Copy _____

IDA PAPER P-3104

A GENERAL APPROACH TO INVESTING IN THE NEW MODELING AND SIMULATION TOOLS WITH A CASE STUDY: NAVAL MINE COUNTERMEASURES PROGRAMS

W. J. Hurley, *Project Leader*

July 1995

Prepared for
Deputy Under Secretary of Defense for Advanced Technology
and
Deputy Assistant Secretary of the Navy for Mine and Undersea Warfare

Approved for public release; distribution unlimited.

INSTITUTE FOR DEFENSE ANALYSES
1801 N. Beauregard Street, Alexandria, Virginia 22311-1772

19960320 086

DTIC QUALITY INSPECTED 1

IDA Log No. H 95-46735

DEFINITIONS

IDA publishes the following documents to report the results of its work.

Reports

Reports are the most authoritative and most carefully considered products IDA publishes. They normally embody results of major projects which (a) have a direct bearing on decisions affecting major programs, (b) address issues of significant concern to the Executive Branch, the Congress and/or the public, or (c) address issues that have significant economic implications. IDA Reports are reviewed by outside panels of experts to ensure their high quality and relevance to the problems studied, and they are released by the President of IDA.

Group Reports

Group Reports record the findings and results of IDA established working groups and panels composed of senior individuals addressing major issues which otherwise would be the subject of an IDA Report. IDA Group Reports are reviewed by the senior individuals responsible for the project and others as selected by IDA to ensure their high quality and relevance to the problems studied, and are released by the President of IDA.

Papers

Papers, also authoritative and carefully considered products of IDA, address studies that are narrower in scope than those covered in Reports. IDA Papers are reviewed to ensure that they meet the high standards expected of refereed papers in professional journals or formal Agency reports.

Documents

IDA Documents are used for the convenience of the sponsors or the analysts (a) to record substantive work done in quick reaction studies, (b) to record the proceedings of conferences and meetings, (c) to make available preliminary and tentative results of analyses, (d) to record data developed in the course of an investigation, or (e) to forward information that is essentially unanalyzed and unevaluated. The review of IDA Documents is suited to their content and intended use.

The work reported in this document was conducted under contract DASW01 94 C 0054 for the Department of Defense. The publication of this IDA document does not indicate endorsement by the Department of Defense, nor should the contents be construed as reflecting the official position of that Agency.

IDA PAPER P-3104

A GENERAL APPROACH TO INVESTING IN THE NEW MODELING AND SIMULATION TOOLS WITH A CASE STUDY: NAVAL MINE COUNTERMEASURES PROGRAMS

W. J. Hurley, *Project Leader*
B. C. McCaffree
M. M. Stahl

July 1995

Approved for public release; distribution unlimited.

INSTITUTE FOR DEFENSE ANALYSES

Contract DASW01 94 C 0054
Task T-D1-1153

PREFACE

This study was performed in support of a task done by the System Evaluation Division of IDA for the offices of the Deputy Under Secretary of Defense for Advanced Technology (DUSD(AT)) and the Deputy Assistant Secretary of the Navy for Mine and Undersea Warfare (DASN(MUW)).[1] The authors are particularly grateful to Mr. Edward Zdankiewicz (DASN(MUW)) for his guidance and support.

Throughout the course of this study the authors have benefitted from the interest, comments and suggestions of dozens of individuals who have generously shared their expertise in both mine warfare and in modeling and simulation. They would particularly like to acknowledge the assistance of RADM John D. Pearson and his staff at the Mine Warfare Command; Dr. Dale G. Uhler of the office of the Program Executive Officer for Mine Warfare; Dr. Elan Moritz and the staff of the Naval Surface Warfare Center, Dahlgren Division, Coastal Systems Station; Dr. Thomas D. Taylor and coworkers at the Center for Naval Analyses; CAPTs Joseph W. Davis and Benjamin Jaramillo of the Office of the DASN (MUW); CAPT Frank Bossio (N6C), CAPT Bruce Vanbelle (N852) and Dr. Ray Widmayer of the CNO staff; Dr. Louis C. Marquet and CDR Dennis K. McBride of the office of the DUSD(AT); Mr. Randy C. Zittel of the Defense Systems Management College; VADM Albert J. Baciocco, USN (Ret.); and Dr. J. Thomas Warfield.

The authors also express their appreciation to the many staff members at IDA who contributed numerous suggestions. In particular, the study's reviewers included Dr. David L. Randall (chairman); Dr. Marvin H. Hammond, Jr.; Dr. Alfred I. Kaufman; Dr. Peter S. Liou; and Dr. Richard E. Schwartz. Finally, the authors thank Mr. John F. Donahue for editorial assistance and Mrs. Cynthia S. Maloney for typing and preparing the paper.

---

1 "Science and Technology Thrust: Sea Control and Undersea Superiority," Contract No. DASW-01-94-C-0054, Task Order T-D1-1153, 18 April 1994.

(This page intentionally left blank)

CONTENTS

EXECUTIVE SUMMARY ES-1

BRIEFING REPORT 1

GLOSSARY 83

APPENDIXES

A. References

B. Key Questions Concerning M&S Investments

C. Overview of Naval Mine Countermeasures (MCM)

D. Application of the Approach to MCM

E. Cost for Typical Node on Defense Simulation Internet

F. Improving the Acquisition Process--Some Examples from Government and Industry

G. Value Added in Acquisition Cycle--Generic Cases and Rough Bounds

H. Approved Distribution List for IDA Paper P-3104

(This page intentionally left blank)

ABSTRACT

Recent advances in computing, networking and visualization have led to dramatic improvements in modeling and simulation (M&S) capabilities. The key issue for DoD is how to successfully convert these impressive technical developments into useful tools for addressing DoD's needs. This study proposes a general framework for deciding how to invest in the new M&S tools. The framework begins with an articulation of a key need facing the decision maker. It then repeats this process for a range of needs facing the decision maker, and, by looking for common elements and setting priorities, seeks to integrate the results across all of the needs into a single M&S plan. As a case study, this process is applied to the area of naval mine countermeasures (MCM). No detailed road map for M&S investment is given, but the issues that arise are described along with some methods that may be used to resolve them. A strawman approach to MCM M&S investments is presented. This is a "fleet first" approach which focuses initially on training, tactical development and mission rehearsal with later applications to acquisition once acceptance of the M&S tools, and confidence in them, have been established. The general framework described should be applicable to any area where the benefits and costs of the new M&S tools are under consideration.

EXECUTIVE SUMMARY

"Live" simulations of military operations are those in which the systems, operators and environment are all "real" such as in a training exercise. "Constructive" simulations are those in which the systems, operators and environment are all "synthetic", that is, modeled on a computer. "Virtual" simulations are somewhere in between. They have both real and synthetic components such as in a flight simulator which has a real operator, a synthetic aircraft, and a synthetic environment.

Traditionally, live and virtual simulations have been used by the Fleet for training, while constructive simulation has been a major tool used by the acquisition community for planning and system development.[2] Interactions between these two simulation communities have been relatively rare: predictions of constructive simulations are seldom compared to exercise results, and training simulators are seldom used for analysis in support of acquisition decisions.

Dramatic advances in computer memory, processing power, networking and visualization have now led to improved "virtual" simulations with simultaneous "man-in-the-loop" participation by many remote players and vivid graphical "immersion" into the battle scene. Meanwhile, improved computer-aided design (CAD) tools are also revolutionizing design and manufacturing capabilities. The arrival of these impressive tools onto the scene has heightened some of the long-standing issues regarding the use of modeling and simulation by DoD (such as the gap between the acquisition and training applications just mentioned) and also raised some new ones.

The central issue is, "How should DoD be investing in the new modeling and simulation tools?" On the one hand, these tools offer revolutionary advances in the simulation of military operations, and high-detail interactive representations for design and manufacture. On the other hand, in order to be useful these tools must be suited to the task at hand and faithfully represent a complex reality. These are difficult challenges that bring with them their own costs and risks. This study proposes a general approach to deciding how to invest in the new M&S tools, and applies it to a particular warfare area: naval mine countermeasures.

A. GENERAL APPROACH

First, a general "needs-driven" process is described. The process begins with a series of questions, given in Table 1, that first describes a key need, challenge or problem being faced, and then determines whether and how the new M&S tools might help. It then addresses the tools' characteristics, costs, potential value added, risks, funding and management.

Table 1. Needs-Driven Approach to Investing in M&S: Key Questions

1.	What is the need?
2.	How might new M&S tools help?
3.	What characteristics should the M&S tools have?
4.	What do the M&S tools cost?
5.	What is the value added?
6.	What are the risks?
7.	Who should fund and manage the M&S effort?

2 This association of primary users with types of simulation is not intended to be rigidly exclusive. For example, "table top" wargames that support force planning have "real" people and "synthetic" forces, so these may be classified as virtual simulations, while the Fleet uses constructive simulations for the development of tactics.

The process is then repeated for each of a series of key needs facing the decisionmaker. The final part of the process then integrates the results into a single M&S investment plan. This process is illustrated in Figure 1.

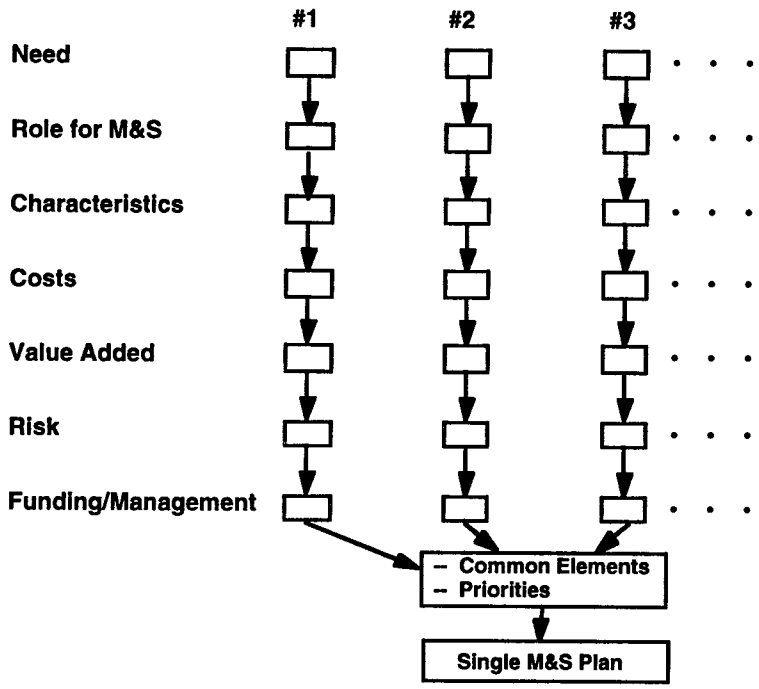


Figure 1. Needs-Driven Approach to Investing in M&S: Integration

The end result is a structured decision process that relates the M&S investment decisions back to the driving needs and identifies the expected benefits, costs, risks and implementation mechanisms. Note however that, though structured, this is not a "paint-by-the-numbers" process. The judgment of the decisionmaker is required at every stage.

B. APPLICATION TO MCM

As a case study, the general approach is applied to the (naval) MCM warfare area. This example is used to illustrate the types of issues that arise and some methods that may be used to address those issues. No detailed investment plan is presented. In the following we briefly discuss each step of the process.

1. Needs

In this step we describe the key challenges facing MCM. These are expressed independently of any M&S considerations, and are given in Table 2.

2. Roles for M&S

This step seeks to determine how the new M&S tools might be used to help address the identified needs. For example, with regard to the first need in Table 2, the ability to represent MCM systems and operations on the Defense Simulation Internet (DSI) could help to integrate the requirements and benefits of MCM forces into larger force simulations.

Table 2. Key Challenges Facing MCM

1. Integrating MCM into Navy and Joint force planning for
   - Acquisition
   - Operations
2. Tactical development and training in face of:
   - Geographical separation of MCM forces from Fleet
   - Dispersal of reserve component
3. Timely development of "right" technologies and systems to counter threat that is:
   - Rapidly changing
   - Increasingly sophisticated
   - Affordable to all potential enemies
   - Likely to be in difficult coastal environments
4. Improved understanding of environments relevant to mine warfare in littoral regions:
   - Shallow-water
   - High frequency acoustics
   - Non-acoustics (turbidity, ...)
   - Clutter

3. M&S Characteristics

Given the roles that the M&S tools could play, this step addresses the characteristics that those tools should have. First, the purpose and scope are identified. This locates the M&S tool on an "M&S Landscape" such as the one illustrated in Figure 2. The specific characteristics that fit the problem at hand are then addressed. These include such features as level of detail and whether the simulation is interactive, real-time, distributed, connected to other M&S tools, etc.

PURPOSE \ SCOPE	Joint Force	Naval Force	Force Element	Unit	System	Sub-System
ACQUISITION						
Requirement						
Concept Dev						
Design/Plan						
Build						
Test						
Support						
Cost						
OPERATIONS						
Tactical Dev/Aids						
Train						
Exercise Analysis						
Support						
Cost						
PROGRAM SUPPORT						
Planning						
Management Info						
External Comms						

Figure 2. An M&S Landscape

4. Costs

Having identified the characteristics of the M&S tools that are needed, we now ask, "What do such tools cost?" We first determine what is currently available that could be adapted to meet the requirements, and what would have to be developed. Both dollars and time are considered. For example, a minimal buy-in for a new MCM simulation facility that is Distributed Interactive Simulation (DIS)-compatible is roughly $1-3M for acquisition plus $1-3M per year for operations and support.

5. Value Added

The value added by M&S is difficult to assess since it is generally in areas such as: potential performance gain, avoiding cost or schedule overruns, risk reduction, quality, or expertise, all valuable--but hard-to-measure--commodities. Also, in any given case, the benefits of M&S may be hard to separate from the effects of other actions. However, we do suggest some possible metrics in specific areas. These fall into three general categories: "quantifiable goals", "related examples" and "rough bounds".

a. Quantifiable Goals

The first approach relates the M&S value-added to a program goal such as a system's performance requirements cost, number of defects, etc.

b. Related Examples

"Related examples" come from analogous cases where the benefits of M&S have been analyzed. For example, Reference 7 addresses the effect of physical prototyping on cost and schedule growth for a number of DoD development programs. Such results may provide insights into the expected payoffs resulting from virtual prototyping during the development of analogous systems.

c. Rough Bounds

Using "rough bounds" to estimate the potential value added by M&S starts with a "benchmark" cost such as the total program cost for an acquisition program, a system's development cost, or the cost of conducting an exercise. The M&S cost is then compared to the benchmark cost, and the expected increase in effectiveness due to M&S is compared to the relative cost increase. For example, a system such as the MCM-1 class of minesweepers with an annualized life-cycle cost of about $170M (FY-1995) need only improve performance by 1.2 percent to justify an annual investment of $2M in M&S dedicated to the program. Likewise, the percentage increase in exercise costs due to M&S may be compared to the percentage increase in training benefits, e.g., by increasing the number of participants.

Yet another example is in the area of influencing funding decisions. Here the analogy is to advertising budgets. In the commercial sector the cost of advertising is compared to the expected increase in revenues that results from the advertising. In an analogous way the cost of M&S used to support DoD investment decisions may be compared with the potential change in budget allocations as a result of the M&S efforts.

6. Risks

We discuss three types of risk associated with the use of M&S.

a. M&S Do Not Solve the Problem

The fundamental MCM challenges are cultural. New M&S tools may heighten awareness, but they must be accompanied by organizational determination. The ultimate utility of M&S will be driven by the establishment and support of the activities that M&S serve, such as:

- Consistent, Navy-wide understanding of MCM value and requirements
- Communication between the MCM community and force-level commands
- Integrated product development teams.

b. M&S Results Not General Enough

How does one relate the results of a few simulated experiences to a general decision regarding, say, the acquisition of MCM forces? An accompanying analytical process is required to help relate the insights gained to the more general issues.

c. M&S May Be Unrealistic or Misleading

The main risk associated with M&S is that the results may be unrealistic or misleading. This risk can only be addressed by maintaining a parallel, continuous verification, validation and accreditation (VV&A) program for both the models and their supporting data bases. Such a program should include:

- Assessments by experienced operators
- Comparisons to exercise results
- Applications to known cases
- Comparisons to other models
- Checks of code.

Such a program can never completely "validate" a model, that is, guarantee that it faithfully represents reality, but can provide a "degree of confidence" that should increase as experience with the model increases.

7. Funding and Management

Key elements consistent with each of the needs of MCM M&S have either started or are under consideration. These include activities within the MCM community as well as overarching Navy and DoD organizations. However, programmed funding has not followed suit. M&S investments are long-term investments and cultural acceptance of M&S at all levels will be required for success.

8. Common Elements Across MCM Needs

When the above process is applied to the four MCM needs, three common themes emerge.

a. Focus on Operational M&S

"Structural" M&S tools, such as Computer Aided Design (CAD) systems, only affect the design and manufacturing phases in a single area, Technology and

System Development, and even in that case it is uncertain whether commercial or government initiatives should take precedence. Clearly these M&S tools should be applied to the acquisition process, but Navy development of them did not emerge as a priority in this example. On the other hand, the simulation of operations affects all areas, and its development will only be achieved by the MCM community.

b. Establish Linkages

The second common theme is the need for linkages: linkages between MCM and higher levels in support of planning processes for both operations and acquisition, and linkages within the MCM force for tactics, training, mission rehearsal, exercises, system requirements, concept development and testing.

c. Environmental Support

The third common theme is the need to support the range of M&S tools with environmental models and data bases that reflect new-world scenarios.

9. Strawman Program

The results of the process described in Figure 1 are now brought together into an integrated (strawman) MCM M&S program as outlined in Table 3.

The key element of the strawman program is the development of a Distributed Interactive Simulation (DIS)-compatible representation of MCM systems and operations. Such a capability would provide linkage to higher level simulations when they become available; linkage within the MCM force to improve coordination, tactics, training and mission rehearsal capabilities; the ability to extend and enhance the value of exercises by linking live and virtual systems; a communications vehicle for developers and users to use throughout the acquisition process; and linkage to remote environmental data bases and models.

Table 3. Strawman MCM M&S Program

1. Develop facilities that are DIS-compatible, and representations of MCM systems and operations
2. Make M&S facilities available to following communities:
   - Operators
   - Training
   - TAC D&E
   - CINCs and CINC Staff
   - R&D
   - Acquisition
   - Industry
3. Develop supporting environmental:
   - Data Bases
   - Models
   - Linkages to M&S Facilities
4. Establish dedicated management and funding for M&S
5. Emphasize commercial development of "structural" M&S tools such as CAD systems

The locations of the M&S facilities would depend upon the total available resources, priorities for applications, and the traditional roles of the installations involved.

With regard to "structural" M&S tools such as CAD systems, this approach would emphasize commercial development and resort to government development only in special cases.

10. Focusing M&S Development

One approach to M&S development is to focus initially on the Fleet for training, tactical development, exercise support and mission rehearsal. This would take direct advantage of the unique features of the new M&S tools:

- Man-in-the loop
- Blue/Red dynamics
- Effects of C3I
- "Immersion" via graphics
- Remote linking

and the value of interactive simulation for training is already well-established. This approach would keep operators intimately involved, thereby assuring that the applications would be practical, needs-driven, and rooted in "real" data. It would also provide a critical "hands-on" VV&A process during the early stages of development. Later, as M&S tools mature and confidence is gained, M&S applications could be extended into the system development and force planning arenas. After all, the sole value of M&S is its ability to faithfully represent real operations. Therefore it may be best to establish credibility with Fleet applications before applying these techniques to the acquisition process.

11. Summary - MCM M&S

In summary, the new M&S tools can support needed linkages: between MCM and larger forces, within the MCM force, and between the MCM force and its acquisition community. The key elements are the developments of DIS-compatible facilities, supporting MCM software, and environmental data bases. Progress in all of these areas has been made but success will depend upon: support from the top, cultural acceptance of M&S at all levels, a well-defined M&S management structure, and dedicated M&S funding.

We suggest a "Fleet first" approach to M&S investments focusing initially on training, tactical development and mission rehearsal with later applications to acquisition once acceptance of the M&S tools, and confidence in them, have been established.

C. DISCUSSION OF GENERAL ISSUES

We offer the following general points based on our review of the literature and on our discussions with individuals involved in M&S issues.

1. New M&S Tools Are Here to Stay

It's not whether they will be used, but where and how.

2. M&S Capabilities Are Lagging M&S Technologies

The ability to transform the new technological advances into useful applications represents a distinct challenge. The gulf between demonstration and application

is wide and may require new technological or methodological advances to bridge. It is critical that this fact be recognized and addressed.

3. Developing Effective M&S Capabilities Takes Time and Money

Quick fixes may work for demonstrations, but useful applications require a long-term effort. The decision maker must stay involved to maintain relevance to the motivating issues. A parallel VV&A process is essential.

4. M&S Are Only Tools

M&S serve an underlying process that must itself be supported. The user must want to use them, and therefore the choice of M&S must be driven by the user's needs.

5. Usage of M&S in the Acquisition Process

Simulations can provide a limited amount of experience, whereas an acquisition decision maker must generally address a wide range of potential situations and environments in an uncertain future. For example, the experience gained through fleet exercises or the use of training simulators has not generally been used as a dominant basis for acquisition decisions. Rather, other analytical tools (generally "constructive" ones) have been used because they more directly address the influence of broad features (such as system characteristics or the environment) on performance. The emergence of the new simulation tools still leaves us with this challenge. How does one relate the limited experience gained through a simulated experience to the general problems faced by an acquisition decision maker? There still must be an analytical process that focuses on the broad needs of the decision maker while benefitting from the lessons learned through simulation. However, the methodological tools for bridging this gap are generally undeveloped. If the new simulation tools are going to successfully contribute to the acquisition decision process, the nature of this gap must be appreciated and ways of bridging it developed. It is the difference between having a set of tools and having the know-how to apply them to a given problem.

The new M&S tools may not be for everyone. Some programs may have, by nature, limited or isolated needs that may be satisfied by traditional M&S tools. Some may have reached a point in their development where "going back and doing M&S" would be counterproductive. Other programs may be so tentative that the impact of M&S requirements on funds and schedule could jeopardize the program itself. In any case, to be successful, M&S must be desired by the user as a tool for solving the user's problems. Rather than broad, blanket requirements, one might consider focusing M&S resources on selected user-driven applications.

6. High Level of Detail Does Not Equal "High Fidelity"

Precision does not equal accuracy. High level of detail generally increases costs and is not necessarily a

measure of progress. The "right" balance between level of detail and cost will depend upon the problem at hand.

7. Number of Nodes and 3-D versus 2-D Graphics

Early M&S developments were driven by Army requirements which tend to stress the coordination of many elements and have a "heads-up", visual emphasis. Many Navy applications, on the other hand, are composed of fewer elements and have a "heads-down", sensor emphasis. It may be sufficient (and easier) for some Navy M&S applications to emphasize, at least initially, fewer nodes and 2-D plots that can be directly related to existing C^4I systems and tactical decision aids.

8. Software Ownership

With regard to both the commercial sector and government laboratories there is a tension between the need to encourage the development of software, yet make the results widely available. Software "ownership" may lead to parallel, redundant or incompatible systems. DoD must reach a compromise position where DoD-developed software is available to all DoD users, but the developing organization realizes sufficient benefits from its products.

9. "Multi-Use" M&S Tools

Extending the range of applicability of any particular M&S tool is certainly desirable. However, applications of M&S tools beyond their original purposes should be carefully scrutinized. The use of CAD representations for vulnerability testing is appealing but the requirements for design and those for testing may be quite different. The CAD system may capture the location of an interior structure but vulnerability testing must also address its response to various physical and chemical affronts. This response is generally well beyond the capabilities of a CAD representation.

10. "Structural" M&S Tools

Structural M&S tools (for example, CAD systems) are naturally evolving into system acquisition programs. Progress in this area is being driven by commercial interests, and the services seem to have different approaches concerning industry or government development. Decisions concerning government initiatives must be made on a case-by-case basis.

11. Interoperability

There have probably been a large number of less-than-fruitful discussions regarding the requirement that a given M&S tool be "interoperable". This is due to the wide range of degrees to which two simulations can "interoperate". On the high end, Simulations A and B may exchange large amounts of data every time step, with each action of A dependent upon the input from B and vice versa. On the low end, Simulation A may be a specialized off-line tool (such as a CAD representation) that performs detailed

calculations and responds to B with limited parametric input only when queried. In both cases one may say that A and B are "interoperable".

The degree to which any given M&S tool is interoperable with any other tool is a cost-benefit decision which, like other characteristics of M&S tools, should be driven by the user's needs.

D. SUMMARY

In summary, we propose a general needs-driven approach to investing in the new M&S tools, and apply it to the case of MCM. We do not give a detailed roadmap for MCM M&S investments, but do suggest some general directions. The decisions faced within the framework are still not easy ones, but the process does seem to lead us to the relevant issues, and it should be applicable to any area where the benefits and costs of the new M&S tools are under consideration.

(This page intentionally left blank)

BRIEFING REPORT

A GENERAL APPROACH TO INVESTING IN THE NEW MODELING AND SIMULATION TOOLS WITH A CASE STUDY: NAVAL MINE COUNTERMEASURES PROGRAMS

William J. Hurley

RADM Burnham C. McCaffree, USN (Ret.)

Marchelle M. Stahl

July 1995

Here is the outline for the briefing. First we review the background, approach and objectives of the task and sketch the overarching "vision" held out by the new modeling and simulation (M&S) tools. We then propose a needs-driven approach to investing in these tools and, as a case study, apply the approach to the example of naval mine countermeasures (MCM) programs. Finally we discuss the results both with regard to MCM M&S and to M&S investments in general.

OUTLINE

- BACKGROUND, APPROACH, OBJECTIVE
- M&S "VISION"
- PROPOSED NEEDS-DRIVEN APPROACH TO INVESTING IN THE NEW M&S TOOLS
- APPLICATION TO MCM
- RESULTS AND COMMENTS

Although modeling and simulation (M&S) of military operations have been important tools for decades, new technologies in the areas of memory capacity, processing power, networking and visualization have made revolutionary advances in M&S possible. These advances are of two types: improved versions of traditional M&S tools and the creation of totally new capabilities.

By "traditional" M&S tools we generally mean stand-alone analytical models and simulations that are hands-off during a run and that communicate their results abstractly. We also include table-top wargames among traditional tools.

We see in our desktop computers the kind of advances that have also improved traditional M&S tools: increased level-of-detail and complexity, faster execution, networking with other models and data bases, and improved graphical interfaces.

But, in addition to improving the traditional tools, the new technologies also provide strikingly new M&S capabilities. First, the effects of man-in-the-loop can be explored thanks to real-time processing power and vivid man/machine interfaces. In traditional M&S the human element could only be treated through crudely estimated parameters. Now that critical facet of military operations can be explored directly.

Likewise, combat operations are dynamic complexes of actions and counter-actions which can only be crudely approximated by the traditional tools. The new interactive tools have the potential of capturing these dynamic features.

Coordination and the value of C3I assets are also critical facets of combat operations that are very difficult to represent using traditional analytical models. Here too, the new tools can explore many-person effects using distributed, interactive simulation.

Finally, new graphics capabilities have the potential of immersing the warfighter (or analyst) into the combat environment. This can greatly facilitate one's understanding of the complexities of the operation as well as provide vivid access to the simulated world.

There has been a lot of recent activity in the M&S areas, a lot of impressive demos and videos, and a lot of hype. Billions of dollars are allocated in the DoD budget for M&S. The basic issue is stated here.

BACKGROUND

- NEW COMPUTER TECHNOLOGIES IN AREAS OF:
  - Memory capacity
  - Processing power
  - Networking
  - Visualization
- HAVE LED TO TWO TYPES OF ADVANCES IN M&S:
  1. Evolutionary Improvements in Traditional Tools
  2. Revolutionary Capabilities:
     - Effects of man-in-the-loop
     - Blue/Red dynamics
     - Many-player effects (e.g., C^3I & IW)
     - Remote linking
     - Vivid communication of results ("immersion")
- LOTS OF ACTIVITY
  - Impressive demonstrations
  - Hype
- LOTS OF FUNDS: $Bs in DoD
- BASIC ISSUE:
  - How should DoD be investing in this area?

Accordingly, there have been a number of efforts addressing these issues from various perspectives. Some of these are listed here. See Appendix A for complete references. The current study examines these issues from the viewpoint of a particular warfare area--naval mine countermeasures (MCM) programs.

BACKGROUND (Cont'd.)

- **LOTS OF RECENT WORK ON THIS ISSUE**

  SOME EXAMPLES:

  - DoD Directive 5000.59, DepSecDef, Jan 1994, (EXCIMS & DMSO)
  - Creation of Service M&S Management Offices
  - SECNAVINST 5200.38, *DoN M&S Program*, Oct 1994
  - DoD 5000.59-P, *Modeling and Simulation Master Plan*, USD(A&T), Draft, Jan 1995
  - *Defense Technology Plan*, DDR&E, Sep 1994
  - *Final Report of the Acquisition Task Force on Modeling and Simulation*, Jun 1994
  - *Modeling and Simulation*, Report by Naval Research Advisory Committee, Sep 1994
  - *System Acquisition Manager's Guide for the Use of Models and Simulations*, Defense Systems Management College, Sep 1994
  - *The Role of Distributed Simulation in Defense Acquisition*, IDA, Nov 1993

In general there are two basic approaches to applying M&S tools. The first approach, and the one that seems most prevalent, is to let the simulation technology drive the development of new M&S tools, and then look around for potential applications. This is the "technology push" approach--tools in search of problems.

The other approach--requirements pull--focuses on the problems being faced in a given area and asks whether the new M&S tools might help, that is, problems in search of tools.

In practice, of course, any particular application will involve a combination of these two approaches. However, in this study we examine the potential of the new M&S tools from the perspective of the user, that is, we take the requirements pull approach.

APPROACH

- TWO GENERAL TYPES OF APPROACHES:
  - Technology-push
    - » Tools in search of problems
  - Requirements-pull
    - » Problems in search of tools
- THIS STUDY TAKES THE REQUIREMENTS-PULL APPROACH

The objectives are stated here. Note that the emphasis is on the process of identifying key M&S tools. Although we will arrive at some strawman suggestions for such investments in the MCM area, our main purpose is to describe a framework for reaching such decisions rather than their specific content. For this reason, we try to keep the discussion general enough to be applicable to other areas as well.

OBJECTIVES

- PROPOSE A GENERAL NEEDS-DRIVEN APPROACH TO INVESTING IN THE NEW M&S TOOLS
- APPLY PROCESS TO SPECIAL CASE: MCM

We now turn to a brief discussion of the "vision" held out by the new M&S tools.

OUTLINE

- BACKGROUND, APPROACH, OBJECTIVE
- M&S "VISION"
- PROPOSED NEEDS-DRIVEN APPROACH TO INVESTING IN THE NEW M&S TOOLS
- APPLICATION TO MCM
- RESULTS AND COMMENTS

The "grand vision" for M&S is to construct an electronic "parallel universe." In this universe one can conduct virtual military operations that immerse operators into synthetic environments with virtual (or real) systems. In this way warfighters can train, develop tactics, plan and rehearse missions, analyze exercises and augment them with virtual systems.

In support of the acquisition process, virtual operational "experience" can help establish requirements for system development, provide a test bed for new ideas, and demonstrate the utility of a given system to those who are asked to support it.

In addition to the simulation of military operations that we have been discussing, the new M&S capabilities also provide improved "structural" simulations such as computer-aided design (CAD) systems that hold the promise of improving the responsiveness and efficiency of the design, manufacturing and testing phases of the acquisition process.

For the official DoD version of the M&S vision, see Reference 2 in Appendix A.

However, the down side of M&S is that, although, as is often heard, moving electrons may indeed be cheaper than bending metal, telling electrons where to go is not cheap. Therefore, one has to decide which elements of this parallel universe to construct, and how these elements should interact with the real universe and with other analytical tools relevant to the issues at hand.

GRAND VISION FOR M&S

- ELECTRONIC "PARALLEL UNIVERSE":
  - Virtual operations
    - » Training
    - » Tactics
    - » Planning
    - » Rehearsal
    - » Augment exercises
  - Virtual Acquisition
    - » Requirements
    - » Concept Development
    - » Program support
    - » Design
    - » Build
    - » Test
- HOWEVER,
  - Although "moving electrons is cheaper than bending metal,"
  - Telling electrons where to go is <u>not</u> cheap
- MUST DECIDE:
  - Which elements of parallel universe to construct, and
  - How to interact with:
    - » Real universe
    - » Other analytical tools

The table illustrates a general classification of simulations that is often used. The operators, systems and environment may each be either real or synthetic, where "synthetic" generally means that it is represented on a computer. A "live" simulation is one in which all of the elements are real such as in an exercise. A "constructive" simulation is one in which all of the elements are synthetic, as in a computer-based warfare model. And a "virtual" simulation has a mixture of real and synthetic elements such as in a flight simulator (real operator, synthetic aircraft, synthetic environment) or in a "hardware-in-the-loop" system (synthetic operator, real system, synthetic environment).

In general, a simulation may be a combination of the types described in the table. For example, a live exercise (real simulation) may be augmented by real operators operating synthetic systems (virtual simulation) against an automated opposing force (constructive simulation).

The new M&S tools emphasize virtual types of simulation. As described earlier, they stress "man-in-the-loop" operations of synthetic forces in a synthetic combat environment.

Turning to the second bullet, it is also important to distinguish what we call operational simulations from structural ones. Operational simulations simulate operations and performance (e.g., as does a manned simulator), whereas structural simulations represent a system's structure (e.g., as in a computer-aided design (CAD) system). As we will discuss later, these types are very different and lessons learned with one type may or may not be relevant to the other.

TYPES OF SIMULATION

- REAL (R) vs. SYNTHETIC (S) ELEMENTS:

	OPERATORS	SYSTEMS	ENVIRONMENT
LIVE	R	R	R
CONSTRUCTIVE	S	S	S
VIRTUAL	MIXTURE OF R AND S		

  - Generally have combinations
  - New M&S tools emphasize virtual

- OPERATIONAL vs. STRUCTURAL
  - Operational: e.g., manned simulator
  - Structural: e.g., computer-aided design (CAD)

For example, in order to help distinguish between the various types of M&S tools, we have found it useful to think in terms of an "M&S Landscape" as described here. The coordinates of the landscape are the level of aggregation of the system of interest (along the top) and, (on the vertical) the purpose for which the M&S tool is being used. In this way we can place specific M&S tools on the map to help establish their distinguishing characteristics as well as their interrelationships. We will discuss an example of this later.

AN M&S LANDSCAPE

SCOPE

PURPOSE	JOINT FORCE	NAVAL FORCE	FORCE ELEMENT	UNIT	SYSTEM	SUB-SYSTEM
ACQUISITION						
Requirement						
Concept Dev						
Design/Plan						
Build						
Test						
Support						
Cost						
OPERATIONS						
Tactical Dev/Aids						
Train						
Exercise Analysis						
Support						
Cost						
PROGRAM SUPPORT						
Planning						
Management Info						
External Comms						

We now turn to the proposed needs-driven approach to investing in M&S.

OUTLINE

- BACKGROUND, APPROACH, OBJECTIVE
- M&S "VISION"
- → PROPOSED NEEDS-DRIVEN APPROACH TO INVESTING IN THE NEW M&S TOOLS
- APPLICATION TO MCM
- RESULTS AND COMMENTS

It is a two-part approach. The first part, shown here, is a series of questions that begins with a description of a key need or challenge being faced by a decision maker independent of any M&S considerations. It then goes on to determine how the new M&S tools might help, and addresses the tools' characteristics, costs, potential value added, risks and, finally, their funding and management.

Appendix B explores these questions in more detail and presents secondary questions that can help answer the primary ones.

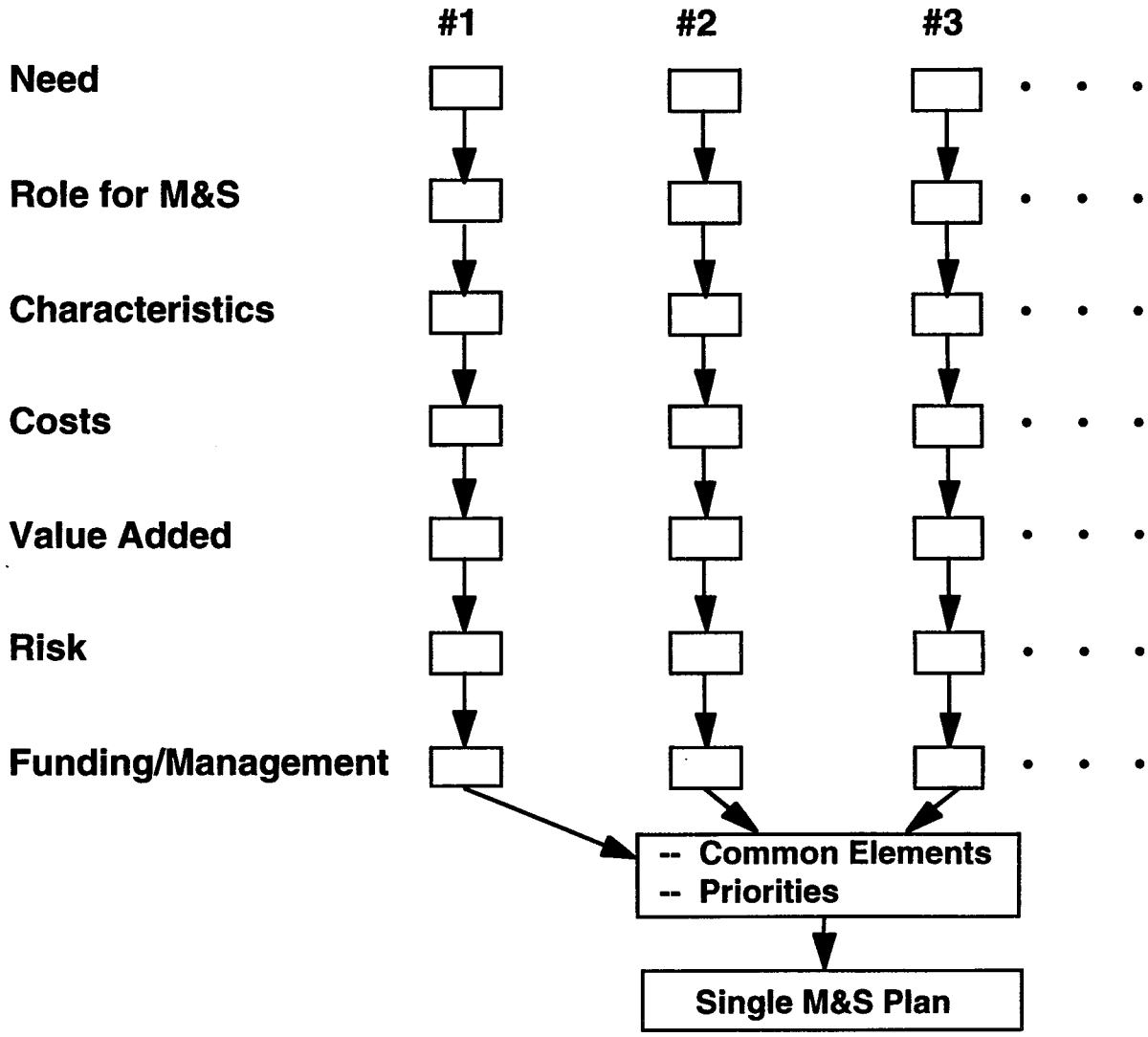
NEEDS-DRIVEN APPROACH TO INVESTING IN M&S: KEY QUESTIONS

1. What is the need?
2. How might new M&S tools help?
3. What characteristics should the M&S tools have?
4. What do the M&S tools cost?
5. What is the value added?
6. What are the risks?
7. Who should fund and manage the M&S effort?

The second part of the approach, illustrated here, involves repeating the first part for each of a series of key needs facing the decisionmaker, and then integrating the results into a single M&S investment plan. The end result is a structured decision process that relates the M&S investment decisions back to the driving needs and that identifies the expectations, costs, risks and implementation mechanisms.

Note however that, though structured, this is still not an easy, "paint-by-the-numbers" process. The judgment of the decisionmaker is required at every stage.

NEEDS-DRIVEN APPROACH TO INVESTING IN M&S: INTEGRATION



We now turn to the application of the proposed approach to the case of naval mine countermeasures.

OUTLINE

- BACKGROUND, APPROACH, OBJECTIVE
- M&S "VISION"
- PROPOSED NEEDS-DRIVEN APPROACH TO INVESTING IN THE NEW M&S TOOLS
- → APPLICATION TO MCM
- RESULTS AND COMMENTS

A brief overview of MCM is given in Appendix C. See, for example, References (17 and 18) for further details.

The process that we have just described is summarized here in the first three bullets. We note that we use notional, rather than official, statements to explore and illustrate the process. Also, in many cases illustrative methods or directions are suggested without pursuing these in detail. Finally, we do not attempt to determine a detailed investment roadmap for MCM M&S, but only to illustrate a process that might be used to arrive at such a roadmap.

The first step is to articulate the key needs or challenges. We attempt this for the MCM warfare area on the next viewgraph.

CASE STUDY: MCM

PROCESS:

- LIST KEY NEEDS/CHALLENGES FACING MCM
- FOR EACH NEED, ADDRESS KEY QUESTIONS CONCERNING M&S INVESTMENTS
- INTEGRATE FINDINGS ACROSS NEEDS TO GET SINGLE M&S PLAN

NOTE:

- NOTIONAL (VICE OFFICIAL) STATEMENTS TO EXPLORE <u>PROCESS</u>
- ILLUSTRATIVE METHODS AND RESULTS
- GENERAL DIRECTIONS, NOT DETAILED ROADMAP

Here is a proposed list of the key challenges facing the MCM warfare area. We identify four general types.

First, and foremost, is the fundamental challenge that has long faced mine warfare: isolation from mainline Navy planning either for acquisition or operations. The Desert Storm experience underscored the interdependence of an MCM force and other elements of a joint force in a littoral warfare environment. To be effective, naval forces need effective MCM. To be effective, MCM forces need surveillance/reconnaissance, counterstrike, C^3I, logistical support and defense by elements of the larger force.

The challenge is to consistently integrate MCM's value and requirements into Navy thinking.

The second challenge is in the areas of tactical development and training. Most of the MCM force is based on the Texas Gulf coast, far from the rest of the Fleet. This adds to the difficulty in integrating MCM into Navy exercises and tactical development at a time when the need for such integration has been vividly demonstrated by the Gulf War experience.

In addition, the MCM force has a large, dispersed, reserve component which further challenges the ability to train for coordinated operations.

The third area is motivated by threat mines that are rapidly changing, increasingly sophisticated, yet cheap enough to be available to literally all potential enemies. In addition, littoral warfare emphasizes shallow coastal areas, the surf zone and ashore--all offering extreme technical challenges to MCM.

In the face of this technical challenge, MCM technology and system development must advance quickly and efficiently. A consistent, disciplined approach must be taken to succeed in getting the "right" systems into the Fleet in a timely manner.

The last key challenge follows from the change in emphasis from the Cold-War, deep-water, submarine-warfare environment to the littoral-warfare, shallow-water, mine-warfare environment. That change in emphasis has heightened the need for a better understanding of both acoustic and nonacoustic phenomena in shallow-water areas, including the effects of surf, bottom interactions, clutter, etc.

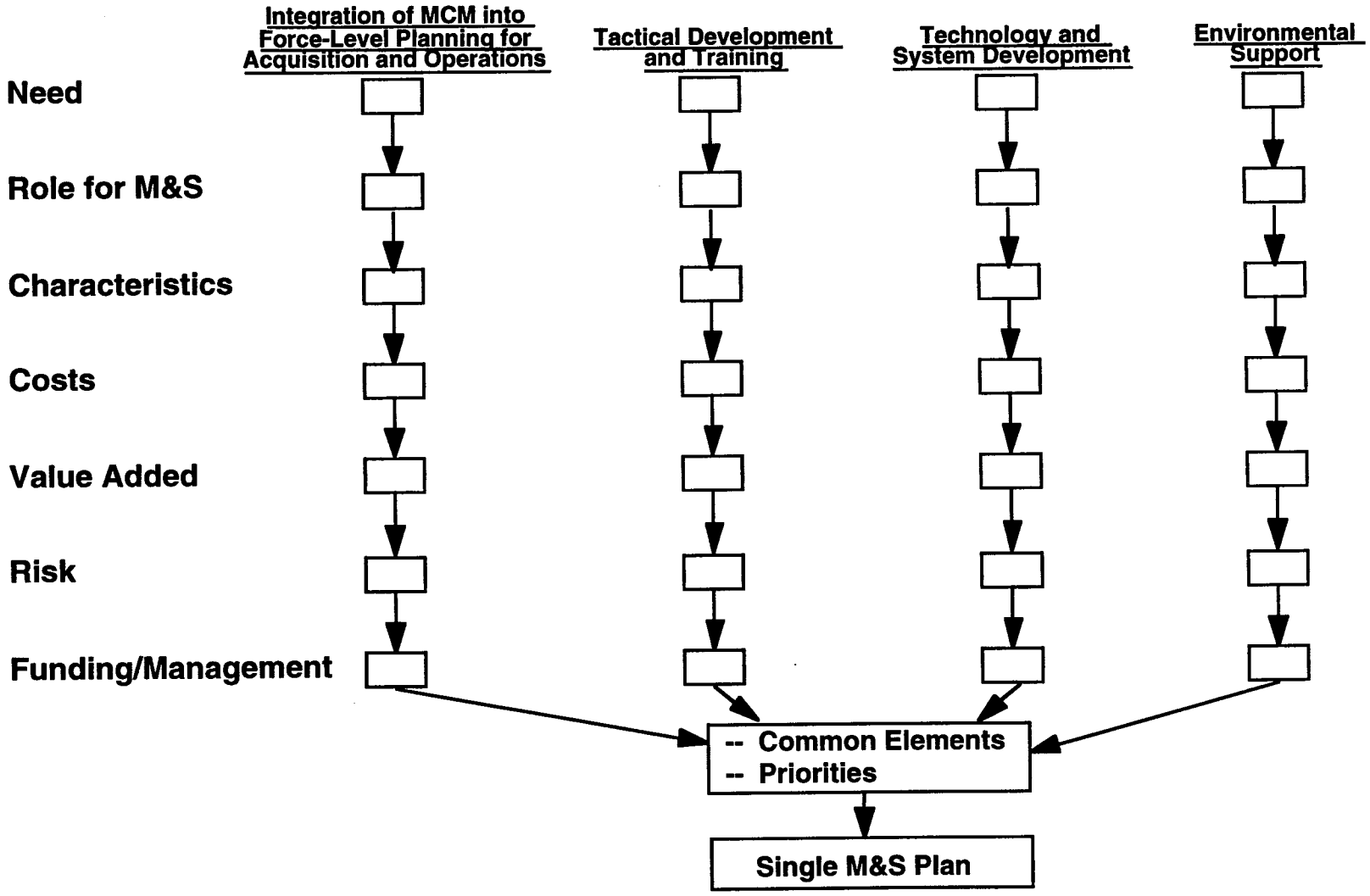
KEY CHALLENGES FACING MCM

1. Integrating MCM into higher level force planning for:
   - Acquisition
   - Operations
2. Tactical development and training in face of:
   - Geographical separation of MCM forces from Fleet
   - Dispersal of reserve component
3. Timely development of "right" technologies and systems to counter threat that is:
   - Rapidly changing
   - Increasingly sophisticated
   - Affordable to all potential enemies
   - Likely to be in difficult coastal environments
4. Improved understanding of environments relevant to mine warfare in littoral regions
   - Shallow water
   - High frequency acoustics
   - Non-acoustics (turbidity, ...)
   - Clutter

We now take these four problem areas and, for each one separately, go through the proposed process for M&S planning. This is illustrated in this viewgraph where we have listed the problem areas along the top and the key questions of the process vertically. After going through the questions independently for each area we look for common elements, priorities, etc. across the different areas in order to integrate the results into a single MCM M&S plan.

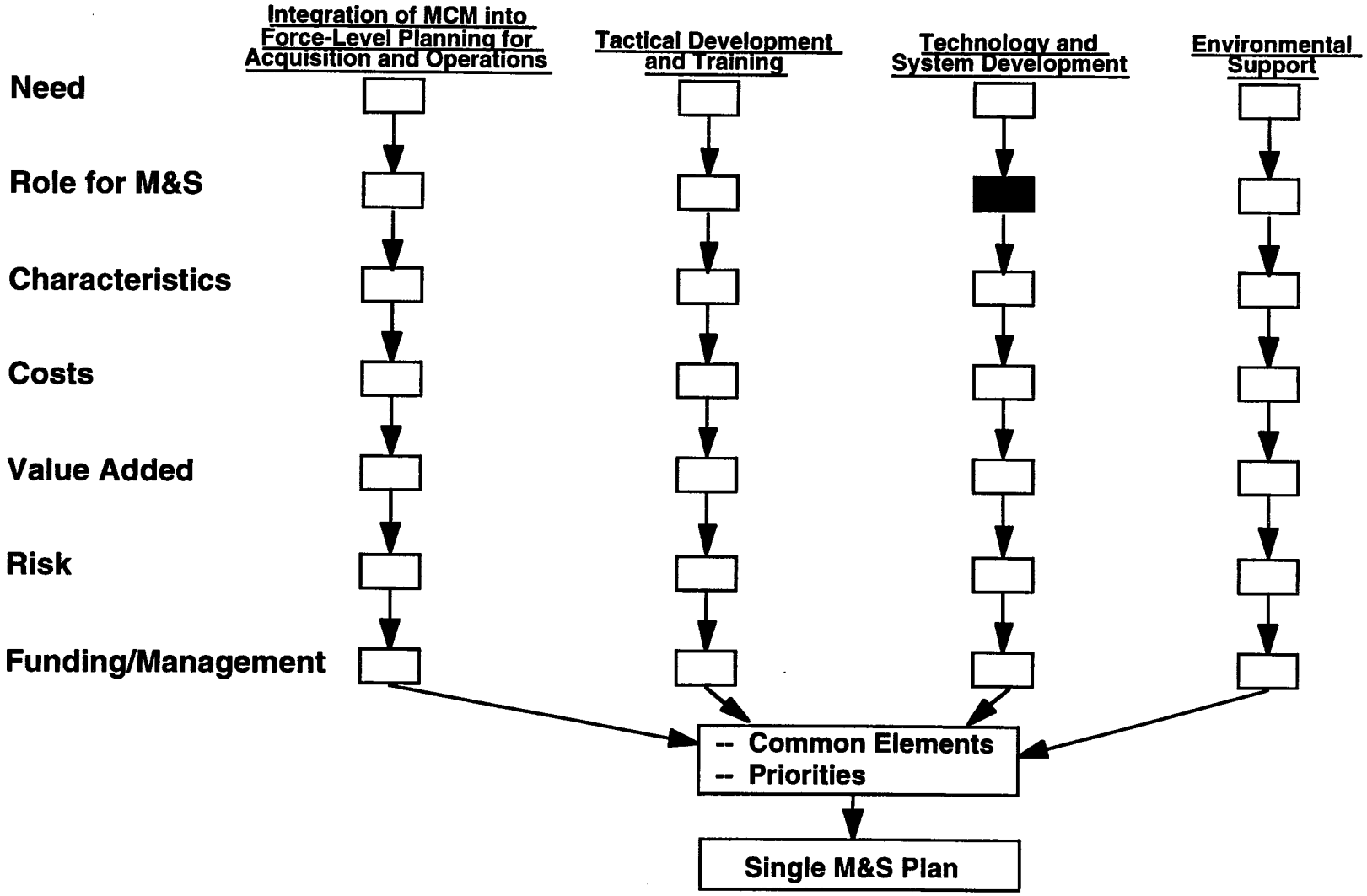
We refer the reader to Appendix D for detailed information on each of the steps shown. Here we illustrate the process by following it through for one of the key needs: Technology and System Development.

NEEDS-DRIVEN APPROACH TO INVESTING IN M&S: MCM CASE STUDY



We have just discussed the nature of the challenge in the area of technology and system development. This is the first step. We now address the second step and ask how the new M&S tools might help.

NEEDS-DRIVEN APPROACH TO INVESTING IN M&S: MCM CASE STUDY



As discussed previously, there are two general types of M&S tools that are applicable to technology and system development: operational and structural.

Operational M&S tools can help bring the "right" systems into the fleet more quickly and efficiently through the applications listed.

Structural M&S tools are discussed in the next viewgraph.

2. HOW MIGHT NEW M&S TOOLS HELP?

TWO WAYS:

A. OPERATIONAL

- Bring users and developers together at earliest stages of development
  - Vehicle for integrated product development teams
- Provide virtual test bed for proposed systems
  - Operator "hands-on" trials
  - Identify high-payoff systems
  - Early kill (or non-start) of low-payoff systems
- Enable virtual systems to be imbedded in "live" exercises
- Smooth fleet introduction
- Plan, assess, enhance operational testing
- Communicate value of system to decisionmakers

Structural M&S tools such as those listed can provide powerful communications tools for the acquisition team and can greatly improve the timeliness, efficiency and quality of the design and production phases.

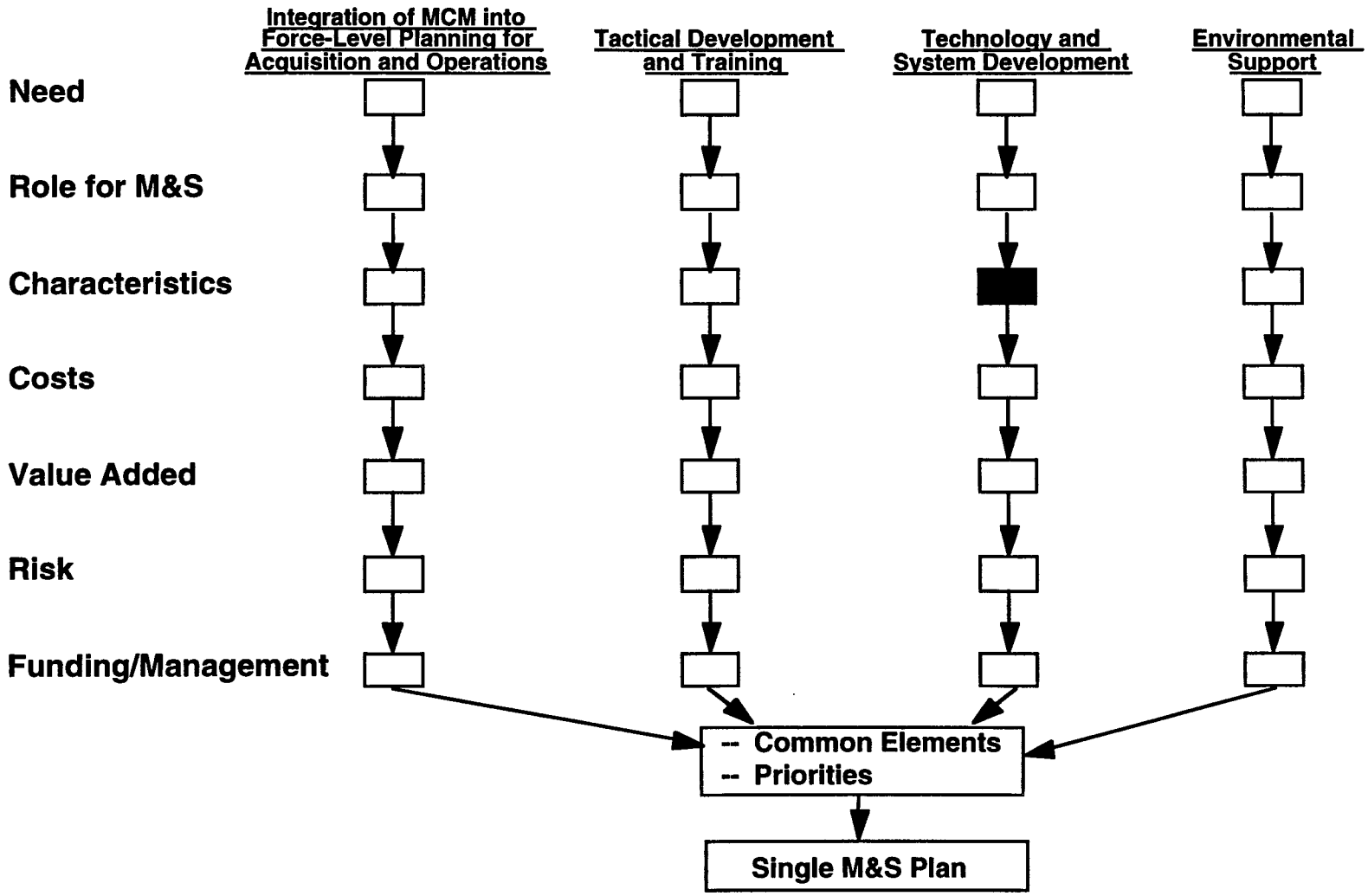
2. HOW MIGHT NEW M&S TOOLS HELP? (Cont'd.)

B. STRUCTURAL

- Computer-aided:
  - Design (CAD)
  - Engineering (CAE)
  - Manufacture (CAM)
- Communication tool for acquisition program
- Provide early identification of problems:
  - Reduce rework
  - Shorten development cycle
  - Increase efficiency of development funds
  - Improve quality

The desired characteristics for the operational and structural M&S tools are quite different. This is discussed in the next step of the process.

NEEDS-DRIVEN APPROACH TO INVESTING IN M&S: MCM CASE STUDY



The emphasis is on virtual simulations for both the operational and structural M&S tools. In the operational case, this provides the basic link between the developers and the operators.

As is indicated, the desired characteristics of the tools are quite different for the operational and structural cases.

Operational M&S tools have a wide range of desired level of detail depending on their purpose. On the one hand, an operational assessment of the contribution of a system to large-scale MCM operations may require only a simple characterization of the system in terms of a few parameters. On the other hand, an assessment of the detailed performance of, say, a mine-hunting sonar may require a high-level-of-detail simulation of the system, its targets and the environment.

Structural simulations provide extremely detailed representations of a system but need not consider the threat or the environment.

Both types should be interactive, the operational with operators and the structural with designers.

Operational, man-in-the-loop simulations must be real-time, whereas structural models should respond quickly for the sake of convenience and efficiency but need not do so in real-time.

It is desirable for the operational models to be distributed, multisided (e.g., Blue vs. Red) and connected to the other M&S tools shown so that proposed systems can be played by operators in an operational environment.

Structural models must be distributed across the design team, but the desired degree of interoperability with other M&S tools will depend on the issues of interest and the cost. Interoperability with related structural tools is certainly desirable. With regard to operational tools, one wants to capture the operational implications of design changes but not burden the link with structural detail. Thus a "translation" of structural detail into a much smaller number of performance parameters will generally be required.

3. WHAT CHARACTERISTICS SHOULD THE M&S TOOLS HAVE?

TYPES:

- Virtual operational simulations
- Virtual structural representations

CHARACTERISTICS:

	Operational	Structural
Level of Detail		
– Systems	Low-High	High
– Threat Systems	Low-High	N/A
– Environment	Low-High	N/A[a]
Interactive	Yes (operators)	Yes (designers)
Real-time	Yes	No
Distributed	Desirable	Yes
Multisided	Yes	N/A
Connectivity to Other M&S Tools	Desirable to – "Live" exercises – Fleet units/trainers – Environmental data bases	Desirable to – Structural – Operational (via performance parameters)

[a] Engineering models may require very high level of detail for environmental representation.

We now pause for a few comments on the characteristics of M&S tools.

We first note the great difference between operational and structural M&S tools. This distinction is sometimes blurred in M&S discussions, and successes achieved by CAD systems may be offered as evidence for expecting similar success for operational M&S tools. We suggest that these analogies be examined with extreme care.

The second point is that high level of detail does not equal "high fidelity" and is not necessarily a measure of progress. This is the old precision vs. accuracy issue. It is appropriate that the technology be pushed to the limit to see how much data can actually be moved in real-time simulations. However, since detail comes at a price, the practical user must ask, How much is enough? What is the right level of detail for the problem at hand?

The third comment addresses the type of visualization used by an M&S system. In its beginnings, distributed interactive simulation was designed to address Army needs, and the emphasis in Army applications is on a "heads-up", visually-interactive linking of large numbers of entities. Thus 3-D imagery, despite its technical challenges, is essential to present the picture to the participants.

The Navy, on the other hand, may more often stress heads-down, sensor-oriented linkages among a few elements. Therefore 3-D imagery may be less important for some Navy applications. The 2-D representations may in fact, be technically easier, cheaper and more readily linked to the Navy's standard tactical displays.

Note, however, that 3-D imagery does have valuable uses for Navy applications. It can aid in the understanding of a complex situation by providing various vantage points, and the Navy's M&S tools must support 3-D representations if they are to link with joint force simulations. However for some applications--at least initially--the use of 2-D displays may be sufficient.

The final comment is that the desired degree of interoperability of an M&S tool depends on the costs and benefits of its linkage to other tools. In general, a high degree of interoperability is desirable. However, some tools may have unique roles and their full detail would only burden the network without offering commensurate advantages. This issue is illustrated in the next viewgraph.

COMMENTS ON CHARACTERISTICS OF M&S

1. Operational and structural M&S tools very different.

2. High level of detail does not equal "high fidelity."

3. 2-D graphics may be sufficient for some Navy applications.

4. Desired degree of "interoperability" of an M&S tool is a cost/benefit decision.

Here the M&S landscape chart shown before is used to illustrate three M&S applications. "A" is an operational M&S tool used to assess requirements for, say, a new ship-based mine-hunting sonar. It is highly desirable that the simulation used to assess system requirements be the same as (or linkable to) a simulation, "B", that is used for the tactical development of an MCM force. In this way the sonar's performance characteristics can be directly assessed in terms of their contribution to overall force effectiveness.

"C", on the other hand, represents a detailed sonar design tool. Changes in design must, of course, be relatable to changes in system performance characteristics, but it is not desirable to burden the link with all of the design details that are the real focus of C. Only a few parameters will suffice. Nor is it necessary that a designer's change in C be communicated in real-time to an operational model. Thus we indicate the linkage between "C" and "A" with a dotted line. Whether such a linkage means that A and C are "interoperable" depends on how one interprets that term. The definition given in DoD Directive 5000.59 (Reference 1) is "M&S interoperability" is "the ability of a model or simulation to provide services to, and accept services from, other models and simulations, and to use the services so exchanged to enable them to operate effectively together." This definition is pretty broad and leaves the above case of A and C still open to interpretation.

In any case, the desired nature of the linkage that governs the type and timeliness of the data exchanged between two M&S tools is a cost/benefit decision driven by the issues at hand.

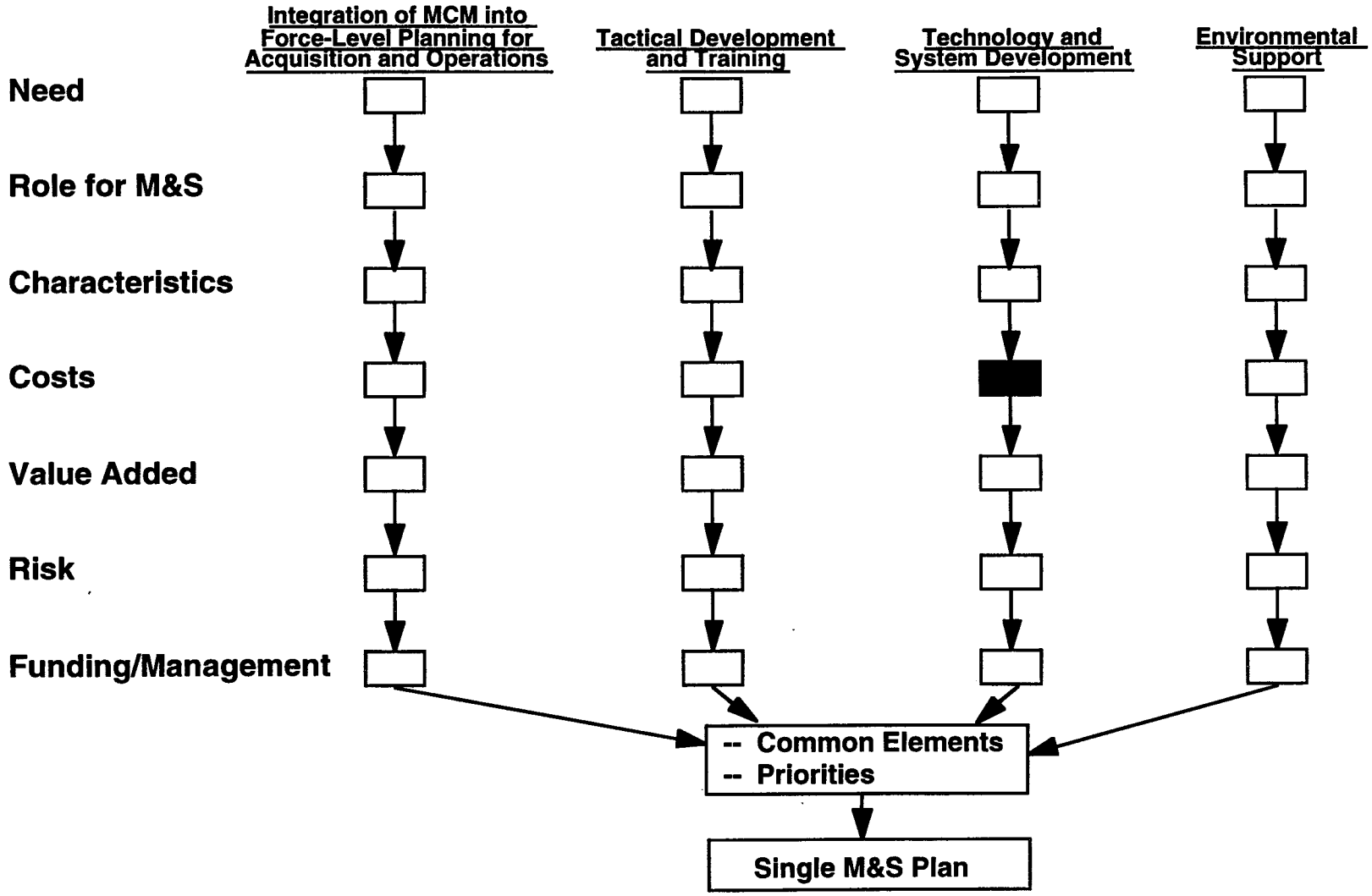
AN M&S LANDSCAPE

SCOPE

PURPOSE	JOINT FORCE	NAVAL FORCE	FORCE ELEMENT	UNIT	SYSTEM	SUB-SYSTEM
ACQUISITION						
Requirement					A	
Concept/Dev						
Design/Plan					C	
Build						
Test						
Support						
Cost						
OPERATIONS						
Tactical/Dev/Aids			B			
Train						
Exercise Analyses						
Support						
Cost						
PROGRAM SUPPORT						
Planning						
Management Info						
External Comms						

We now turn to the costs associated with the M&S tools we have been discussing.

NEEDS-DRIVEN APPROACH TO INVESTING IN M&S: MCM CASE STUDY



The costs are estimated very roughly--we give only ballpark estimates.

The cost of developing a facility that is DIS-compatible and capable of representing MCM systems and operations is roughly $1-3M for acquisition plus $1-3M per year for operations and support. See Appendix E for additional details. Such a system could serve as the hub for a more extended network of installations, the number and nature of which will determine the total cost.

A range of capabilities would also be possible for structural simulations such as CAD packages. The costs there are roughly comparable to the above estimates.

The time from program initiation to an initial operational capability is (again roughly) on the order of two years.

4. WHAT DO THE M&S TOOLS COST?

OPERATIONAL SIMULATION

- Single DIS-compatible facility with representation of MCM systems and operations:
  - $1-3M acquisition, plus $1-3M/yr O&S

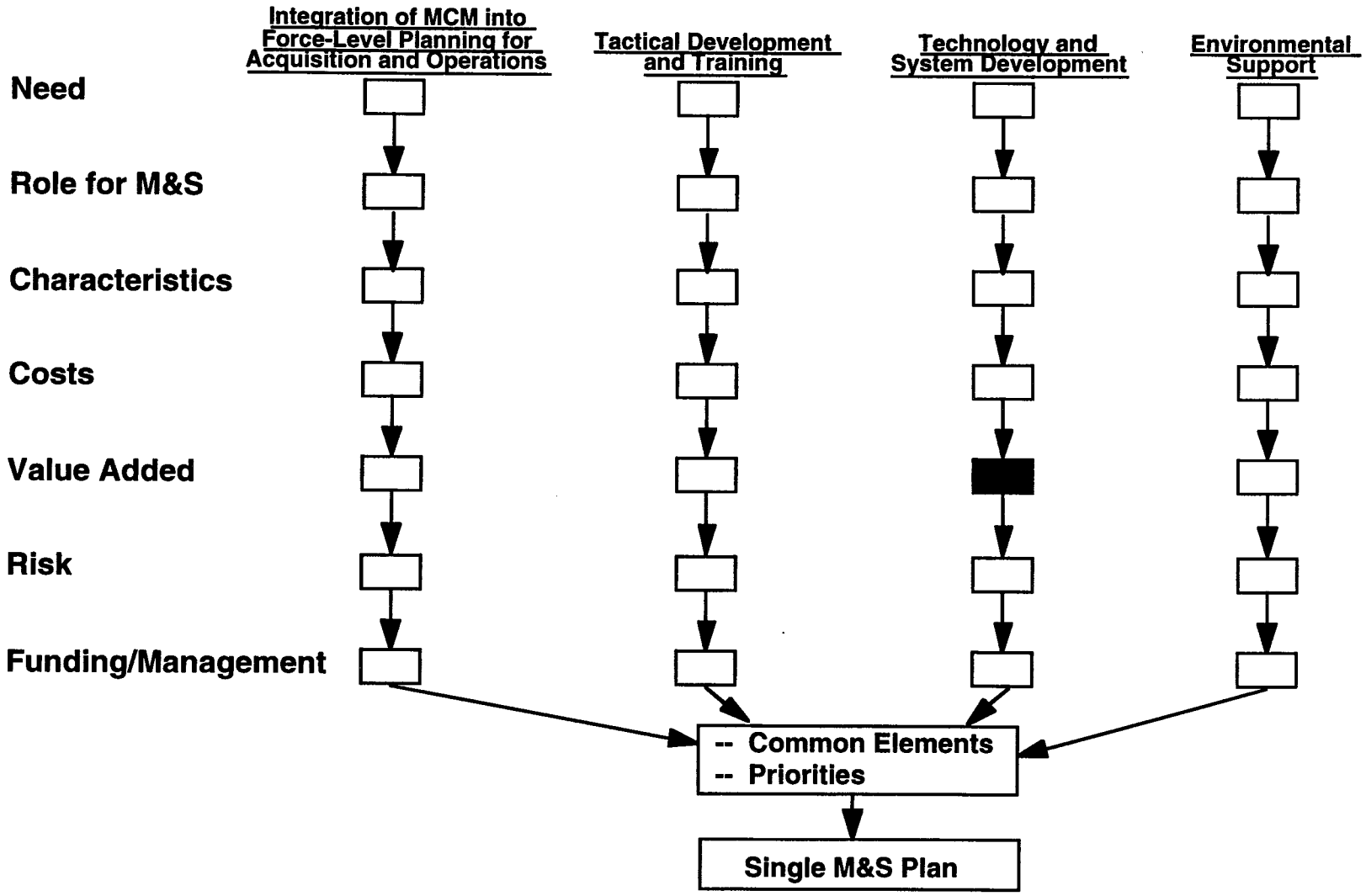
STRUCTURAL SIMULATION

- Similar estimates for CAD systems

APPROXIMATE TIMES TO IOC: 2 yrs

We now turn to the potential value-added of the M&S tools.

NEEDS-DRIVEN APPROACH TO INVESTING IN M&S: MCM CASE STUDY



The value-added by M&S is difficult to assess since it is generally in areas such as: potential performance gain, avoiding cost or schedule overruns, risk reduction, quality, or expertise, all valuable--but hard-to-measure--commodities. Also, in any given case the benefits of M&S may be hard to separate from the effects of other actions. However, we do suggest a few approaches that might be taken.

The first approach relates the M&S value-added to a program goal such as a system's performance requirement, cost, schedule, number of defects, etc.

The second approach looks at related experience where the benefits of M&S may have been assessed. These are mostly related to structural M&S tools. See Appendix F for a brief description of some related studies from government and industry such as the IDA study on the value of physical prototyping for reducing cost and schedule overruns, or, regarding structural M&S, the Boeing 777 experience.

A third approach is to use cost benchmarks and rough improvement estimates to gauge the added value of M&S. For example, the annualized life-cycle cost of the MCM-1 (Avenger) class of minesweepers is about $170M (FY-1995) (Reference 19). This represents the value that the nation currently places on this asset. Using this cost as a benchmark, if we were to invest, say, $2M per year in an M&S program dedicated to improving the performance of the MCM-1 class, then the break-even point for return on investment would be a 1.2 percent improvement in performance--one that would appear to be quite achievable.

Analogous benchmarks can be used in other areas as well, such as the cost of an exercise and the ability of M&S to augment it. See Appendix G for some generic examples.

5. WHAT IS VALUE ADDED?

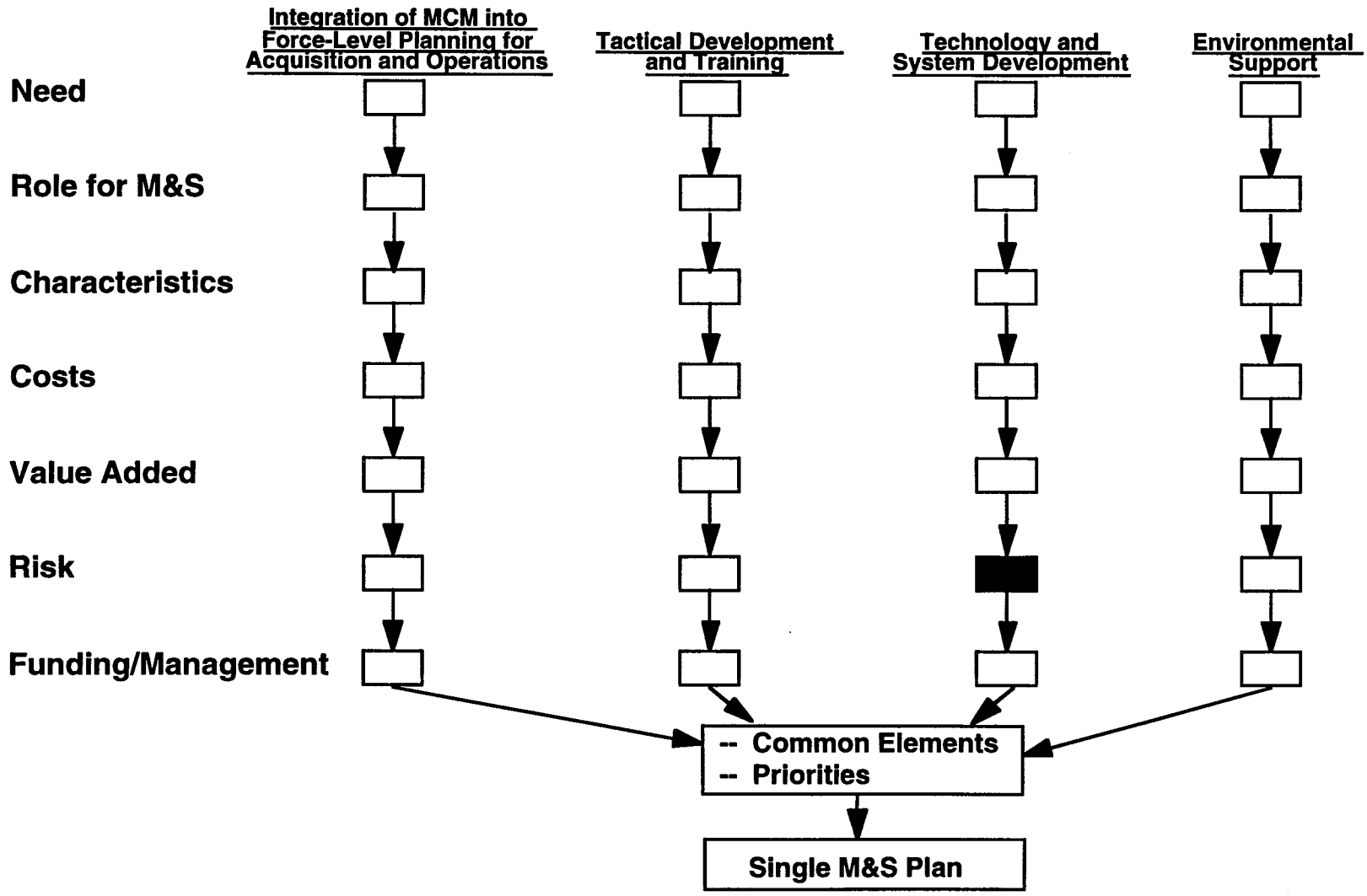
DIFFICULT TO MEASURE; SOME POSSIBLE APPROACHES:

- QUANTIFIABLE GOALS
  - Cost, time, quality
- RELATED EXPERIENCE
  - Most related to structural M&S
    - » Examples:
      - Government: Value of prototyping
      - Industry: Boeing 777
- ROUGH BOUNDS
  - Cost benchmarks and improvement estimates
    - » Examples:
      - Annualized life-cycle cost of MCM-1 class (14 minesweepers): ~$170M[a]
      - Break-even point for $2M/yr M&S investment: 1.2 percent improvement in performance

[a] Selected Acquisition Report (12/93)

We now turn to the risks associated with the M&S tools.

NEEDS-DRIVEN APPROACH TO INVESTING IN M&S: MCM CASE STUDY



The risks associated with M&S investments may be limited to the M&S process itself or, more importantly, may have a wider impact on the program as a whole.

The first type of risk involves the applicability of the M&S to the real problem at hand. M&S is a tool that can assist in the solution of problems but is never the solution itself. Thus, for example, M&S can facilitate organizational communications (say, within integrated product development teams) assuming the members want to communicate in the first place.

A related risk is the generality of the M&S results. For example, a large operational simulation is often a "one-shot deal". What does one conclude from a complex, low data rate experience? Instead of always "fighting the last war", participants may end up fighting the last simulation. In general the interpretation of M&S results requires parallel supporting analyses based on "what if" drills, understanding why things happened as they did, and relationships to other experiences.

The main risk of M&S, however, is that the model is unrealistic. After all, M&S tools are constructs created by "real-world" people. They therefore reflect their creators' perceptions, approximations, self-interests, etc. Thus an independent parallel process must be instituted to try to reduce the chances that the M&S tools will be unrealistic. This leads us to the verification, validation and accreditation (VV&A) process discussed in the next viewgraph.

6. WHAT ARE THE RISKS?

- M&S MAY NOT BE RELEVANT TO UNDERLYING PROBLEM
  - M&S are tools that can aid a more basic process
  - Process itself must be desired and supported
    - » Example:
      - Integrated Product Development Team
- M&S RESULTS MAY NOT BE GENERAL ENOUGH
  - Must be accompanied by analytical process
- M&S MAY BE UNREALISTIC AND/OR MISLEADING
  - M&S are constructs that reflect their creators': perceptions, approximations, styles, self-interests,...
  - Must be accompanied by independent VV&A process

The VV&A process must address not only the model itself but also the input to the model (or supporting data bases) and the specific application. It cannot be a zero-one process, but rather one that is expressed in degrees of confidence for specific applications. Some of the key elements of a VV&A process are listed here. It should be noted that historically there has been great unwillingness to devote resources to such VV&A activities.

A key element is simply maintaining independent parallel models to check for consistency. Trying to eliminate all but a single "blessed" model is risky and counterproductive.

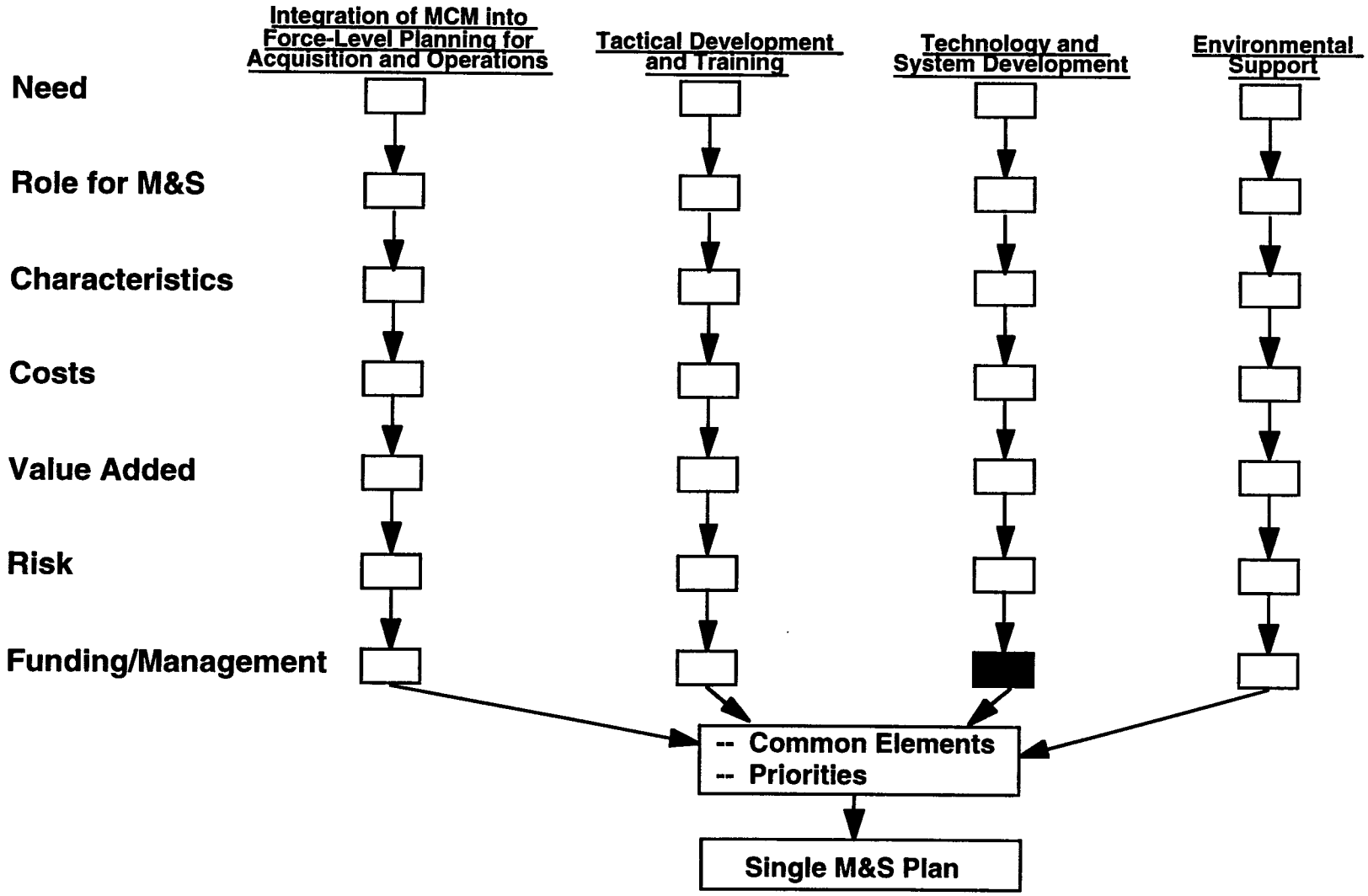
Finally, as with physical theories, complete validation of a model (that is, a guarantee that it faithfully represents reality), can never be achieved. The VV&A process must be a continual one.

VERIFICATION, VALIDATION AND ACCREDITATION (VV&A)

- MUST ADDRESS:
  - Model
  - Input (data bases)
  - Specific application
- NOT A 0-1 PROCESS, BUT DEGREES OF CONFIDENCE
- BASED ON:
  - Assessments by experienced operators
  - Comparisons to exercise results
  - Applications to known cases
  - Comparisons to other models
  - Checks of code
- MUST MAINTAIN INDEPENDENT MODELS
- MUST BE AN ON-GOING PROCESS
  - Can never completely validate a model
- "SIMULATE BUT VERIFY"

The last question addresses the organizational implementation of the M&S effort. Who will set requirements? Who will pay for it? And, who will actually be responsible for running the effort?

NEEDS-DRIVEN APPROACH TO INVESTING IN M&S: MCM CASE STUDY



Here we list some of the key individuals who must determine the requirements for the M&S tools for technology and system development in MCM, provide its funding, and oversee its execution and VV&A. We do not make specific recommendations, but we do point out that, since this is a process driven by the fundamental needs of the organization, the key decisionmakers must continue to stay involved.

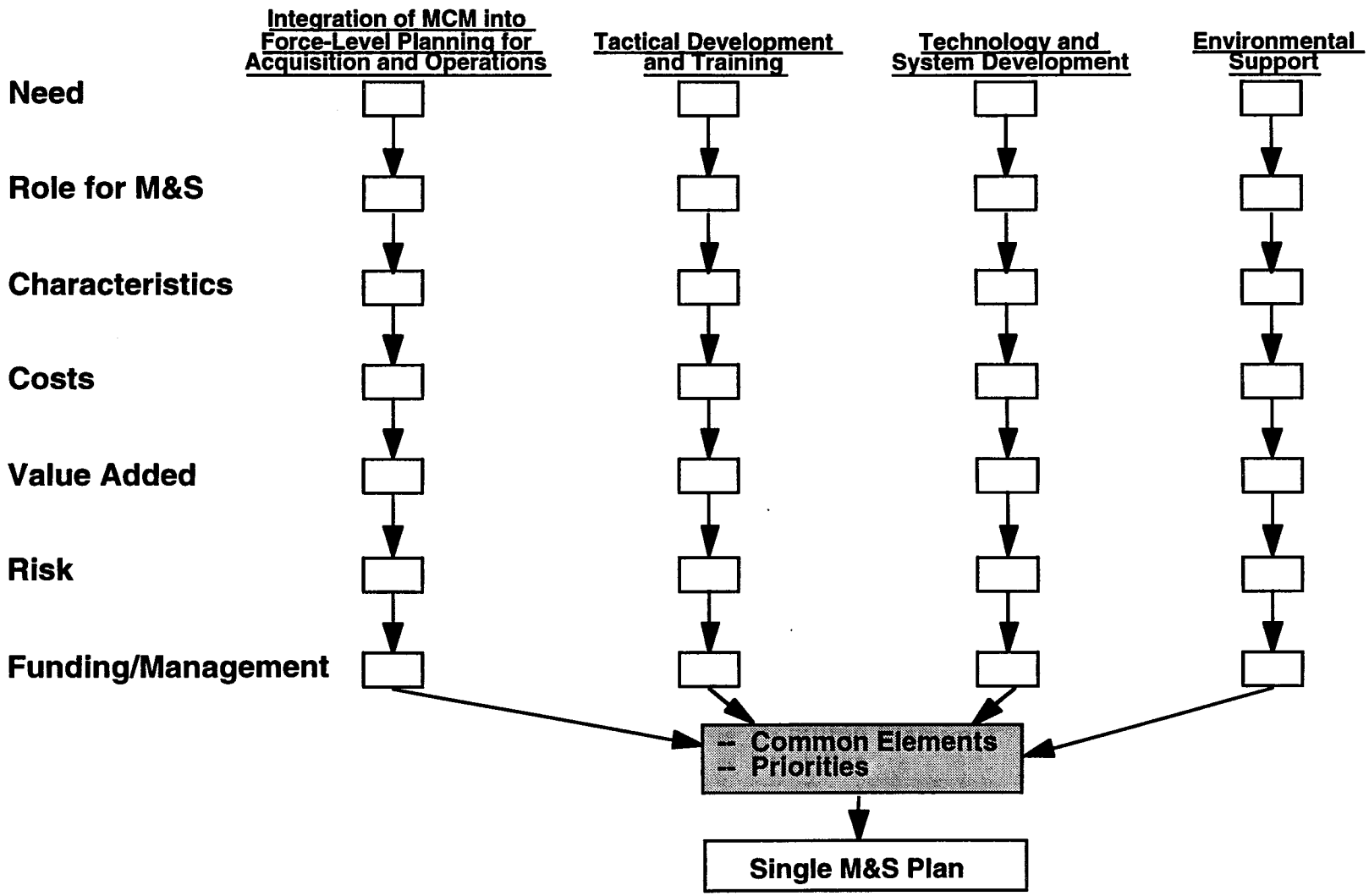
7. WHO SHOULD FUND AND MANAGE THE M&S EFFORT?

SOME KEY PLAYERS:

- M&S REQUIREMENTS AND FUNDING:
  - CNO (N85, N6, N091, ...)
  - CMC
  - ASN (RDA), PEO (MIW)
  - CMWC
  - CNR
  - MCCDC
  - OSD
- EXECUTION AND VV&A:
  - PEO (MIW), PMs
  - CMWC
  - MARCORPS SYSCOM

We now bring together the results from the four areas of need that have been identified. (See Appendix D for details on the three areas not treated in the main text.) We look for common elements across the areas and decide upon priorities. These are described in the next viewgraph.

NEEDS-DRIVEN APPROACH TO INVESTING IN M&S: MCM CASE STUDY



Three overriding common themes emerged. The first was a focus on operational M&S tools. This is because the structural tools were relevant only to the design and manufacturing phases in a single area, Technology and System Development, and even in that case it is uncertain whether commercial or government initiatives should take precedence. Clearly, these M&S tools should be applied to the acquisition process, but Navy development of them did not naturally emerge as a priority in this example.

The second common theme is the need for linkages: linkages between MCM and higher levels in support of planning processes for both operations and acquisition, and linkages within the MCM force for tactics, training, mission rehearsal, exercises, system requirements, concept development and testing.

The third common theme is the need to support the range of M&S tools with environmental models and data bases that reflect new-world scenarios.

The priorities are, of course, judgmental and dependent on available resources. However, one approach would be to establish a "Fleet first" priority to help establish confidence in the M&S tools. We will discuss this in more detail later.

INTEGRATION OF MCM M&S PLANNING PROCESSES

COMMON ELEMENTS:

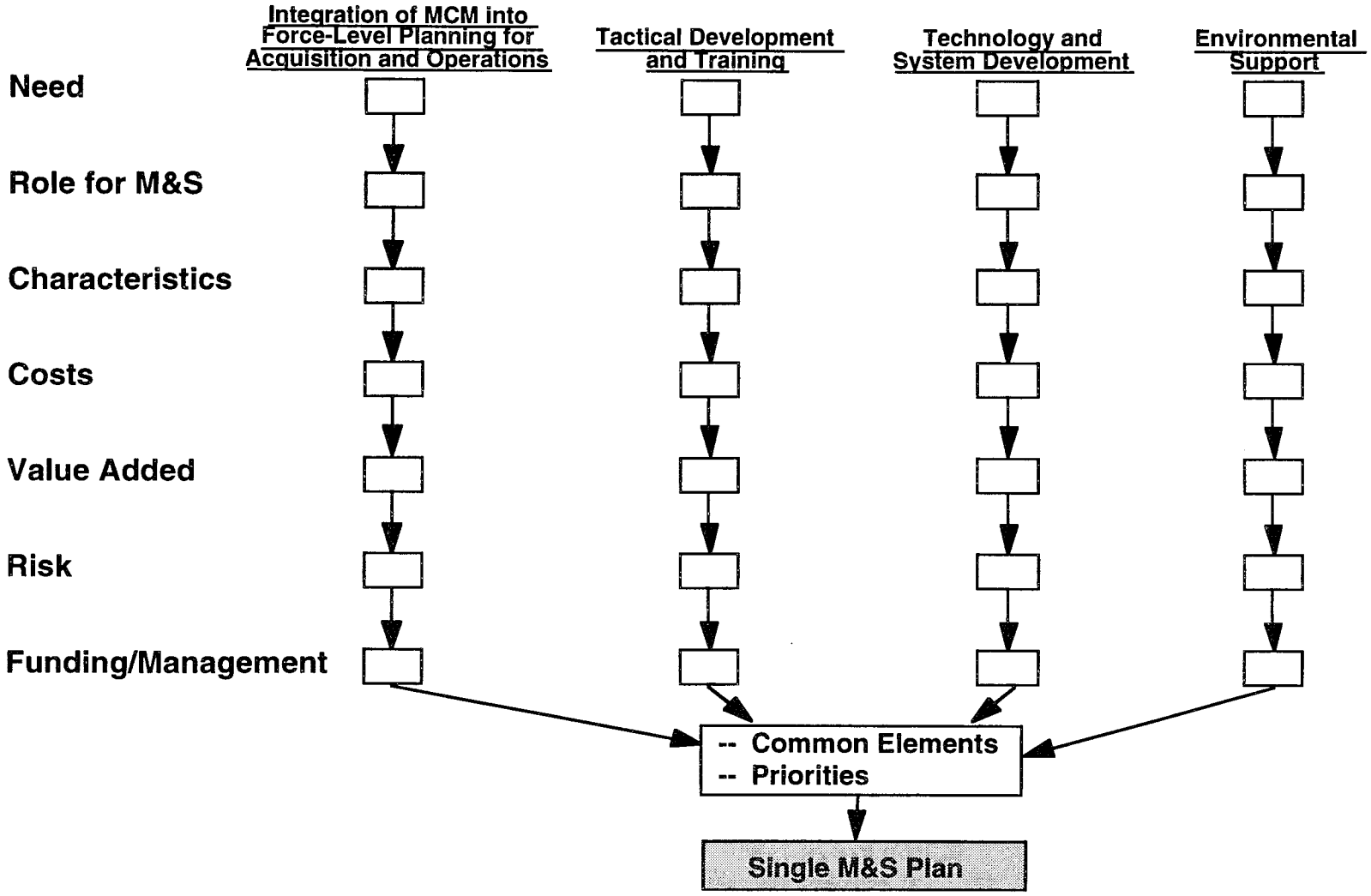
- Focus on operational M&S
- Establish linkages:
  - Between MCM and higher levels
    - » Operations
    - » Acquisition
  - Within MCM force (operators and developers)
    - » Tactics
    - » Training
    - » Mission rehearsal
    - » Exercises
    - » System requirements
    - » Concept development
    - » Test & evaluation
- Need for supporting environmental models and data bases

PRIORITIES:

- Depend on resources
- "Fleet first" could help establish confidence in M&S tools

The last step is to consider the common elements and priorities, and integrate them into a single M&S plan. A strawman example of such a plan (in broad outline) is described in the next viewgraph.

NEEDS-DRIVEN APPROACH TO INVESTING IN M&S: MCM CASE STUDY



Here we list the five key elements of a strawman plan.

The development of the capability to represent MCM systems and operations in a DIS-compatible M&S facility is relevant to all of the problem areas. As outlined here such a capability could provide linkages up to higher-level simulations, down to environmental models and data bases, and within the MCM force itself to improve tactics, training, exercises, and the development and acquisition of new systems.

Where should such M&S facilities be located? The answer depends, of course, on the resources available, the priorities among the potential M&S applications, the traditional roles of the candidate sites, and the local interest and capability regarding the new M&S tools. One approach to setting these priorities was mentioned earlier and will be described in the following viewgraph.

In any event, in light of the still unproven nature of these tools, a prototype approach that focuses M&S resources on particular applications may be preferred.

The third element is the need for a sound scientific understanding of the environment and an ability to link that understanding to the M&S facilities. A process must be in place to assure that the environmental information is available to the new M&S tools in a form that they can readily use.

The fourth element of the strawman program is its effective implementation within the Navy organization. Dedicated M&S funding is a key ingredient.

Finally, this approach would focus on operational M&S tools and emphasize commercial development of structural M&S tools such as CAD systems. Governmental development would be resorted to only in special cases.

STRAWMAN MCM M&S PLAN

1. DEVELOP FACILITIES THAT ARE DIS-COMPATIBLE AND REPRESENTATIONS OF MCM SYSTEMS AND OPERATIONS

2. MAKE M&S FACILITIES AVAILABLE TO FOLLOWING COMMUNITIES:
   - Operators
   - Training
   - TAC D&E
   - CINCs and CINC Staff
   - R&D
   - Acquisition
   - Industry

3. DEVELOP SUPPORTING ENVIRONMENTAL:
   - Data Bases
   - Models
   - Linkages to M&S Facilities

4. ESTABLISH <u>DEDICATED</u> MANAGEMENT AND FUNDING FOR MCM M&S

5. EMPHASIZE COMMERCIAL DEVELOPMENT OF STRUCTURAL M&S TOOLS SUCH AS CAD SYSTEMS

Returning to the question of priorities for the focusing of M&S resources, we describe here one possible approach.

This approach would focus initial M&S developments on the Fleet for training, tactical development and evaluation, exercise support, and mission rehearsal. Such applications take direct advantage of the unique features offered by the new M&S tools as listed here, and would take advantage of the well-established position that simulation holds within the training communities. That, after all, is the route historically followed by the Army/ARPA development of SIMNET using, as a basis, existing training facilities.

PRIORITIES FOR DEVELOPMENT OF MCM M&S: ONE APPROACH

OPERATIONAL M&S

- Focus initial M&S developments on the Fleet
  - Training
  - Tactical development and evaluation
  - Exercise support/augmentation
  - Mission rehearsal
- These applications take direct advantage of unique features of new M&S tools:
  - Man-in-the-loop
  - Blue/Red dynamics
  - C^3I
  - Remote linking
  - Immersion via graphics
- Value of simulators for training already well-established
  - Army/ARPA: SIMNET grew out of training systems
- High confidence of near-term benefits

An initial focus on Fleet operations would also keep the operators directly involved, thus helping to keep the applications practical and useful, and providing a "hands-on" VV&A process to help keep the M&S representations on track.

The idea here would be that once a degree of confidence in the realism of the tools was achieved, their usage could be increased for system development and force planning. After all, the sole value of M&S is its ability to faithfully represent real operations; therefore it may be best to establish this capability through Fleet usage before moving on to the acquisition and force-planning processes.

Finally, in this strawman approach we have been focusing on operational simulations. The use of structural simulations within the acquisition process (such as CAD/CAE/CAM systems) is to be strongly encouraged. However the government's role in developing such tools will depend upon the capabilities within the relevant elements of the commercial sector. The strawman approach described here focuses initial government resources on operational M&S tools.

PRIORITIES FOR DEVELOPMENT OF MCM M&S: ONE APPROACH (Cont'd.)

OPERATIONAL M&S (Cont'd.)

- Fleet applications:
  - Keep operators directly involved
  - Practical, needs-driven
  - Provide "hands-on" VV&A
  - Keep M&S rooted in "real" data
- Then, as M&S tools mature and confidence is gained, increase usage for:
  - Technology and system development
  - Force acquisition and planning

STRUCTURAL M&S

- Strong commercial interests make government role unclear
- Focus initially on operational M&S

Finally, we present some comments on the funding and management of MCM M&S.

The key issue here is, Who's in charge? There must be agreement at the highest levels concerning the requirements, funding and authority for MCM M&S, and the key decisionmakers have to stay involved in the M&S process.

As indicated, some MCM M&S activities are either already underway or are being considered. These include the Navy Mine Warfare Simulation at CSS, Panama City, and the Fleet Operational Simulation Project (FOSP) at CNA. Both are contributing to the development of a DIS-compatible representation of MCM systems and operations. The Joint Countermine Operational Simulation (JCOS), being funded through ONR, is an MCM initiative that has both M&S and C4I components. It is part of a larger Advanced Concept Technical Demonstration addressing both sea and land mines. The "Kernel Blitz" exercise integrated mine sweeping operations in the Gulf of Mexico into larger force operations off the West Coast.

The Mine Warfare Readiness/Effectiveness Measuring Program (MIREM) is a proposal by COMINEWARCOM to create a program at the Surface Warfare Development Group (SWDG) that is analogous to the well-established SHAREM program in ASW.

Both JCOS and MIREM have central goals of providing new M&S tools to the Fleet.

In addition, overarching organizations, the DoN Modeling and Simulation Management Office (DoNMSMO) and the Defense Modeling and Simulation Office (DMSO), have been created to oversee and coordinate DoN and DoD M&S activities.

However, if these M&S activities are to succeed, they must have long-term dedicated funding and a cultural acceptance at all levels. A selective, focused application may offer the best chance to demonstrate that the new M&S tools can provide valuable results, and thereby gain credibility for further support of M&S activities.

Another issue involves software ownership. There is a tension both in the commercial sector and in the government laboratories between the conflicting needs to encourage the development of software, and make the results widely available. Software "ownership" may lead to parallel, redundant or incompatible systems. DoD must reach a compromise position where DoD-developed software is available to all DoD users, but the developing organization realizes sufficient benefits from its product.

The final point pertains to structural M&S tools such as CAD representations of systems. As discussed earlier, these are often the first examples cited in M&S discussions (e.g., the Boeing 777 case) but are quite distinct from simulations of operations. The usage of structural M&S tools is naturally evolving into system acquisition programs. Progress in this area is being driven by commercial interests, and decisions concerning government initiatives must be made on a case-by-case basis.

COMMENTS ON FUNDING/MANAGEMENT OF MCM M&S

- Key issue: Who's in charge? (Decisionmaker has to remain involved)
- Some MCM M&S activities already underway or being considered
  - Navy MIW Simulation
  - Fleet Operational Simulation Project
  - Joint Countermine Operational Simulation
  - "Kernel Blitz" Exercise
  - Mine Warfare Readiness/Effectiveness Measuring Program
- Overarching organizations formed
  - DoN M&S Management Office
  - Defense M&S Office
- But long-term, dedicated funding must follow
  - Requires cultural acceptance of M&S at all levels
  - Perhaps focus on selected user-driven applications
- Software ownership issues must be addressed
- Handle government vs. commercial development of structural M&S tools on case-by-case basis

Finally, we summarize the central points in this viewgraph.

SUMMARY

- WE HAVE:
  - Proposed a general, needs-driven process for deciding how to invest in the new M&S tools
  - Applied process to a special case: MCM
    - » General methods and directions
    - » No detailed roadmap
- PROCESS ITSELF:
  - Still not easy, but
  - Structures the problem
  - Does seem to raise the relevant issues
  - Should be applicable to other warfare areas
- NEW M&S TOOLS HAVE REVOLUTIONARY POTENTIAL--BUT MUCH REMAINS TO BE DONE

(This page intentionally left blank)

GLOSSARY

ALISS	Advanced Lightweight Influence Sweep
ALMDS	Airborne Laser Mine Detection System
AMCM	Airborne Mine Countermeasures
ASW	Antisubmarine Warfare
C4I	Command, Control, Communications, Computers and Intelligence
CAD	Computer-Aided Design
CAM	Computer-Aided Manufacturing
CNA	Center for Naval Analyses
COMINE-WARCOM	Commander, Mine Warfare Command
CSS	Coastal Systems Station (in Dahlgren Division of the Naval Surface Warfare Center)
DASN (MUW)	Deputy Assistant Secretary of the Navy for Mine and Undersea Warfare
DET	Distributed Explosive Technology
DIS	Distributed Interactive Simulation
DMSO	Defense Modeling and Simulation Office
DoNMSMO	Department of the Navy Modeling and Simulation Management Office
DSI	Defense Simulation Internet
DUSD (AT)	Deputy Under Secretary of Defense for Acquisition and Technology
EOD	Explosive Ordnance Disposal
FOSP	Fleet Operational Simulation Project
JCOS	Joint Countermine Operational Simulation
LCAC	Landing Craft Air Cushion
LPH	Helicopter Landing Ship
M&S	Modeling and Simulation
MCAC	Multi-Purpose Craft Air Cushion
MCM	Mine Countermeasures
MCS	Mine Countermeasures Command, Control and Support Ship
MHC	Mine Hunter, Coastal
MIREM	Mine Warfare Readiness/Effectiveness Measuring Program
MIW	Mine Warfare
MMS	Marine Mammal Systems
NAS	Naval Air Station
NLOS	Non-Line-of-Sight
NMRS	Near-term Mine Reconnaissance System

ONR	Office of Naval Research
PEO	Program Executive Officer
RDT&E	Research, Development Test and Evaluation
RMOP	Remote Minehunting Operational Prototype
SABRE	Shallow Water Assault Breaching System
SCN	Ship Construction Navy
SEAL	Sea-Air-Land (special warfare forces)
SHAREM	Ships Antisubmarine Warfare Readiness Evaluation Measurement Program
SIMNET	Simulation Network
SWDG	Surface Warfare Development Group
TAC D&E	Tactical Development and Evaluation

APPENDIX A

REFERENCES

Appendix A

REFERENCES

1. *DoD Modeling and Simulation (M&S) Management*, DoD Directive (DoDD) 5000.59, January 4, 1994.
2. *Modeling and Simulation Master Plan* (Draft), Department of Defense, DoD 5000.59-Paa, January 1995.
3. *Modeling and Simulation Successful Examples*, Defense Systems Management College Instructor Support Package, November 1994.
4. *Systems Acquisition Manager's Guide for the Use of Models and Simulations*, Defense Systems Management College Press, September, 1994.
5. *Virtual Prototyping: Concept to Production*, Defense Systems Management College Press, March 1994.
6. *Impact of Advanced Distributed Simulation on Readiness, Training and Prototyping*, Report of the Defense Science Board Task Force on Simulation, Readiness and Prototyping, Office of the Under Secretary of Defense for Acquisition, January 1993.
7. *The Effects of Management Initiatives on the Costs and Schedules of Defense Acquisition Programs*, Volume I, Main Report, Volume II, Analyses of Ground Combat and Ship Programs, Institute for Defense Analyses Paper P-2722, November 1992.
8. *Verification, Validation, and Confirmation of Numerical Models in the Earth Sciences*, N. Oreskes, K. Shrader-Frechette, K. Belitz, Science, 263 pp. 641-6, February 4, 1994.
9. *Perspectives on the Use of Modeling & Simulation (M&S) in the Acquisition Process*, J. Schoen and S. H. Starr, Mitre Report M 93B04, January 1993.
10. *Defense Modeling and Simulation Initiative*, Director Defense Research and Engineering, Defense Modeling and Simulation Office, 1991.
11. *The DIS Vision - A Map to the Future of Distributed Simulation*, Version 1, Institute for Simulation and Training, IST-SP-94-01, May 1994.
12. *Report on Modeling and Simulation*, Naval Research Advisory Committee, Office of the Assistant Secretary of the Navy (Research, Development and Acquisition), Report NRAC 94-3, November 1994.
13. *Final Report of the Acquisition Task Force on Modeling and Simulation*, Office of the Director of Defense Research and Engineering, June 17, 1994.
14. *The Role of Distributed Simulation in Defense Acquisition*, Institute for Defense Analyses Paper P-2902, November 1993.

15. *Introduction to Modeling and Simulation*, W. A. Menner, Johns Hopkins APL Technical Digest, 16 pp.6-18, January-March 1995.

16. *Navy Modeling and Simulation (M&S) Master Plan*, Department of the Navy, December 27, 1994.

(This page intentionally left blank)

APPENDIX B

KEY QUESTIONS CONCERNING M&S INVESTMENTS

In this appendix we give a little more detail on the key questions that comprise the needs-driven approach to M&S investment decisions. In each case secondary questions are suggested that may help address the primary question.

In order to help define the problem it is useful to identify its focus and purpose as outlined here. It may be helpful to refer to a "landscape" chart such as shown in the following viewgraph.

KEY QUESTIONS CONCERNING M&S INVESTMENTS

1. WHAT IS THE NEED?

- What is the Focus?
  - System level? (force, ship, sonar, ...)
  - Operations? Structure?
- What is the Purpose?
  - Force planning?
  - Technology development?
  - Acquisition?
  - Tactics?
  - Training?

This is a characterization of the "M&S landscape". The horizontal axis identifies the level of aggregation addressed by the M&S tool and the vertical axis identifies the purpose.

For example, a simulation of an MCM operation for the purpose of evaluating alternative tactics would be located at point "A", which might also be used to determine an individual system's performance requirements at point "B". However, a CAD representation for the structural design of that system at point "C" may not directly interoperate with the other two.

This chart indicates the wide variety of possible M&S tools and can help assess their interrelationships.

AN M&S LANDSCAPE

SCOPE

PURPOSE	JOINT FORCE	NAVAL FORCE	FORCE ELEMENT	UNIT	SYSTEM	SUB-SYSTEM
ACQUISITION						
Requirement					A	
Concept/Dev						
Design/Plan					C	
Build						
Test						
Support						
Cost						
OPERATIONS						
Tactical/Dev/Aids			B			
Train						
Exercise Analyses						
Support						
Cost						
PROGRAM SUPPORT						
Planning						
Management Info						
External Comms						

The next question is: Given the nature of the problem, how might the new M&S tools help? This is approached by considering the attributes of the M&S tools and relating those attributes to the problems described. Here we list the key features of the new M&S tools.

QUESTIONS CONCERNING M&S INVESTMENTS (Cont'd.)

2. HOW MIGHT NEW M&S TOOLS HELP?

- How Might New Capabilities Be Used?
  - Effects of man-in-the-loop
  - Blue/Red dynamics
  - Many-player effects (e.g., C^3I, IW)
  - Remote linking
  - Vivid communication of results ("immersion")

The next step is to determine the characteristics that the M&S tools should have: the type, as discussed earlier, the level of detail required, and so forth, as indicated. In each case there is a tension between the M&S characteristic and its cost. This can only be resolved by referring back to the specific needs of the underlying problem.

KEY QUESTIONS CONCERNING M&S INVESTMENTS (Cont'd.)

3. WHAT CHARACTERISTICS SHOULD THE M&S TOOLS HAVE?

- Type? (live, virtual, constructive, combination)
- Level of detail?
  - System
  - Threat
  - Environment
- Interactive?
- Real-Time?
- Distributed?
- Multi-Sided?
- Connectivity to other M&S tools?

The fourth question addresses the M&S costs which can be in terms of both dollars and time. The answer depends on the difference between what is already available and what is needed, and on the potential for cost-sharing with other funding sources. A rough estimate of the cost of a DIS-compatible installation is indicated in Appendix E.

KEY QUESTIONS CONCERNING M&S INVESTMENTS (Cont'd.)

4. WHAT DO THE M&S TOOLS COST?
   - Dollars and time
   - What are existing M&S resources?
     - Hardware
     - Software
     - Data bases
     - Facilities
   - What is needed?
   - What is potential for cost-sharing with other applications?

Having addressed the needed types of M&S tools and their costs, we now ask, What is the value-added of the M&S tools? This is a difficult question to answer since the return on an M&S investment is generally in areas such as avoidance of cost and schedule overruns, avoidance of rework, expertise, etc.

Notwithstanding these difficulties, however, we mention three possible approaches. The first approach establishes goals for the program and gauges the value of the M&S in terms of these goals. Examples of such goals might be: number of training hours provided, cost or schedule goals, amount of time or money spent in rework, etc.

The second approach looks at related experience where the benefits of M&S have been addressed. In this way the potential benefits to the present program can be estimated. See the main text (p. 54) and Appendix F for examples.

The third approach begins by associating a benchmark value to the system or program to which the M&S is being applied. This might be the annualized life cycle cost of a system, the cost of an exercise, etc. The value added by the M&S is then gauged, for example, in terms of the percentage improvement in performance that might reasonably be expected as a result of the M&S activities. Again, see the main text (p. 54) and Appendix F for further discussion.

KEY QUESTIONS CONCERNING M&S INVESTMENTS (Cont'd.)

5. WHAT IS VALUE ADDED?
   - In Areas of:
     - Performance
     - Cost/efficiency
     - Schedule
     - Quality
     - Risk reduction
     - Expertise
   - What is the goal?
     - Associated standards or metrics?
   - Are there lessons from related experiences?
   - Can rough-but-plausible bounds be used?
     - Cost benchmarks
     - Improvement estimates

The next question addresses the risks associated with using M&S tools. These are outlined here and discussed further in the main text (p. 58). A verification, validation and accreditation (VV&A) process is critical to reducing this risk. The elements of such a process are outlined in the next viewgraph.

KEY QUESTIONS CONCERNING M&S INVESTMENTS (Cont'd.)

6. WHAT ARE THE RISKS?
   - M&S MAY NOT BE RELEVANT TO UNDERLYING PROBLEM
     - M&S are tools that can aid a more basic process
     - Process itself must be desired and supported
       - » Example:
         - Integrated Product Development Team
   - M&S RESULTS MAY NOT BE GENERAL ENOUGH
     - Must be accompanied by analytical process
   - M&S MAY BE UNREALISTIC AND/OR MISLEADING
     - M&S are constructs that reflect their creators': perceptions, approximations, styles, self-interests,...
     - Must be accompanied by independent VV&A process

Here we outline the characteristics of a VV&A process. See the main text (p. 60) for further discussion.

VERIFICATION, VALIDATION AND ACCREDITATION (VV&A)

- MUST ADDRESS:
  - Model
  - Input (data bases)
  - Specific application
- NOT A 0-1 PROCESS, BUT DEGREES OF CONFIDENCE
- BASED ON:
  - Assessments by experienced operators
  - Comparisons to exercise results
  - Applications to known cases
  - Comparisons to other models
  - Checks of code
- MUST MAINTAIN INDEPENDENT MODELS
- MUST BE AN ON-GOING PROCESS
  - Can never completely validate a model
- "SIMULATE BUT VERIFY"

The last question addresses the organizational implementation of the M&S effort. Who will set requirements? Who will pay for it? And, who will actually be responsible for running the effort?

KEY QUESTIONS CONCERNING M&S INVESTMENTS (Cont'd.)

7. WHO SHOULD MANAGE THE M&S EFFORT?
   - Who will determine M&S requirements?
     - Who has responsibility for related M&S tools and applications?
   - Who will provide funding?
   - Who will be responsible for execution, VV&A and upkeep?

(This page intentionally left blank)

APPENDIX C

OVERVIEW OF NAVAL MINE COUNTERMEASURES (MCM)

In this appendix we briefly list the key elements of the MCM force. For details see, for example, References 17 and 18 and references cited therein.

NAVY MINE COUNTERMEASURES ORGANIZATION

POLICY AND RESEARCH, DEVELOPMENT AND ACQUISITION

- Assistant SECNAV, Research, Development and Acquisition
- Program Executive Officer, Mine Warfare (PEO-MIW)
  - Program Managers for Air MCM, Surface MCM, AND Explosive Ordnance Disposal (EOD)
- Director, Expeditionary Warfare Division (OPNAV)
- Naval Air and Sea Systems Commands
  - Coastal Systems Station, Panama City

CONCEPTS, FORCES, OPERATIONS, AND TACTICS

- Commander in Chief, U.S. Atlantic (Pacific) Fleet
  - Surface Warfare Development Group
- Commander, Mine Warfare Command
  - Mine Countermeasures Groups ONE, TWO, and THREE

MCM FORCES

AIRBORNE MCM FORCES

- Two AMCM Squadrons of 12 MH-53E helicopters each
  - Each squadron composed of 6 MH-53E in active force, 6 MH-53E in Naval Reserve Force
  - Plan is to move AMCM squadrons to NAS Corpus Christi

SURFACE MCM FORCES

- 14 newly constructed MCM-1 *Avenger* Class ships
  - Split between active and reserve
- 12 MHC-51 *Osprey* Class ships under construction
  - Split between active and reserve
- One MCM Support Ship (MCS)
  - Conversion of former LPH to commence soon

  All MCM ships to be homeported at Mine Warfare Center of Excellence at Ingleside, Texas
- MCM (MCAC) version of Landing Craft, Air Cushion (LCAC) in development

OTHER MCM FORCES

- Explosive Ordnance Disposal Teams
  - MCM Detachments
  - Marine Mammal Systems (MMS)
- Naval Special Warfare (SEAL) Forces

CURRENT MCM SYSTEMS

MINEHUNTING SONARS

- AN/AQS-14 towed by MH-53E helicopters
- AN/SQQ-30 and AN/SQQ-32 in MCM ships
  - SQQ-30 equipped MCM-1 ships will be backfitted with SQQ-32 sonar

MECHANICAL SWEEP SYSTEMS

- Mk 103 towed by MH-53E helicopters
- AN/SLQ-38(V) towed by MCM-1 Class ships

CURRENT MCM SYSTEMS (Cont'd.)

INFLUENCE SWEEP SYSTEMS

- Mk 104 Acoustic Sweep towed by MH-53E helicopters
- Mk 105 Magnetic Sweep towed by MH-53E
- MK 106 combined Acoustic/Magnetic Sweep towed by MH-53E
- AN/SPU-1W (Magnetic Orange Pipe "MOP") towed by MH-53E
- Mk 2(g) Acoustic Sweep towed by MH-53E (and can be employed by MCM-1 Class ships)
- AN/SLQ-37(V) Acoustic/Magnetic Sweep towed by MCM-1 Class ships

CURRENT MCM SYSTEMS (Cont'd.)

MINE NEUTRALIZATION SYSTEMS

- AN/SLQ-48 in MCM-1 and MHC-51 Class ships

OTHER MCM SYSTEMS

- Mine reconnaissance and neutralization by SEALs
- Mine reconnaissance and neutralization by Mk 4 and Mk 7 MMS
- Mine neutralization by EOD divers
- Mine neutralization by M58 line charges
- Ship degaussing systems

DEVELOPMENTAL MCM SYSTEMS

MINEHUNTING SONAR

- AN/AQS-20 for MH-53E helicopters (and MCAC)

MECHANICAL SWEEP SYSTEMS

- AN/37U deep sweep to be towed by MH-53E helicopters
- AN/SLQ-53 Single Ship Deep Sweep to be towed by MHC-51 Class ships

DEVELOPMENTAL MCM SYSTEMS (Cont'd.)

INFLUENCE SWEEP SYSTEMS

- Advanced Light-Weight Influence Sweep (ALISS) with magnetic and acoustic components, to be towed by helicopters, ships, and MCAC

MINE NEUTRALIZATION SYSTEMS

- "Mission Package 3" for AN/SLQ-48 in ships
- Shallow Water Assault Breaching System (SABRE)
- Distributed Explosive Technology (DET)

MINE RECONNAISSANCE SYSTEMS

- Airborne Laser Mine Detection System (ALMDS)
- ALMDS program *Magic Lantern* (Adaptation)
- Remote Minehunting Operational Prototype (RMOP) also known as "Dolphin"
- Near-term Mine Reconnaissance System (NMRS)

CONCEPT OF OPERATIONS

I. SURVEILLANCE AND RECONNAISSANCE SHOULD PRECEDE MINE CLEARANCE OPERATIONS
   - Surveillance to be conducted by national and/or theater assets
   - Reconnaissance can be conducted by joint assets and naval assets, including MCM assets
   - Intelligence is an <u>essential</u> element of MCM planning

II. MCM OPERATIONS WILL USUALLY BE PRECURSOR TO OTHER NAVAL OPERATIONS (e.g., by carrier battle force or amphibious task force)

III. BATTLE SPACE DOMINANCE IS A PREREQUISITE FOR MCM OPERATIONS
   - This is the job of other combatant forces

IV. MINE CLEARANCE OPERATIONS WILL PROGRESS FROM OPEN OCEAN AREAS AND DEEP WATER INTO CONSTRICTED STRAITS, SHALLOW DEPTHS, AND ASHORE

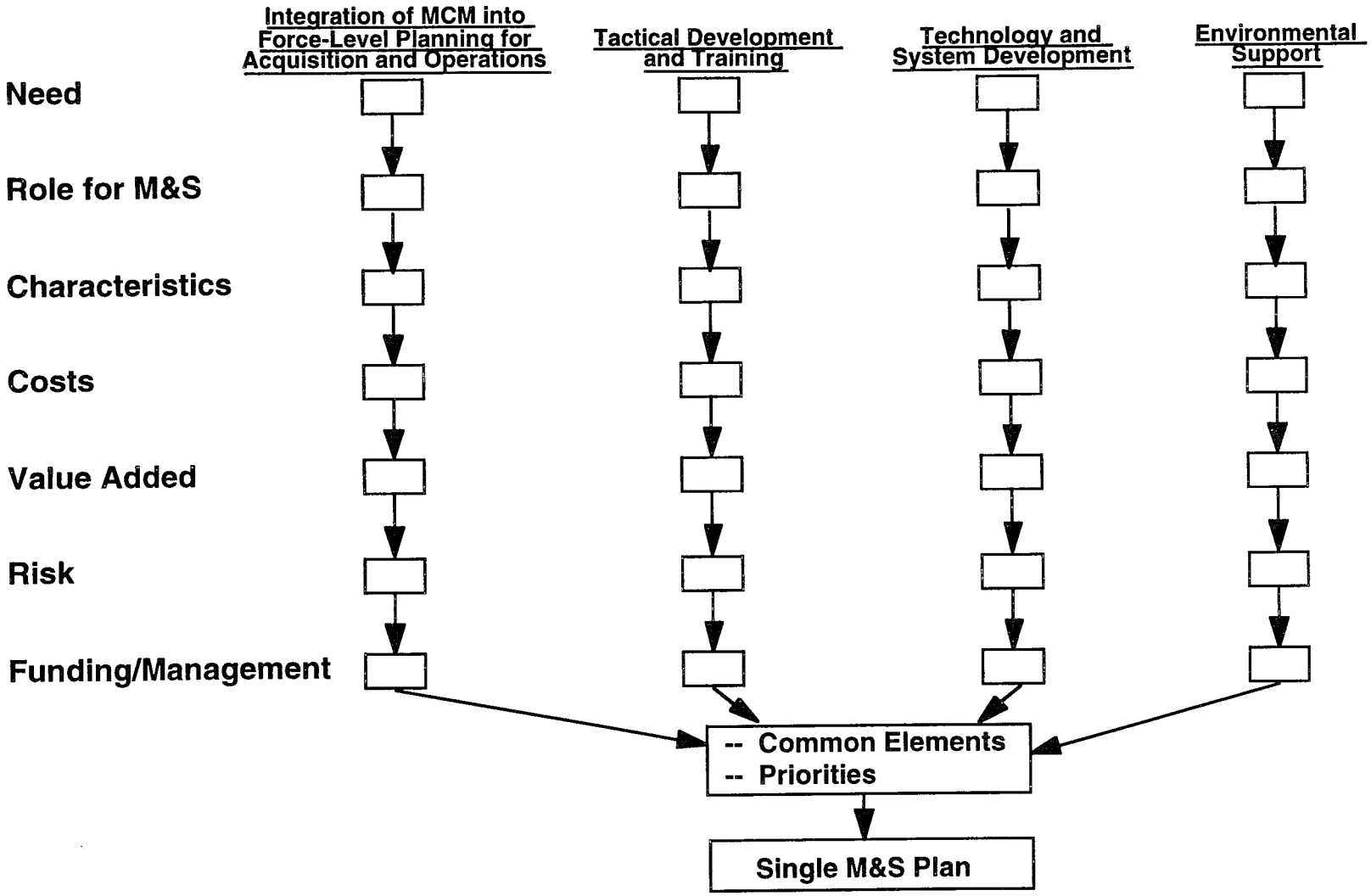
(This page intentionally left blank)

APPENDIX D

APPLICATION OF THE APPROACH TO MCM

The main text illustrated the application of the proposed approach to MCM M&S as shown here by going through it for a particular MCM need, Technology and System Development. This appendix provides additional details in that area and describes the analogous procedures for the three other needs shown: Integration of MCM into Larger-Force Planning, Tactical Development and Training, and Environmental Support. Viewgraphs addressing the seven key questions concerning M&S investments in each of these four areas are presented.

NEEDS-DRIVEN APPROACH TO INVESTING IN M&S: MCM CASE STUDY



1. WHAT IS THE NEED?

NEED

- MCM isolated from Navy planning for force acquisition and operations
- Root cause is "cultural" within Navy
- Persian Gulf experience:
  - MCM critical to naval operations
  - Combatants put out of action by mines
  - Shortfalls in:
    - » MCM systems and organization
    - » Integration of MCM into larger force
      - Surveillance/Reconnaissance
      - Counterstrike
      - C^3I

1. WHAT IS THE NEED? (Cont'd.)

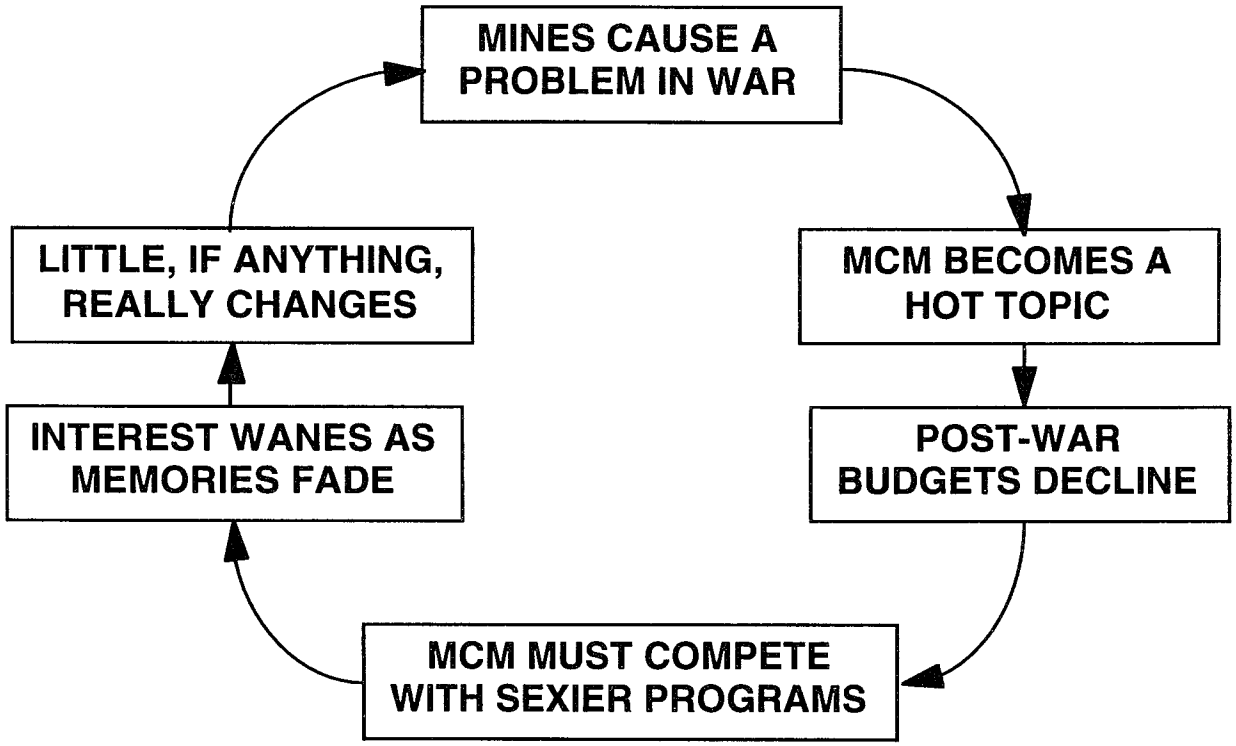
FOCUS

- Unit level (ships, A/C, ...) and above
- Operational performance

PURPOSE

- Support planning decisions
  - Acquisition
  - Operations

MCM INTEREST CYCLE



Source: *The Mine Threat*, CNA Occasional Paper, July 1993.

2. HOW MIGHT NEW M&S TOOLS HELP?

RAISE AWARENESS LEVEL CONCERNING VALUE AND REQUIREMENTS OF MCM IN:

- Acquisition planning
  - Provide more realistic, experience-based input to wargames and analyses
  - Link MCM and force-level simulations
- Operations Planning
  - Help force-wide MCM issues to be recognized:
    - » Surveillance/reconnaissance
    - » Counter-strikes/offensive mining
    - » C^3I
    - » MCM survivability
    - » MCM time requirements
    - » MCM logistical requirements

2. HOW MIGHT NEW M&S TOOLS HELP? (Cont'd.)

- Operations Planning (Cont'd.)
  - Link live and virtual MCM assets to force-level exercises and simulations

FOCUS

- Unit-level (ships, A/C, ...) and above
- Operational performance

PURPOSE

- Support planning decisions

3. WHAT CHARACTERISTICS SHOULD THE M&S TOOLS HAVE?

CONSTRUCTIVE SIMULATIONS

- To provide statistically significant input to Navy and Joint force wargames and analyses on:
  - Effectiveness of MCM operations
  - Impact of MCM systems and operations on other Fleet assets

VIRTUAL SIMULATIONS

- To:
  - Represent MCM systems and operations
  - Link to
    - » Higher level simulations
    - » Live and virtual MCM assets

3. WHAT CHARACTERISTICS SHOULD THE M&S TOOLS HAVE? (Cont'd.)

CHARACTERISTICS:

	Constructive	Virtual
Level of Detail		
- Units (Ships, A/C)	Low	Low
- Threat Mines	Low	Low
- Environment	Low	Low
Interactive	Desirable	Yes (Unit CO and above)
Real-Time	Desirable	Yes (faster)
Distributed	Desirable	Yes
Multisided	Desirable	Yes
Connectivity to Other M&S Tools	Desirable	Yes: To higher level models and live exercises

4. WHAT DO THE M&S TOOLS COST?

EXISTING M&S RESOURCES:

- Stand-alone simulations and analytical models

DESIRED M&S RESOURCES:

- DIS-compatible simulation capability that can represent
  - Threat mines
  - MCM systems and operations
  - Environment
- Semi-automated mine warfare representation for constructive simulations

4. WHAT DO THE M&S TOOLS COST? (Cont'd.)

POTENTIAL COST-SHARING:

- DIS structure provided
- Environmental data bases may be common with ASW and other areas
- Potential applicability to TAC D&E, training, system evaluation

APPROXIMATE COST (See Appendix E): $1-3M acquisition plus $1-3M/yr O&S for single installation; number of nodes will determine total cost

APPROXIMATE TIME TO IOC: 2 yrs

5. WHAT IS VALUE ADDED?

GOAL:

ACQUISITION:

- Demonstrate military worth of MCM forces
- Affect funding decisions; provide more efficient focus for MCM funds

OPERATIONS:

- Improved effectiveness of joint force

RELATED EXPERIENCE: Limited

ROUGH BOUNDS:

ACQUISITION

- Commercial advertising analogy:
  - Advertising costs should be less than anticipated increases in revenues
  - Benchmarks:
    - » Total annual MCM budget
    - » MCM M&S annualized cost
  - M&S costs should be less than anticipated changes in budget

5. WHAT IS VALUE ADDED? (Cont'd.)

OPERATIONS:

- Return on investment analog:
  - Benchmarks:
    - » Value of joint force (annualized life-cycle cost): J
    - » MCM M&S annualized cost: S
  - Required fractional increase in overall performance due to M&S: S/J
- Capital value of losses avoided as result of M&S-enhanced planning

POTENTIAL APPLICABILITY TO OTHER AREAS:

- M&S hardware, software, data bases, facilities, experience
- Also applicable to TAC D&E, training, system evaluation

6. WHAT ARE THE RISKS?

RELEVANCE OF TOOLS TO PROBLEM:

- No guarantee that cultural problem will be affected
  - M&S tools only provide vehicle for an accompanying communications process which requires strong, top-level support

GENERALITY OF RESULTS:

- Need accompanying analytical process to determine input to higher level models

REALISM OF M&S TOOLS:

- Need parallel, continuous VV&A process at MCM force level

OVERALL RISK TO PROGRAM:

- Low--new M&S tools are enhancements, not showstoppers

RISK MITIGATION:

- Maintain current capabilities while gaining experience with new M&S tools

7. WHO SHOULD MANAGE THE M&S EFFORT?

SOME KEY PLAYERS:

M&S REQUIREMENTS AND FUNDING:

- CMWC, N85, DASN (MUW), DASN (EXP. WAR), PEO (MIW), N6, NAVDOC, MCCDC, ...

EXECUTION, VV&A AND UPKEEP:

- N85, PEO (MIW), N81, NAVDOC, MCCDC, ...

1. WHAT IS THE NEED?

NEEDS:

- MCM TAC D&E separated from larger force TAC D&E
  - But must integrate MCM tactics with rest of force:
    - » Surveillance/reconnaissance
    - » Counter-strikes, offensive mining
    - » C3I
    - » MCM survivability
    - » MCM time requirements
    - » MCM logistical requirements
  - Current basing scheme adds to isolation of MCM force
- Current MCM manning and basing schemes present a challenge to force training and readiness
  - Reserves major, but dispersed, component of force
- Fleet exercises:
  - Costly, safety constraints, infrequent, limited scenarios and tactical situations

1. WHAT IS THE NEED? (Cont'd.)

FOCUS:

- Operations of MCM force and individual MCM systems

PURPOSE:

- Improve operational performance

2. HOW MIGHT NEW M&S TOOLS HELP?

POSSIBLE CONTRIBUTIONS:

- Provide linkages (virtual presence):
  - Between MCM and larger force M&S
  - Between remote, dispersed MCM force elements
  - Between "virtual" and "live" forces in exercises
- Provide exercise reconstruction and "what if" excursions to broaden and enhance value of exercise, and to create feedback mechanism between exercises and simulations
- Provide mobile mission-rehearsal capability

3. WHAT CHARACTERISTICS SHOULD THE M&S TOOLS HAVE?

VIRTUAL OPERATIONAL SIMULATIONS

CHARACTERISTICS:

	Tactical Development	Training
Level of Detail:		
– Systems	Low/Moderate	High
– Threat Systems	Low/Moderate	High
– Environment	Low/Moderate	High
Interactive	Yes	Yes
Real-time	Yes (faster)	Yes
Distributed	Yes	Yes (for coordinated training)
Multisided	Yes	Yes (especially for force-level)
Connectivity to Other M&S Tools	– Larger force simulations – Unit simulators – "Live" exercises – Environmental data bases	– Other MCM unit simulations – "Live" exercises – Environmental data bases

4. WHAT DO THE M&S TOOLS COST?

EXISTING M&S RESOURCES:

- Stand-alone systems:
  - Traditional tactical development tools (analytical models, simulations)
  - System trainers (e.g., SSQ-94 being acquired for individual ships)

DESIRED M&S RESOURCES:

- DIS-compatible simulation capability that can:
  - Represent MCM forces, threats and operations
  - Allow man-in-the-loop, Blue/Red dynamics and C3I to be played
  - Link to distant MCM forces for coordinated operations
  - Link to higher force-level TAC D&E simulations
  - Link to "live" exercises
  - Allow hardware -in-the-loop to be played
- Realistic mission-rehearsal capabilities for deployed forces

4. WHAT DO THE M&S TOOLS COST? (Cont'd.)

POTENTIAL COST-SHARING:

- Force-level planning simulations
- System evaluation
- Environmental data bases

APPROXIMATE COST:

- $1-3M acquisition plus $1-3M/yr O&S for core facility plus fleet installations

APPROXIMATE TIME TO IOC:

- 2 yrs

5. WHAT IS THE VALUE ADDED?

GOAL

- Improve MCM effectiveness through improved:
  - Tactics
  - Operator expertise
- Provide enhanced training within operational budget constraints

RELATED EXPERIENCE:

- Resources-to-readiness studies
- Measuring improved performance achieved through training simulators
- Experience with value of tactical decision aids
- Enhancement of exercise results using M&S

5. WHAT IS THE VALUE ADDED? (Cont'd.)

ROUGH BOUNDS:

- Annual cost of M&S versus cost of:
  - MCM force
  - MCM TAC D&E
  - MCM training
  - MCM exercises
- Determine percent improvement that would be required in force or operator effectiveness to pay back M&S investment

POTENTIAL APPLICABILITY TO OTHER AREAS:

- Force level operational and acquisition planning
- System development

6. WHAT ARE THE RISKS?

RELEVANCE OF TOOLS TO PROBLEMS:

- High confidence

GENERALITY OF RESULTS:

- Need accompanying analytical process to design tests and relate to tactical development
- Operator training requires broad range of cases to be available
- M&S itself can be tool for generalizing lessons learned from exercises

REALISM OF M&S TOOLS:

- Need parallel, continuous VV&A process and Fleet involvement

OVERALL RISK TO PROGRAM:

- M&S enhance (vice replace) current processes

RISK MITIGATION:

- Close operator control should moderate risks

7. WHO SHOULD MANAGE M&S EFFORT?

SOME KEY PLAYERS:

REQUIREMENTS, FUNDING:

- CMWC, N7, N4, PEO (MIW), NAVDOC, MCCDC

EXECUTION, VV&A AND UPKEEP

- CMWC, PEO (MIW), CNET, TRAGRUs, NAVDOC, MCCDC, SWDG

1. WHAT IS THE NEED?

NEED:

- Mines major threat in littoral warfare
  - Large number, variety
  - Inexpensive, available to all potential adversaries
  - Increasingly sophisticated (hard to find, neutralize, sweep)
  - Environment difficult (shallow water, surf zone, ...)
- Finding/neutralizing/sweeping pose difficult technical challenges
  - For example:
    - -- buried mines hard to detect
    - -- neutralization often done "by hand"
    - -- pressure mines hard to sweep
  - Current procedures chancy, slow
  - Systems for surveillance/reconnaissance and C3I increasingly important

1. WHAT IS THE NEED? (Cont'd.)

NEED (Cont'd.)

- Need to:
  - Develop the right technology and systems, i.e., operationally effective
  - Shorten the development schedule
  - Increase efficiency in use of development funds

FOCUS:

- Unit level (ships, A/C, ...) and below (systems, sub-systems)
- Operational performance and system structure (at various levels of detail)

PURPOSE:

- Assess military worth of alternatives
- Streamline acquisition process

2. HOW MIGHT NEW M&S TOOLS HELP?

TWO WAYS:

A. OPERATIONAL

- Bring users and developers together at earliest stages of development
  - Vehicle for integrated product development teams
- Provide virtual test bed for proposed systems
  - Operator "hands-on" trials
  - Identify high-payoff systems
  - Early kill (or non-start) of low-payoff systems
- Enable virtual systems to be imbedded in "live" exercises
- Smooth fleet introduction
- Plan, assess, enhance operational testing
- Communicate value of system to decisionmakers

2. HOW MIGHT NEW M&S TOOLS HELP? (Cont'd.)

B. STRUCTURAL

- Computer-aided:
  - Design (CAD)
  - Engineering (CAE)
  - Manufacture (CAM)
- Communication tool for acquisition program
- Provide early identification of problems:
  - Reduce rework
  - Shorten development cycle
  - Increase efficiency of development funds
  - Improve quality

3. WHAT CHARACTERISTICS SHOULD THE M&S TOOLS HAVE?

TYPES:

- Virtual operational simulations
- Virtual structural representations

CHARACTERISTICS:

	Operational	Structural
Level of Detail		
– Systems	Low-High	High
– Threat Systems	Low-High	N/A
– Environment	Low-High	N/A[a]
Interactive	Yes (operators)	Yes (designers)
Real-time	Yes	No
Distributed	Desirable	Yes
Multisided	Yes	N/A
Connectivity to Other M&S Tools	Desirable to – "Live" exercises – Fleet units/trainers – Environmental data bases	Desirable to – Structural – Operational (via performance parameters)

[a] Engineering models may require very high level of detail for environmental representation.

4. WHAT DO THE M&S TOOLS COST?

EXISTING M&S RESOURCES

- Stand-alone simulations and analytical models, no direct operator input
- Traditional engineering and design tools

DESIRED M&S RESOURCES

- DIS-compatible simulation capability that can represent threat mines, and MCM forces and operations
- Computer-aided structural representations for MCM systems

POTENTIAL COST SHARING

- Operational: TAC D&E, training, mission rehearsal
- Structural: Industry, CAD packages may have other applications

APPROPRIATE COST AND TIME: Similar to previous cases

5. WHAT IS VALUE ADDED?

GOALS:

- Improved utility and quality of systems delivered to Fleet
- Reduced time to IOC
- More efficient use of acquisition funds
- Smoother Fleet integration, reduced Fleet introduction costs

RELATED EXPERIENCE:

- Development horror stories
- Examples from Government and Industry:
  - NASA study of value of investments in initial design phase
  - IDA study of costs of lack of design convergence in DoD
  - IDA study of value of physical prototyping
  - Army comparison of live and virtual operational test costs for Non-Line-of-Sight (NLOS) missile

5. WHAT IS VALUE ADDED? (Cont'd.)

RELATED EXPERIENCE: (Cont'd.)

- More examples from Government and Industry:
  - ARPA Simulation - based Design program
  - Army virtual prototyping at Tank Automotive and Armaments RD&E Center
  - MIT study of automotive industry
  - Boeing 777
  - Chrysler Neon

ROUGH BOUNDS

- Cost benchmarks and improvement estimates
  - Examples:
    - » Generic
    - » MCM-1 class ship

5. WHAT IS VALUE ADDED? (Cont'd.)

POTENTIAL APPLICABILITY TO OTHER AREAS:

- Tactical development and tactical decision aids (TDAs)
- Training systems
- Mission rehearsal
- CAD packages applicable to other areas

6. WHAT ARE THE RISKS?

RELEVANCE OF TOOLS TO PROBLEMS:

OPERATIONAL:

- Success depends on support for underlying integrated product development process

STRUCTURAL:

- High confidence

GENERALITY OF RESULTS:

- Need accompanying analytical process

REALISM OF M&S TOOLS:

- Need parallel, continuous VV&A process and Fleet involvement

6. WHAT ARE THE RISKS? (Cont'd.)

OVERALL RISK TO PROGRAM:

- M&S is not for everyone:
  - Up-front costs and schedule may endanger a tentative program
  - Mature programs may be unable to adequately realize M&S benefits

RISK MITIGATION:

- Apply M&S selectively
- Maintain current processes while introducing M&S
- Separately fund general M&S developments
- Be wary of special-purpose M&S systems

7. WHO SHOULD MANAGE THE M&S EFFORT?

SOME KEY PLAYERS:

- M&S REQUIREMENTS AND FUNDING:
  - CNO (N85, N6, N091, ...)
  - CMC
  - ASN (RDA), PEO (MIW)
  - CMWC
  - CNR
  - MCCDC
- EXECUTION AND VV&A:
  - PEO (MIW), PMs
  - CMWC
  - MARCORPS SYSCOM

1. WHAT IS THE NEED?

NEED:

- Change in emphasis:
  - Old: open-ocean, ASW
  - New: littorals, MCM
- Need understanding of, and data bases for:
  - Shallow-water areas including surf zone and ashore
  - High-frequency acoustic properties
  - Non-acoustic phenomena (turbidity, ...)
  - Clutter

FOCUS:

- Scientifically valid representations of environment and signal propagation

PURPOSE:

- Support MCM planning, training, development and acquisition processes

2. HOW MIGHT NEW M&S TOOLS HELP?

POSSIBLE CONTRIBUTIONS:

- High level-of-detail data bases
  - Area, season, conditions, ...
- Fast (real-time) propagation models
- Real-time remote access to data bases and models
- Vivid graphical representation of data

3. WHAT CHARACTERISTICS SHOULD THE M&S TOOLS HAVE?

TYPES:

- Traditional, constructive:
  - Data bases
  - High speed propagation models

CHARACTERISTICS:

Level of Detail	
– Units (ships, A/C, ...)	N/A
– Systems (sonars, ...)	N/A
– Threat Mines	N/A
– Environment	High (but adjustable depending on issues of interest)
Interactive	No Man-in-Loop
Real-time	Yes (faster)
Distributed	Server to other systems
Multisided	No
Connectivity to other M&S tools	Yes, as server

4. WHAT DO THE M&S TOOLS COST?

EXISTING RESOURCES:

- NAVOCEANO data bases and propagation models emphasizing non-coastal areas and low frequency acoustics (ASW)

DESIRED M&S RESOURCES:

- Extended data bases
  - Areas, conditions, clutter, ...
- Acoustic models applicable to high-frequency domain
  - Propagation, scattering, ...
- Non-acoustic properties
  - Turbidity, ...
- Real-time remote access

POTENTIAL COST-SHARING:

- Common interest with submarine warfare, ASW, and other areas

5. WHAT IS THE VALUE ADDED?

GOAL:

- Improve ability to understand and predict MCM system performance in areas and conditions that are currently not well understood

RELATED EXPERIENCE:

- Contributions of acoustic data bases and models to success in submarine and antisubmarine warfare

ROUGH BOUNDS:

- Environmental modeling investment as a fraction of MCM investment
- Compare to estimates of potential gain in MCM effectiveness

POTENTIAL APPLICABILITY TO OTHER AREAS:

- ASW and other warfare areas
- General understanding of inshore ocean environment

6. WHAT ARE THE RISKS?

RELEVANCE OF TOOLS TO PROBLEMS:

- High confidence

REALISM OF M&S TOOLS:

- As in all scientific areas, need continuous supporting data collection and experimentation

GENERALITY OF RESULTS AND OVERALL RISK:

- High confidence

RISK MITIGATION :

- Monitor to assure operational relevance
- First-class scientists, adequately funded

7. WHO SHOULD MANAGE THE M&S EFFORT?

SOME KEY PLAYERS:

REQUIREMENTS, FUNDING:

- CMWC, ASN(RDA), PEO (MIW), other PEOs, ONR

EXECUTION, VV&A AND UPKEEP:

- N096

(This page intentionally left blank)

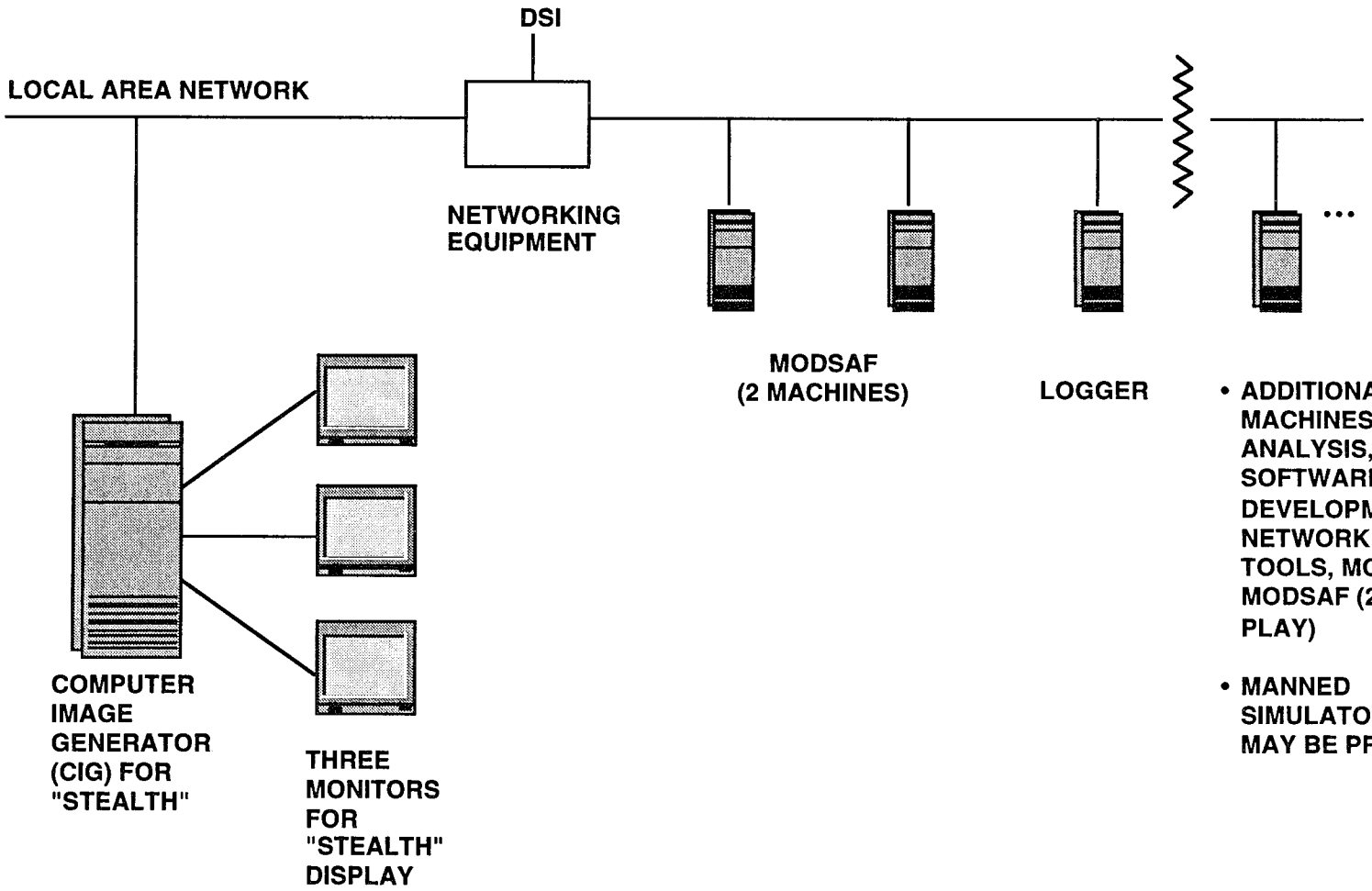
APPENDIX E

COST FOR TYPICAL NODE ON DEFENSE SIMULATION INTERNET

This appendix presents viewgraphs that characterize a typical Defense Simulation Internet (DSI) node along with a range of associated costs. These are shown in the accompanying charts. In the main text we have used a rough estimate of $1-3M (FY-1995) for the acquisition cost and another $1-3M per year for operation and support.

A typical DSI node can: generate forces that can be controlled by a human operator but whose low-level behavior is controlled by a computer program; display a 3-D view of the virtual battlefield and adopt any point of view on, above, or below the battlefield; and log and relay virtual exercises. On the viewgraph, these capabilities are referred to as MODSAF, the Stealth, and the logger, respectively. In addition, a site may have manned simulators and additional machines used for network or exercise analysis, software development, or more workstations for more operators to run MODSAF.

TYPICAL NODES ON DEFENSE SIMULATION INTERNET (DSI)



- ADDITIONAL MACHINES FOR ANALYSIS, SOFTWARE DEVELOPMENT, NETWORK TOOLS, MORE MODSAF (2-SIDED PLAY)
- MANNED SIMULATORS MAY BE PRESENT

TYPICAL NODES ON DSI -- EQUIPMENT ($K)

	VERY LOW BUDGET		LOW BUDGET		MODERATE BUDGET	
STEALTH: CIG	SGI INDIGO2 EXTREME	40	SGI CRIMSON	85	SGI ONYX	200+
MONITORS	---		3 SONY 25" TVs	3	3 PIONEER 50" TVs	7.5
					(add'l hardware)	2.5
MOD SAF (2)	SGI INDY	40	SGI INDIGO2	50	SGI INDIGO2	50
LOGGER	SGI INDY	20	SGI INDY	20	SGI INDY	20
NETWORK EQUIPMENT		2.5		2.5		20
ADDITIONAL HARDWARE		0		0	5 INDIGO2	125
EQUIPMENT TOTAL		102.5		160.5		425
DSI CONNECTION [a] - SECURE						
- 1st YEAR		300		300		300
- SUBSEQUENT YEARS		125/YR		125/YR		125/YR
TOTAL						
- 1st YEAR		402.5		460.5		725
- SUBSEQUENT YEARS		125		125		125

NOTE: HARDWARE DOES NOT INCLUDE MEMORY UPGRADES, SOFTWARE, OR GOVERNMENT DISCOUNTS (PRICES AS OF AUG 9, 1994).

[a] DSI CONNECTION IS $216K FOR A NON-SECURE CONNECTION, $300K FOR A SECURE CONNECTION (AS OF DEC 5, 1994). PRICE INCLUDES SOME NETWORK HARDWARE, INSTALLATION, TRAINING, SUPPORT, AND COSTS OF LEASING A PHONE LINE BETWEEN DSI BACKBONE AND SITE.

TYPICAL NODES ON DSI -- PEOPLE

FUNCTIONS	VERY LOW BUDGET	LOW BUDGET	MODERATE BUDGET
NETWORKING	1	1	1
SYSTEM ADMINISTRATION			1
SOFTWARE DEVELOPMENT		1	1-2
ANALYSIS	1	1	1-2
MANAGEMENT			1-3
TOTAL[a]	2	3	5-9

[a] SUPPORT STAFF NOT INCLUDED, E.G., PROPERTY MANAGER, RECEPTIONISTS, ADMINISTRATOR, LIBRARIAN.

(This page intentionally left blank)

APPENDIX F

IMPROVING THE ACQUISITION PROCESS--SOME EXAMPLES FROM GOVERNMENT AND INDUSTRY

In this appendix we review some examples of how M&S (or activities analogous to M&S) have improved the acquisition process. See References 3, 4, 5, and 14, and references cited in the examples for further details.

IMPROVING THE ACQUISITION PROCESS

- ONE PROBLEM:

  Failure to converge on <u>successful</u> design early

  Inability to define concept → Technical problems →

  Delays in EMD → Increased cost and schedule growth

- SOLUTION DEMONSTRATED IN DOD AND INDUSTRY: New Process
  - integrated product teams (multifunctional groups)
  - early development of prototypes

- M&S IS ONE TOOL TO USE IN A REVISED ACQUISITION PROCESS:
  - means of promoting communication among various groups
  - design tool
  - virtual prototyping to allow early testing

COSTS OF LACK OF DESIGN CONVERGENCE

- NASA STUDY OF THEIR PROGRAMS
  - Programs investing 5% of planned program funds in initial design phase averaged cost overruns of 30%
  - Programs investing 10% averaged cost overruns of 5%
  - 25% of program development costs could be saved by ensuring design convergence before FSD

IDA Paper P-2902, *The Role of Distributed Simulation in Defense Acquisition,* November 1993.

COSTS OF LACK OF DESIGN CONVERGENCE - DOD

	Average Schedule in Months		Reasons for Program Stretch
	Planned	Time Added	
Pre-FSD Programs	30 mos.	30 mos.	Lack of Convergence in Program Definition (11 of 19 cases)
FSD & LRIP Programs	51 mos.	33 mos.	Technical Difficulties (20 of 27 cases) Lack of Convergence in Program Definition (5 of 27 cases)

IDA Paper P-2902, *The Role of Distributed Simulation in Defense Acquisition*, November 1993.

INDUSTRY EFFORTS

- NEW PROCESS = New Management Techniques/Structures
- AUTOMOTIVE INDUSTRY (MIT Study of European, Japanese and American Manufacturers)
  - New process allows 25% faster design of new model
  - Process characterized by four management principles:
    1) Strong project leadership
    2) Full-time, multifunctional teams
    3) Design team communication incl. performance metrics and milestone exit criteria
    4) Development of production equipment in parallel with product

INDUSTRY EFFORTS - BOEING 777

- GOALS:
  - In first 5 years and again in next 5 years
    - » reduce costs by 25%
    - » reduce cycle time by 50%
  - Reduce later changes to engineering design to 50% of 767 changes
- MEANS:
  - Use a common virtual aircraft model throughout development, manufacturing and testing process (CAD tool - CATIA). Physical prototyping only of specific subsystems. First production 777 is first plane built.
  - Use integrated process teams and move responsibility downwards.
- KEY POINTS:
  - Primary challenge: cultural, not technical
    - » main resistance from middle managers, despite top management support
    - » training and education are critical, esp. for management
  - Large initial investment required - $B, exact amount not revealed
    - » training
    - » software development (linking CATIA to specialized models)
  - Specific business goals set to judge effectiveness of process

DOD EFFORTS - PHYSICAL PROTOTYPING

- BENEFITS: – Explore different designs concurrently and reduce risk
  – Early user involvement and testing
- IDA STUDY OF 52 MAJOR PROGRAMS WITH 17 PROTOTYPES (no ships or ground vehicles)
- COSTS:
  - Total development cost growth significantly less for prototypes
    - 17% vs. 62% overall
    - 21% vs. 106% for munitions
  - Fewer unplanned EMD articles
- SCHEDULE:
  - Prototyped programs take about 2 years longer from MS 1 to IOC overall
  - No statistically significant difference for aircraft from MS 1 to IOC
  - Increased time from MS 1 to IOC for prototyped munitions (compounded by complexity), EMD length no different

ARMY EFFORTS - NLOS/SIMNET EVALUATION

- ARMY PERFORMED OPERATIONAL TESTING OF NON-LINE-OF-SIGHT SYSTEM (NLOS - a ground-launched fiber optic-guided missile) USING SIMNET IN 1991
- OBJECTIVES:
  - Determine effect of cue delays on armor and helicopter availability
  - Determine suitability of SIMNET as an operational test tool
    - -- compare outcomes to previous field tests of prototype NLOS (FOG-M)
- COST OUTCOME:

	Captive Flight	Missile Firing	NLOS/SIMNET
Weapon System/Simulator	$ 300,000	$5,100,000	$1,372,128
Test Facilities	3,900,000	1,400,000	150,000
Test Team Personnel	2,445,939	2,292,315	472,006
TOTAL COST	$6,645,939	$8,792,315	$1,994,134
Test Trials* Completed	637	19	936
Cost/Trial*	$ 10,433	$ 462,753	$ 2,130
Length of Test	160 days	63 days	30 days
Trials*/Day	3.98	0.30	31.20
Test Team Personnel	205	205	10 Test Supt 11 Gunners
Personnel Requirements/Trial*	0.32	10.79	0.02

*Captive flight tests were live and performed to examine target detection and identification by operators. A trial consisted of an aircraft with the FOG-M sensor mounted on its underbelly flying over targets. The FOG-M missile firings were also live. The NLOS/SIMNET evaluation was a virtual exercise with missile firings. Its operational purpose was to explore the effect of cue delays on target availability.

ARMY EFFORTS - NLOS/SIMNET EVALUATION (Cont'd.)

OTHER OUTCOMES:

- Availability very low for moving helicopter targets using current sensor systems; good for proposed C2 systems
- In 7 of 8 comparisons, detection and identification of helicopter targets in SIMNET was within 10 percentage points of field test results
- NLOS operational evaluators recommended incorporating simulators into developmental life cycle to reduce costs (design convergence), allow early testing, and allow early development of tactics and doctrine

ARMY EFFORTS - VIRTUAL PROTYPING AT TANK AUTOMOTIVE AND ARMAMENTS RESEARCH, DEVELOPMENT AND ENGINEERING CENTER

- DEVELOPING 8-STEP INTEGRATED PROCESS (to be employed by industry in future)
- USED TO LOOK AT M1A3 DESIGN - BELIEVE OLD PROCESS WOULD BE 3X LONGER

STEP 1 - Develop concepts to meet user requirements

(CAD and solids modeling)

STEP 2 - Performance modeling, linked to solid model, of mobility, stealth, etc. User can make trade-offs

STEP 3 - Combat modeling

(Constructive models - typically model has to be changed to incorporate new system capabilities or tactics)

STEP 4 - Detailed design

(CAD)

STEP 5 - Parallel with 4, virtual factory laid out

ARMY EFFORTS - VIRTUAL PROTOTYPING (Cont'd.)

STEP 6 - Crew Station mockup to explore man-machine interface issues (Simulator linked to DSI)

STEP 7 - Electronic prototype
Integrates computer and electronic systems

STEP 8 - Manufacturing based on CAD/CAM output
(not carried out fully - built one prototype)

APPENDIX G

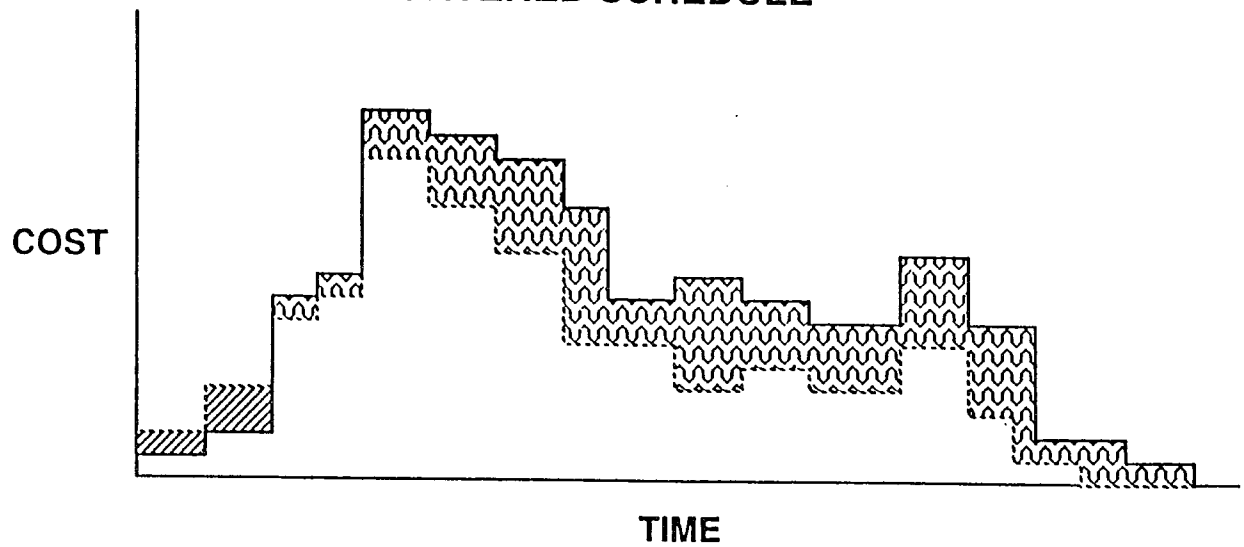
VALUE ADDED IN ACQUISITION CYCLE--GENERIC CASES AND ROUGH BOUNDS

This appendix discusses the use of rough (but plausible) bounds to assess the potential value-added of an M&S investment.

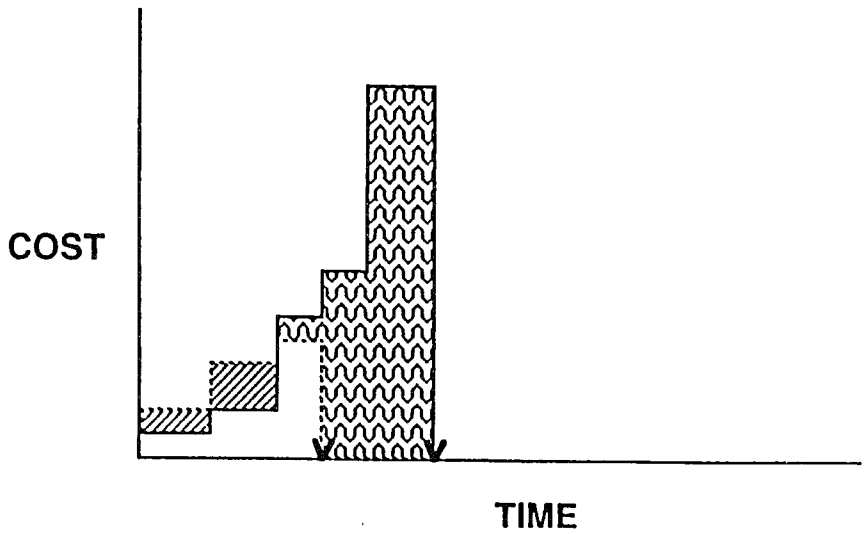
The first chart illustrates this generically. M&S results may add to the early costs (and schedule) of a system in development, but those costs may lead to overall savings later in the program (top figure) or to an earlier realization that a program should be killed (bottom figure).

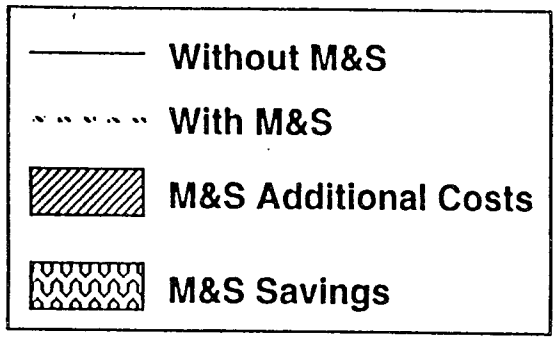
VALUE ADDED IN ACQUISITION CYCLE--SOME GENERIC CASES

1. REDUCED COST/SHORTENED SCHEDULE



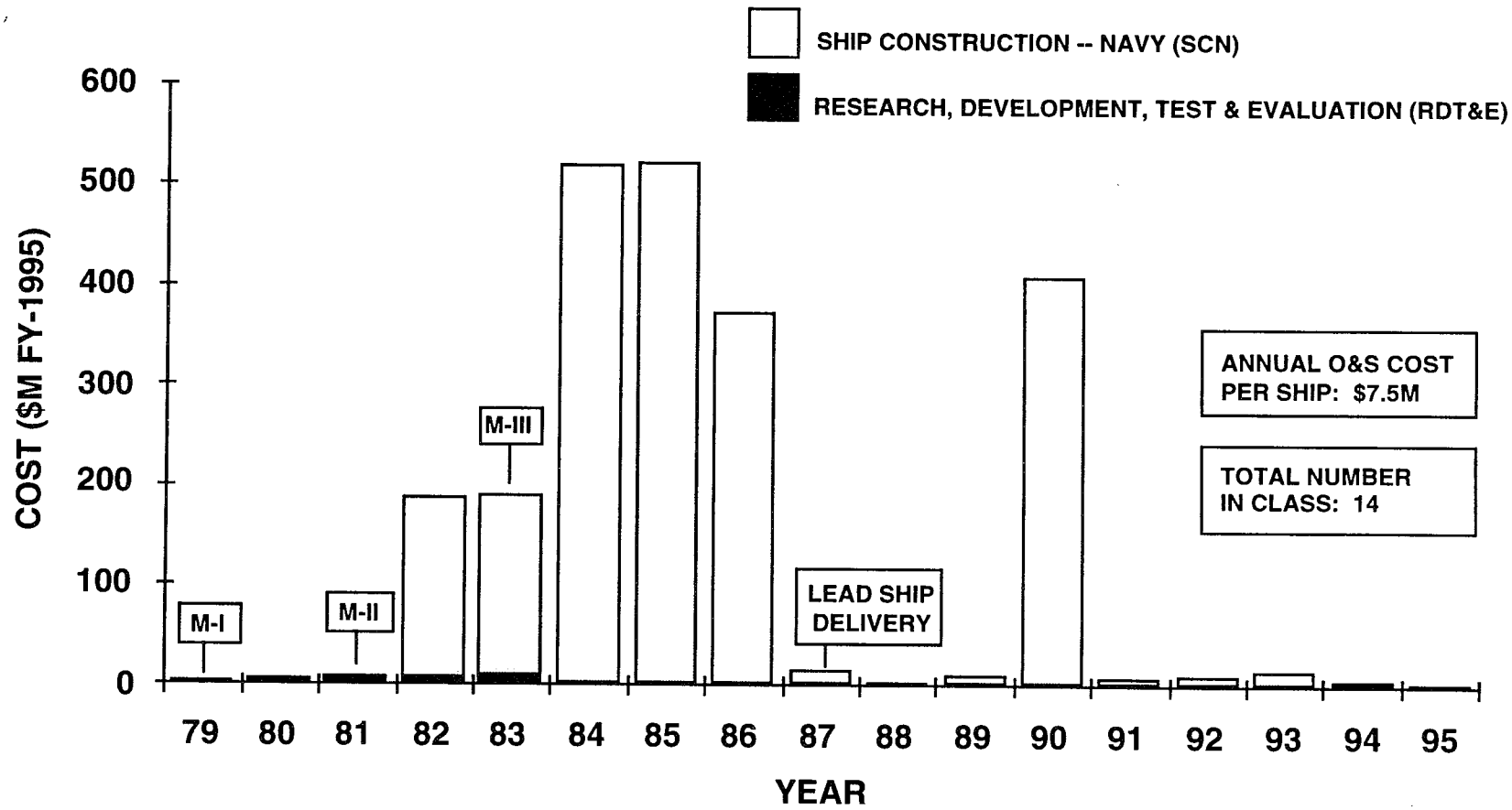
2. EARLIER PROGRAM DECISIONS





This chart shows the actual acquisition cost for the MCM-1 class of minesweepers. RDT&E costs represent less than 1% of the total cost yet have great impact on the characteristics of the system and on its ultimate effectiveness. It is a key leverage point of the acquisition process, and M&S tools can have an important impact during that phase.

ACQUISITION COST: MCM-1 (AVENGER CLASS) MINE COUNTERMEASURES SHIP



If we take the total program cost as a benchmark ($170M per year) then, for example, a $2M per year investment in M&S dedicated to this program need only improve performance (or lower costs) by 1.2% (see next viewgraph) to reach the breakeven point. Some of the ways that this might be achieved are indicated there.

VALUE ADDED BY M&S IN ACQUISITION CYCLE--BOUNDING CASES

- Example: Avenger class (MCM-1) ship
  - 14 units
  - Costs ($M FY-1995)
    - » RDT&E: 32
    - » SCN: 2,252
    - » Annual O&S: 7.5 per ship
    - » Total program: ~$6B
    - » Annualized life-cycle: $170M
- Note:
  - RDT&E costs small
  - Yet development phase drives nature of system
  - Therefore this is high leverage point for M&S contributions
- Total program cost is benchmark for investments in system
- E.g., relevant M&S costs might be $2M per year

VALUE ADDED BY M&S IN ACQUISITION CYCLE--BOUNDING CASES (Cont'd.)

- If so, M&S need only improve system effectiveness (or lower program cost) by ~1.2% to break even
- Examples of improvements:
  - Operational effectiveness
    - » Higher sweep rate through better design
    - » Better C^4I
    - » Better tactics
    - » Increased readiness
    - » Extended lifetime
  - Lower Costs
    - » Improved design
    - » Less rework
    - » Reduced overruns

APPENDIX H

APPROVED DISTRIBUTION LIST FOR IDA PAPER P-3104

APPENDIX H
APPROVED DISTRIBUTION LIST
FOR IDA PAPER P-3104

	Copies
Department of Defense	
Deputy Under Secretary of Defense (Advanced Technology)	
Room 3E1044, The Pentagon	
Washington, D.C. 20301	
ATTN: Mr. John Bachkosky, Room 3E1044	1
Dr. Louis C. Marquet, Room 3D148	1
CDR Dennis K. McBride, Room 3D148	1
Deputy Under Secretary of Defense (Aquisition Reform)	
Room 3E1034, The Pentagon	
Washington D.C. 20301	
ATTN: Ms. Colleen Preston	1
Office of the Under Secretary of Defense (Acquisition Technology)	
Director, Strategic and Tactical Systems	
Room 3E130, The Pentagon 20301	
ATTN: Dr. George R. Schneiter	1

	Copies
Office of the Under Secretary of Defense (Acquisition and Technology)	
Tactical Systems	
Maritime Systems Division	
Room 3D1048, The Pentagon 20301	
ATTN: Dr. Paris Genalis	1
Mr. George Leinweber	1
Assistant Secretary of Defense	
Program Analysis and Evaluation	
Room 2E313, The Pentagon	
Washington, D.C. 20301	
ATTN: Mr. Thomas L. Gibson, Room 2D312	1
Mr. Robert R. Soule, Room 3E835	1
Mr. Michael J. Gilmore, Room 2E330	1
Defense Science Board	
Room 3D865, The Pentagon	
Washington, D.C. 20301-3140	
ATTN: Dr. Craig I. Fields	1
Dr. Jacques S. Gansler	1

	Copies
Advanced Research Projects Agency Correspondence Control, 8th Floor 3701 North Fairfax Drive Arlington, VA 22203-1714	
ATTN: Mr. V. Larry Lynn	1
Dr. H. Lee Buchanan	1
Mr. Ronald Murphy	1
Mr. Larry D. Budge	1
Mr. Gary W. Jones	1
COL Robert P. Reddy, USA	1
CAPT Bruce P. Dyer, USN	1
Director, Research and Engineering Room 3E1014, The Pentagon Washington, D.C. 20301	
ATTN: Hon. Anita K. Jones	1
Mr. George T. Singly	1
Director, Defense Modeling and Simulation Office 1901 North Beauregard Street Alexandria, VA 22311	
ATTN: CAPT James Hollenbach, USN	1
COL Jerry Wiedewitsch, USA	1
Mr. Gary Yerace	1
Dr. Judith Dahmann	1
Defense Systems Management College Attn: FD-SE 9820 Belvoir Road, Suite G38 Fort Belvoir, VA 22060-5565	
ATTN: Mr. Randy C. Zittel	1
Director, Operational Test and Evaluation Room 3E318, The Pentagon Washington, D.C. 20301	
ATTN: Dr. E. Seglie	1

	Copies
Defense Information Systems Agency (DISA) Deputy Director for C4I Modeling, Simulation & Assessment (D8) 8th & S. Courthouse Rd. Arlington, VA 22204	
ATTN: J.L. Osterholz	1
Department of Defense Defense Technical Information Center 8725 John T. Kingman Road, Suite 0944 Ft. Belvoir, VA 22060-6218	2

Department of the Navy

Deputy Assistant Secretary of the Navy (Resources, Analysis and Policy) Room 4E741, The Pentagon Washington, D.C. 20350	
ATTN: The Deputy Assistant Secretary	1
CAPT J. R. McKenzie, Room 5B731	1
Deputy Assistant Secretary of the Navy (C4I/EW/Space Programs) Room 4D745, The Pentagon Washington, D.C. 20350	
ATTN: Mr. M. Langston	1
Deputy Assistant Secretary of the Navy (Mine and Undersea Warfare) Room 5C675, The Pentagon Washington, D.C. 20350	
ATTN: Mr. Edward Zdankiewicz	1
CAPT B. Jaramillo	1
CAPT J. Davis	1

	Copies
Director, Acquisition Reform / SIE Room 578 Crystal Plaza #5 2211 Jefferson Davis Highway Arlington, VA 22202	
ATTN: Mr. D. Porter	1
Mr. Michael D. Roberts	1
Program Executive Officer for Mine Warfare Room 920 Crystal Plaza #6 2221 Jefferson Davis Highway Arlington, VA 22202	
ATTN: RADM R. D. Williams, III	1
Office of the Chief of Naval Operations The Pentagon Washington, D.C. 20350-2000	
ATTN: Director, Space and Strategic Planning	1
Assistant for Strategic Planning (N6C)	1
CAPT Jay Kisstler, USN Room 5C633	1
Deputy Chief of Naval Operations (Resources, Warfare Requirements & Assessments)	
Director, Assessment Division (N81), Room 4A530	1
Mr. Matt Henry, Room 4A522	1
Director, Expeditionary Warfare Division (N85), Room 4A720	1
Mine Warfare Branch	
CAPT B. Vanbelle (N852), Room 5E613	1
Dr. R. Widmayer, Room 5E613	1

	Copies
Director, DoN Modeling and Simulation Management Office 2006 Hawkins Avenue Quantico, VA 22134	
ATTN: Col Paul E. Hanover, USMC	1
Office of Naval Research Head, Ocean Atmosphere and Space Department Room 407-8 Ballston Centre Tower #1 800 North Quincy Street Arlington, VA 22203	
ATTN: RADM M. Y. E. Pelaez, Room 907	1
Mr. F. E. Saalfeld, Room 907	1
Mr. A. E. Bisson, Room 907	1
Dr. J. J. DeCorpo, Room 407-8	1
Col T. J. Singleton, Room 407-17	1
CDR D. McBride, Room 817	1
Space and Naval Warfare Systems Command Director, Naval Warfare Systems Architecture & Engineering Directorate Crystal Park #5 Arlington, VA 22202	
ATTN: RADM L. E. Allen Jr., Room 730	1
Warfare Analysis M&S Group	
Director, CAPT L. L. Dick, Room 730	1
Dep. Dir., G. K. Melcher, Room 730	1
Naval Sea Systems Command Combat Systems Training & Support Division National Center #3 2531 Jefferson Davis Highway Arlington, VA 22202	
ATTN: CAPT Drew Beasely, Room 7E12	1

	Copies
Naval Surface Warfare Center Dahlgren Division Coastal Systems Station Panama City, FL 32407-5000	
ATTN: Dr. Elan Moritz	1
Mr. D. Shepherd	1
Commander Mine Warfare Command 325 Fifth St., S.E. Corpus Christi, TX 78419-5032	
ATTN: RADM John D. Pearson	1
Mr. George W. Pollitt	1

Other Organizations

Center for Naval Analyses 4401 Ford Avenue P.O.Box 16268 Alexandria, VA 22302-0268	
ATTN: Dr. J. Molitoris	1
Dr. D. Perin	1
Naval Studies Board 2101 Constitution Avenue Washington, D.C. 20418	
ATTN: Professor George Carrier C/O Mr. Ron Taylor	1
Johns Hopkins University Applied Physics Laboratory Johns Hopkins Road Laurel, MD 20723-6099	
ATTN: C. Current	1

	Copies
Institute for Defense Analyses 1801 N. Beauregard Street Alexandria, VA 22311-1772	25

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
July 1995

3. REPORT TYPE AND DATES COVERED
Final

4. TITLE AND SUBTITLE
A General Approach to Investing in the New Modeling and Simulation Tools With A Case Study: Naval Mine Countermeasures Programs

5. FUNDING NUMBERS
DASW-01-94-C-0054
T-D1-1153

6. AUTHOR(S)
William J. Hurley, Burnham C. McCaffree, Marchelle M. Stahl

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Institute for Defense Analyses
2001 N. Beauregard Street
Alexandria, VA. 22311-1772

8. PERFORMING ORGANIZATION REPORT NUMBER
IDA Paper P-3104

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Deputy Assistant Secretary of the Navy
for Mine and Undersea Warfare
Room 5C675, The Pentagon
Washington, D.C. 20350

Under Secretary of Defense for
Advanced Technology
Room 3E1049, The Pentagon
Washington, D.C. 20301

Director, FFRDC Programs
2001 N. Beauregard Street
Alexandria, VA 22311

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

Recent advances in computing, networking and visualization have led to dramatic improvements in modeling and simulation (M&S) capabilities. The key issue for DoD is how to successfully convert these impressive technical developments into useful tools for addressing DoD's needs. This study proposes a general framework for deciding how to invest in the new M&S tools. The framework begins with an articulation of a key need facing the decision maker. It then addresses the potential roles for M&S in meeting that need, the implied characteristics of the M&S tools, their costs, value added, risks, funding, and management. It then repeats this process for a range of needs facing the decision maker, and, by looking for common elements and setting priorities, seeks to integrate the results across all of the needs into a single M&S plan. As a case study, this process is applied to the area of naval mine countermeasures (MCM). No detailed road map for M&S investment is given, but the issues that arise are described along with some methods that may be used to resolve them. A strawman approach to MCM M&S investments is presented. This is a "fleet first" approach which focuses initially on training, tactical development and mission rehearsal with later applications to acquisition once acceptance of the M&S tools, and confidence in them, have been established. The general framework described should be applicable to any area where the benefits and costs of the new M&S tools are under consideration.

14. SUBJECT TERMS
mine countermeasures, MCM, modeling, simulation, M&S, investment plan

15. NUMBER OF PAGES
216

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT
UNCLASSIFIED

18. SECURITY CLASSIFICATION OF THIS PAGE
UNCLASSIFIED

19. SECURITY CLASSIFICATION OF ABSTRACT
UNCLASSIFIED

20. LIMITATION OF ABSTRACT
Same as Report