knowledge, in digital form, developed and captured within a computer and/or software based tool, process, or procedure, and made available as input to further production of goods and/or services. It is knowledge digitally captured, packaged, and stored, in a form ready to apply to some productive use.

[90] "Can Ideas Be Capital: Can Capital Be Anything Else?" Howard Baetjer And Peter Lewin, Working Paper 83, George Mason University, August 2007.

[91] "Software as Capital, An Economic Perspective on Software Engineering", by Howard Baetjer, Jr. IEEE Computer Society, p. 83.

[92] Ibid, p. 84.

[93] The ability of one capital asset to work with another. For software, the term is equivalent to "interoperability". See Glossary for definition.

[94] Op. Cit., Howard Baetjer And Peter Lewin.

[95] Adams, Sam S. Object-Oriented RIO: Extending CRC across the Lifecycle. *Hotline on Object-Oriented Technology 3* September, 1992, in "Software as Capital, An Economic Perspective on Software Engineering", by Howard Baetjer, Jr. IEEE Computer Society, 1998, p. 90.

[96] Op. Cit., Howard Baetjer And Peter Lewin.

[97] "Software as Capital, An Economic Perspective on Software Engineering", by Howard Baetjer, Jr. IEEE Computer Society, 1998, p. 67.

[98] Ibid, p. 66.

[99] Rules in this case are things that determine when a piece of data is categorized in a certain way. In computer terms rules appear as IF-THEN statements. An example is: If cost > value Then decision = do not invest.

[100] Englemore, R. S. and Feigenbaum, E., Japanese Technology Evaluation Center Panel on Knowledge Based Systems in Japan, found at http://www.wtec.org/loyola/kb/toc.htm , 1993.

[101] Adler, Michael, and Erio Ziglio (eds.), *Gazing into the Oracle: The Delphi Method and its Application to Social Policy and Public Health,* London: Jessica Kingsley Publishers, 1996.

[102] http://www.iit.edu/~it/delphi.html , Illinois Institute of Technology web-site, author unknown.

[103] Transparency is the property that it is easy to determine how each input impacted the final result from the method.

[104] http://en.wikipedia.org/wiki/Thomas_Saaty

[105] This Table leverages the structure and analysis reported in "An Appraisal of Modeling Tools and Methodologies for Integrated Manufacturing Information Systems", Bipin Chadha, Gintas Jazbutis, Ching-Yang Wang. Graduate Research Assistants. And Dr. R.E. Fulton, Professor, School Of Mechanical Engineering, Georgia Institute Of Technology, Atlanta, Georgia - 30332. URL: http://eislab.gatech.edu/courses/me6754/resources/1999-fulton/chapter5-3.pdf

[106] Cockburn, Alistair, Writing Effective Use Cases, Addison-Wesley, 2001

[107] **Expert Choice:** is a multi-attribute decision support software tool based on the analytic hierarchy process (AHP) methodology. It helps the decision maker examine and resolve problems involving multiple evaluation criteria. Application Areas include: Resource Allocation, Vendor Selection, Strategic Planning, HR Management, Risk Assessment, Project Management, and Benefit/Cost Analysis. - **INPRE and ComPAIRS**: These two decision support programs are early implementations of techniques based on the propagation of imprecise preference statements in hierarchical weighting. In particular, INPRE analyzes interval judgments of relative importance in the analytic hierarchy process (AHP) while ComPAIRS works with similar statements in value tree analysis. - **PRIME Decisions:** This decision analytic tool allows the decision maker to do interval-valued ratio statements in the specification of preferences. It computes value intervals and dominance structures for the alternatives, and supports several decision rules for the development of recommendations. - **HIPRE 3+:** A decision support software that integrates two decision analysis and problem solving methods: AHP and SMART - The Simple Multiattribute Rating Technique. You can run both methods independently or combine them in one model. - **HIPRE 3+ Group Link**: A group decision support software, which combines individual prioritizations given by the AHP into an interval AHP models called preferences programming model. The full group decision support system consists of HIPRE 3+ and HIPRE 3+ Group Link. - **Criterion Decision Plus:** A multi-criterion decision analysis tool that helps users manage decision-oriented data, make decisions, develop decision-making guidelines, and communicate their recommendations. The software helps elicit user

values through pair-wise comparisons, weights and tradeoffs interfaces. - **Winpre:** This decision support program is an implementation of techniques based on the propagation of imprecise preference statements in hierarchical weighting. PAIRS and Preference Programming methods are both implemented in Winpre. - **Automan:** An implementation of AHP designed to support decision about automated manufacturing investments.

[108] Examples of this include Return on Equity (ROE), Return on Assets (ROA), Return on Common Equity (ROCE), Return on Invested Capital (ROIC), etc. While the specifics of how each of the aforementioned ratios is calculated – that is, while each differs in what information/numbers are included in the numerator and the denominator – all calculations such as this fit into the basic model that is herein referred to as The Second Formulation.

[109] A virtual simulation could be someone operating an aircraft simulator, or a similar simulator with human operators, which joins the scenario and "plays" as if it is a live "actor" or participant. A constructive participant or entity is one that is completely played by a computer. Often, live participants in an event cannot tell if the entities are from virtual or constructive simulations or played by live actors if the event interactions are via electronic media, such as the common operational picture.

[110] While risk is always important to consider, it may be that all the options are thought of as equal risk and, therefore, it would not have an influence on the decision.