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# MK 92 MOD 2 Fire Control System Maintenance Advisor Expert System : implementation and deployment

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# NAVAL POSTGRADUATE SCHOOL
## Monterey, California



# THESIS

**MK 92 MOD 2 FIRE CONTROL SYSTEM MAINTENANCE ADVISOR EXPERT SYSTEM: IMPLEMENTATION AND DEPLOYMENT**

by

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September 1996

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This thesis perpetuates research aimed at deploying a diagnostic expert system for the MK 92 Mod 2 Fire Control System to 28 Oliver Hazard Perry class fast frigates. Referred to as the Maintenance Advisor Expert System (MAES), this expert system is being jointly developed by the Naval Postgraduate School and Port Hueneme Division, Naval Surface Warfare Center (NSWC PHD).

This thesis focuses on the long-term implementation issues related to deploying MAES to the fleet, integrating MAES into the formal training pipeline, and transitioning life cycle support for MAES to NSWC PHD. MAES long-term implementation issues, which include hardware, software, documentation, and training requirements, are examined within the context of implementation factors and risks historically associated with deploying expert systems.

Plans for deploying MAES to the fleet and integrating MAES into the formal training pipeline are provided. As part of the documentation necessary to transition life cycle support of MAES to NSWC, a System Level Description document is also provided.

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# MK 92 MOD 2 FIRE CONTROL SYSTEM MAINTENANCE ADVISOR EXPERT SYSTEM: IMPLEMENTATION AND DEPLOYMENT

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# I. INTRODUCTION

## A. BACKGROUND

In early 1992, the Naval Surface Warfare Center, Port Hueneme Division (NSWC PHD) began development of a diagnostic expert system that would assist shipboard fire control technicians in troubleshooting the MK 92 Mod 2 Fire Control System (FCS). Found aboard the U.S. Navy's Oliver Hazard Perry class of guided missile fast frigates, the MK 92 Mod 2 FCS is based on 1970's technology and has evolved into a costly and difficult system to maintain. Outside technical assistance is often required by the ships to troubleshoot problems with the MK 92 Mod 2 FCS.

At the request of NSWC PHD engineers in late 1992, Naval Postgraduate School (NPS) faculty and graduate students joined NSWC PHD in their efforts to develop this expert system which is called the Maintenance Advisor Expert System (MAES). This thesis continues the research, development, and implementation efforts involved in fielding MAES to the fleet.

The development and fielding of MAES, though protracted due to funding constraints, could not come at a more opportune time. MAES promises to improve fault isolation, reduce reliance on overburdened technical representatives, and decrease unnecessary replacement of perfectly good repair parts. (Powell, 1993) All of these benefits offer considerable leverage to shipboard technicians who are tasked with maintaining a system that will receive few modifications or improvements over the system's remaining useful life.

MAES offers shipboard fire control technicians a powerful tool to assist them in their daily efforts to support MK 92 Mod 2 FCS. However, without proper implementation, MAES could very easily be cast aside and its benefits never realized. Having the right system at the right time means nothing if the system is never used.

## B. OBJECTIVES

The objective of this thesis is to address the long-term implementation and deployment issues which should be considered prior to diffusion of MAES to applicable ships. It provides a three-tiered implementation plan for MAES. The plan covers MAES implementation to the fleet, integration into the formal training pipeline, and transition of life cycle support to the Naval Surface Warfare Center, Port Hueneme Division (NSWC PHD). This plan could serve as a framework for future implementation projects if the MAES concept is expanded, and expert systems are developed for other maintenance intensive systems.

## C. RESEARCH QUESTIONS

This thesis pursues answers to three primary research questions which are generally analyzed according to hardware, documentation, training, and support requirements.

1. What are the implementation issues for deploying the MK 92 Mod 2 FCS MAES to all MK 92 Mod 2 Ships? Specifically, what are the implementation issues with respect to:

    a. Hardware requirements
    b. Documentation requirements

c. Training requirements
d. Support requirements/procedures

2. What are the requirements for integrating the MK 92 Mod 2 FCS MAES into the MK 92 Mod 2 "C" School curriculum at Fleet Training Center (FTC), San Diego and Fleet Combat Training Center (FCTC), Dam Neck? Specifically, what are the implementation issues with respect to:

a. Documentation requirements
b. Hardware/Software requirements
c. Course materials requirements

3. What are the requirements for transitioning life cycle support for the MK 92 Mod 2 FCS MAES software to NSWC PHD? Specifically, what are the implementation issues with respect to:

a. Documentation requirements
b. Hardware/Software requirements
c. Training requirements

## D. SCOPE

This thesis focuses on providing (1) an implementation and deployment plan for installing the MK 92 Mod 2 FCS MAES aboard all MK 92 Mod 2 ships; (2) an integration plan for incorporating the MK 92 Mod 2 FCS MAES into the MK 92 Mod 2 "C" School curriculum at the Fleet Training Centers; and (3) a transition plan for shifting life cycle support for the MK 92 Mod 2 FCS MAES software to NSWC PHD.

## E. ORGANIZATION OF THE STUDY

This thesis contains six chapters and six appendices which are organized as follows:

Chapter II, Building an Implementation Strategy, discusses the implementation factors and the risks that should be considered when developing the MAES deployment plan.

Chapter III, Deploying MAES to all MK 92 Mod 2 FCS Ships, details the long-term implementation plan for MAES. The chapter covers hardware, documentation, training, and support requirements related to MAES's installation.

Chapter IV, Integration of MAES into the MK 92 Mod 2 FCS "C" School Curriculum, discusses the on-going relationship between the Naval Postgraduate School (NPS) and the Fleet Training Centers (FTC) with regards to MAES testing and evaluation. This chapter outlines the actions required to formally integrate MAES into the MK 92 Mod 2 FCS "C" School Curriculum.

Chapter V, Transitioning Life Cycle Support for MAES to NSWC PHD, describes the documentation, software/hardware requirement, training requirements, maintenance procedures, and annual support costs associated with the transfer of MAES from NPS to NSWC PHD.

Chapter VI, Summary and Conclusions, summarizes the author's conclusions regarding the long-term implementation issues related to the deployment of MAES. The implementation issues are discussed within the framework of the previously described three-tiered implementation plan.

Appendix A, Fleet Training Center Laboratory Experiments with MAES, provides a description of the evaluation procedures and results of MAES performance tests conducted at Fleet Training Center, San Diego.

Appendix B, Implementation Plan for Deploying MAES to all MK 92 Mod 2 FCS Ships, contains the implementation plan for deploying MAES to the ships.

Appendix C, Integration Plan for Including MAES in the MK 92 Mod 2 FCS "C" School Curriculum, describes actions required to formally integrate MAES into the MK 92 Mod 2 FCS "C" School curriculum.

Appendix D, MAES System Level Description, provides a preliminary version of one of the four documentation requirements needed by NSWC to maintain MAES.

Appendix E, Forms, includes forms which might be used to report errors, recommend changes, or seek help.

Appendix F, Software Transition Plan, provides a standard template for preparing software transition plans.

Appendix G, Hardware, Software, and Documentation Requirements, provides a summary of anticipated hardware, software, and documentation requirements necessary to field MAES to ships, integrate it into the "C" school curriculum, and transition life cycle support for it to NSWC PHD.

# II. BUILDING AN IMPLEMENTATION STRATEGY

## A. OVERVIEW

Building a long-term implementation strategy involves several steps. First, the risks associated with the project must be identified. Second, those factors important to a successful implementation plan must be targeted. And third, an implementation plan should be developed that mitigates the risks while focusing on the implementation factors most critical to success.

This chapter begins with background information on risk management. Next, a risk management plan for deploying MAES is discussed. An analysis of the factors important to implementation success follows. This chapter concludes with a discussion of how implementation factors and risks should be incorporated into an implementation plan.

## B. BACKGROUND ON RISK MANAGEMENT

Risk management is not a new discipline. Its origins can be traced back as far as the Babylonians, to around 3200 BC. (Boehm, 1989) Within DoD, risk management gained the attention of Deputy Secretary of Defense David Packard in 1969 when he wrote that inadequate risk assessment was a major problem in the area of systems acquisition. In 1986, the General Accounting Office (GAO) cited deficiencies in the methodology used to assess technical risk within 25 program offices. GAO's review acted as the catalyst for more intense consideration of risk management throughout DoD.

(DSMC, 1989) The Naval Doctrine Publication, *Naval Warfare*, also emphasizes the importance of effective risk management. (NDP, 1994)

Though narrowly applied to implementation issues in the case of MAES, risk management is a process considered more broadly in areas such as systems acquisition, security planning, and software development. (DSMC, 1989; Rainer, et al, 1991) DoD acquisition policy regulations require program managers to continually assess program risks and emphasize the importance of understanding risks. (DoD Directive 5000.1, 1996)

Even with a small project such as MAES, identifying and understanding risks can play an important part in the project's success. Dart and Krasnov (1995) put the importance of risk management (RM) into perspective:

> RM is a key to successful change. It provides the foundation for the deployment team to make the right kinds of decisions when introducing change and prioritizing all the issues that need to be addressed. RM is a pro-active way of fostering positive change. It enables all the potential users of the new solution to get involved in the change at the earliest possible time and contribute their concerns and suggestions for risk mitigation strategies. (Dart and Krasnov, 1995)

The terms "risk" and "risk management" mean different things to different people. As a result, a study of risk and risk management should begin by defining these terms as they will be applied to MAES implementation issues.

Risk can be defined as "the probability of an undesirable event occurring *and* the significance of the consequence of occurrence." (DSMC, 1989) Expanding this definition, one can specify three key elements of risk, (1) the existence of an event that can cause change, (2) the event has some likelihood of occurrence, and (3) the event has some undesirable consequence. Based on this expanded definition, risk can be controlled by either reducing the likelihood that a certain risk event will occur or by minimizing the impact of the event should it occur, or both. (Cleland, et al, 1993)

Whether approached from a system acquisition, security, or software project perspective, risk is a complex concept subject to individual perception. (DSMC, 1989; Rainer, et al, 1991) Typically, risk is characterized by the fact that it is to some degree unknown, it changes with time, and it is manageable. The term "risk management" encompasses the processes used to manage risk. (DSMC, 1989)

Risk management is "a method of managing that concentrates on identifying and controlling the areas or events that a have a potential for causing unwanted change." (Caver, 1985) For the risk management process to work, it must become "formal, systematic, and applied in a disciplined manner. (DSMC, 1989) Different approaches for dealing with risk are offered in the risk literature. (DSMC, 1989; Boehm, 1989; Cleland, et al, 1993)

The various approaches or structures are typically very similar but they are not connected by standard terminology. Using different definitions to describe the same basic concepts creates confusion.(DSMC, 1989) To avoid miscommunication, a detailed description of expectations should be outlined prior to beginning the risk management process. (Cleland, et al, 1993) Selecting and describing a risk management structure will be the starting point for the MAES risk management plan.

The risk management structure provided by the Defense Systems Management College (DSMC) and illustrated by Figure 2-1 will be used to analyze the risks associated with MAES's implementation. As shown in Figure 2-1, there are four essential activities associated with risk management. These activities include risk planning, risk assessment, risk analysis, and risk handling. (DSMC, 1989)

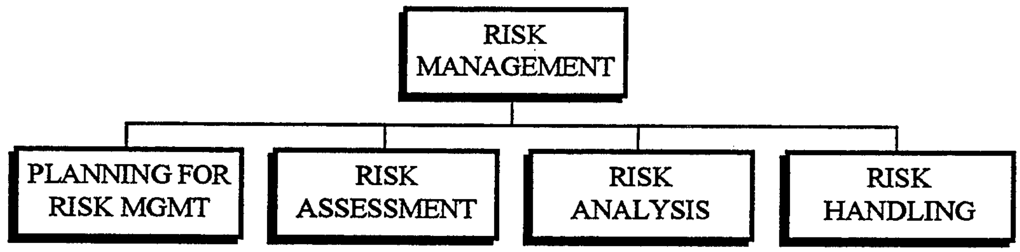


**Figure 2-1. Risk Management Structure (From DSMC, 1989)**

Planning for the management of risk aims to eliminate risk wherever possible, isolate and minimize risk, develop alternate courses of action, and establish a strategy for handling those risks that cannot be avoided. (DSMC, 1989) Research has shown that most software disaster projects could have been avoided or greatly reduced their problems, "if there had been an explicit early concern with identifying and resolving their high-risk elements." (Boehm, 1989)

To have control over risk it is necessary to be fully informed about the risk and to have thought through the actions required to eliminate, minimize, or contain the effects of undesirable occurrences. (Hannsson, 1989; DSMC, 1989) As the first activity in the process, risk management planning forces "formal, systematic" thought about the objectives discussed above. (DSMC, 1989)

The next activity is risk assessment which involves two steps. The first step is risk identification which involves identifying the significant risks and then describing them in an understandable way. Techniques such as expert interviews and "lessons learned" comparisons are used in the assessment phase to develop narrative statements describing the program risks. (DSMC, 1989)

Preliminary quantification is the second step in the risk assessment phase. The primary purpose of this step is to prioritize the identified risks through organization and stratification. Neither the risk planning phase nor the risk assessment phase requires heavy mathematical study; however, some baseline for rating risks should be created to eliminate ambiguity. A simple rating scheme is preferred. (DSMC, 1989)

The next phase of risk management concerns risk analysis. Difficult to clearly separate from the risk assessment phase, this phase involves issues such as the consequences if the risk becomes reality and the available ways of dealing with it. The most useful product of this phase is a risk watchlist which acts as a handy tool for tracking risk activities. (DSMC, 1989)

The final activity in the risk management process is risk handling which is the process of taking actions to mitigate or eliminate the unwanted results of risk. The actions describing risk handling techniques can be categorized as avoidance, control, assumption, transfer, and knowledge and research. (DSMC, 1989)

Selecting a lower risk choice from several alternatives represents a risk avoidance decision. The most common of the risk handling techniques, risk control involves the continual monitoring and adjustment of a program based on a risk reduction plan. While risk assumption represents a decision to accept some consequences, risk transfer includes those actions taken to reduce risk exposure by sharing the risk with someone else. (DSMC, 1989)

Even though it is not a "true" risk handling technique, knowledge and research provides information in support of the other techniques and serves as a reminder that risk management is a continual process. (DSMC, 1989) The risk management process should be viewed as a continuous loop representing a never ending process. (Cleland, et al, 1993)

## C. MAES RISK MANAGEMENT PLAN

The MAES risk management plan will generally follow the risk management structure shown in Figure 2-1. The risk planning phase will not be specifically addressed since the risk management background discussion adequately covers the activities comprising this phase. The MAES risk management plan begins with the risk assessment phase.

### 1. Risk Assessment

Risk assessment involves two steps. The first step is risk identification and the second step is preliminary quantification.

#### *a. Risk Identification*

Risk identification requires that significant risks be identified and described in an understandable way. Part of the risk identification phase involves activities such as expert interviews and "lessons learned" comparisons. Risk identification was begun for the MAES project by discussing "risks" with Susan Dart of Continuus Software, an expert in the field of software configuration risk management. "Lessons learned" comparisons were derived from conversations with NSWC Louisville representatives, U.S. Army Research Laboratory engineers, and NAVSEA engineers about their respective experiences with expert systems implementations.

Categorizing the risks simplifies the process of risk identification and will be expanded during the second step to develop a risk rating scheme. According to Dart (1996) risks can be grouped into three categories - technical, people, and organizational. Based on these categories we identify the risks associated with MAES as follows (Dart and Krasnov, 1995; Dart, 1996):

Technical Risks - evolve around the software development and maintenance environment and the structure of the user's applications.

- Knowledge Accuracy. Knowledge accuracy concerns the domain expert's rendering of his knowledge in a manner that is both technically accurate and consistent with accepted troubleshooting practices.

- Maintainability. Maintainability risks involve how easily the software can be updated with improvements or corrections and the effort required to keep all versions of MAES current.

- Software Reliability/Quality/Availability. This multiple risk represents the need for the software to readily provide results which can be trusted as the best possible troubleshooting solutions.

- Supportability. Supportability risk has two dimensions, one internal and one external to the MAES project. The internal supportability risk comes from the uncertain budgetary environment surrounding MK92. The external supportability risk comes from SoftSell, the software company that created the expert system developmental software used to build MAES. If SoftSell drops support of this software or goes out of business it could complicate future supportability.

- Hardware Durability in a Shipboard Environment. Hardware durability is a risk because of the numerous harsh elements, such as electromagnetic interference (EMI), high heat, frequent power surges, water, and corrosives, which are common in a shipboard environment. Fielding MAES on a commercial-off-the-shelf (COTS) laptop computer raises the risk that that the COTS laptop will be too fragile for a shipboard environment.

- Knowledge and Program Documentation. Knowledge and program documentation risk pertains to the accuracy and completeness of the written references available to support the knowledge represented by the software and the format of the underlying software development program.

- Data Gathering. The data gathering risk stems from the desire to collect data after MAES is fielded to illustrate the impact of MAES. The risk comes from historically low survey response rates and from the difficulty in selecting a metric which can quantitatively reflect MAES's impact.

People Risks - evolve around incorrect expectations, poor communications, fear and lack of knowledge.

- Computer Literacy. This risk arises from the possibility that some of the Fire Control (FC) technicians will not be familiar with computers and/or the Windows® environment.

- Technical Representative Resistance. Driven to some extent by perceptions, this risk encompasses the possibility that technical representatives (or tech reps) will resist this technology because they feel that MAES challenges their expert authority or they believe that MAES is designed to replace them. The very limited role the tech reps played in the development of MAES may also contribute to their resistance.

- Fire Control Technician Resistance. The risk from the FC's is that they will not freely change their troubleshooting paradigm and consequently MAES will not be used. More experienced FC's may be committed to "the way it's always been done" or they may simply enjoy the challenge of isolating faults on their own. Additionally, senior FC's, who have always relied on the technical manuals or technical representatives for guidance, may not trust MAES or encourage its use.

- Hierarchical Resistance. This risk deals with the political considerations inherent in the Navy's hierarchical structure which makes individuals sensitive to seemingly minor issues and peripheral concerns.

- Attitude Towards Change. This risk weaves through every element of this project that involves people. If decision makers and potential users of MAES are not open minded about the possibilities of this technology then this project and any future projects that might advocate this technology are jeopardized.

Organizational Risks - evolve around organizational politics and boundaries and cultural change.

- Chain-of-Command Support. This risk arises because the Naval Postgraduate School (NPS) operates outside of the chain-of-command normally associated with fielding production level systems to the fleet. In dealing with the various commands, such as Naval Sea Systems Command (NAVSEA), COMNAVSURFLANT, COMNAVSURFPAC, CINCLANTFLT, CINCPACFLT, Fleet Training Center (FTC), San Diego, Fleet Combat Training Center (FCTC), Dam Neck, NSWC PHD, Fleet Technical Support Center, Atlantic (FTSCLANT) and Pacific (FTSCPAC), and the various ships, the MAES deployment team must establish its own credibility while concurrently building support for MAES. The risk is that one or more of the commands will withhold their support of MAES because of concerns about the program or NPS's role in the development.

- Fleet Training Centers' (FTC) Acceptance and Adoption. As the front-line trainers of FC technicians, the FTC's create the students' first image of MAES. First impressions are important. Risk arises if the training centers do not accept and readily advocate MAES as a useful troubleshooting tool.

- Fleet Technical Support Center (FTSC) Endorsement. FTSC representatives work closely with the ships in providing troubleshooting assistance for more complex problems and generally are well-respected for their technical expertise. Because of their role as technical experts who work closely with shipboard technicians, they pose a risk to MAES if they do not endorse it as a viable troubleshooting tool. If they do not accept MAES then it is unlikely that shipboard technicians will trust the system.

- System Use by Fire Control Technicians. This risk lies with the older, more experienced FC's who may not trust MAES or may feel that they do not need MAES. Negative attitudes on the part of experienced FC's may create sufficient pressure to keep junior FC's from using MAES.

- MAES Deployment Training. The transient nature of Navy personnel combined with ship deployments create the risk that personnel will not receive proper MAES training.

- Deployment Funding. While MAES is funded through evaluation at COMNAVSURFLANT, funding for deployment is not a certainty. Deployment funding will include funding to field MAES - (computers and training), funding to transition MAES to the Post-Deployment System Support (PDSS) activity and the FTC's, and funding to rework the evaluation software to a production system.

#### *b. Preliminary Quantification*

Preliminary quantification is the second step in the risk assessment phase. The primary purpose of this step is to prioritize the identified risks through a simple rating scheme. The rating scheme for the deployment of MAES contains four risk classifications which are described below:

- Class I: Event poses a minor threat to the success of MAES. Little management attention is necessary to overcome this risk.

- Class II: Event poses a moderate threat to the success of MAES. Active management attention and monitoring is required to overcome this risk.

- Class III: Event poses a significant threat to the success of MAES. Close management attention and monitoring is required to overcome this risk. Improper treatment of this risk could jeopardize the project.

- Class IV: Event poses an extreme threat to the success of MAES. Regardless of management attention, the occurrence of this event will jeopardize the project.

In applying these risk classifications to the applicable events the consequence of occurrence has been incorporated into the classification while the likelihood of occurrence will be subjectively considered as the specific events are classified. Table I illustrates the results of subjectively rating each risk on a scale of one to five, one being low and five being high, for the risk elements, likelihood of occurrence and consequences of occurrence. Ratings were determined based on interviews, historical trends, and risk literature. By no means scientific, the purpose of this classification scheme is merely to provide a method for organizing risks.

Based on the combined risk elements' scores shown in Table I, risks are classified as either Class I, II, III, or IV risks. Class I risks are those risks with combined risk elements' scores between three and five. Class II risks are those risks with combined risk elements' scores of six or seven. Class III risks are those risks with combined risk elements' scores of eight or nine. Class IV risks are those risks with combined risk elements' score of ten. Table II summarizes the risk classifications. Note that no class IV risks exist for MAES. Also note that even though there are more technical risks than people or organizational risks, the risk classification results show that more managerial attention should be focused on the people and organizational issues.

As an overview of how ratings were assigned to the risk elements consider the following examples. Hardware durability, a Class I risk, received a likelihood of occurrence score of one and a consequences of occurrence score of four for a combined risk elements' score of five. While numerous harsh elements found in the shipboard environment threaten COTS equipment, personal experience has shown that COTS computers are far more durable than one would expect and thus the likelihood of this risk occurring is minimal. Alternatively, if the risk does occur, meaning the hardware is unreliable, the consequences will be severe.

Fire Control Technician resistance, a Class II risk, received a likelihood of occurrence score of two and a consequences of occurrence score of four for a combined risk elements' score of six. Feedback received from fire controlmen at FTC, San Diego, and aboard the MAES prototype test ship, reveals that sailors will be receptive to MAES which indicates that the likelihood of occurrence for this risk is small. If the risk does occur the consequences could be severe since resistance would equate to non-use of MAES.

Chain-of-Command support, a Class III risk, received a likelihood of occurrence score of three and a consequences of occurrence score of five for a combined risk elements' score of eight. At least ten different commands, including several different departments within a few of the commands, will be involved in the deployment of MAES. The large number of individuals and commands representing their own interests creates a likelihood that one or more of the commands will withhold full support of MAES. If this occurs support from other commands may fall like dominoes.

As a possible scenario, suppose that either the Fleet Combat Training Center (FCTC), Dam Neck or the Fleet Technical Support Center (FTSC), Atlantic does not fully support MAES. Without the endorsement of FCTC and/or FTSC, COMNAVSURFLANT would probably withdraw their sponsorship of MAES. Risk literature clearly specifies that full management support is required for implementation success. If MAES does not receive full chain-of-command support the consequences could be devastating. (Bradley and Hauser, 1995)

With more experience implementing expert systems, it might be desirable to develop risk templates that define risk areas and the likelihood and consequence of risks' occurrence based on past experience. McDonnell Douglas Aerospace uses such an approach to develop risk templates that can be applied to common risks among different software projects. The templates are used to assign a value of low, minor, moderate, significant, or high to the likelihood and consequence of occurrence for each risk. These values are entered into a two-dimensional matrix to determine the risk level. By relying on past experience, this approach removes some of the subjectivity inherent in determining risk levels. (Mason and Boyd, 1995)

### 2. Risk Analysis

Issues such as the consequences if the risk becomes reality and the available ways of dealing with it are tackled during the risk analysis phase. Using the risk classifications from Table II, risks requiring the most resources are discussed first. Due to time and funding constraints risk prioritization is necessary so that efforts can be focused on the areas that provide the greatest return.

| Risk | Risk Elements | | Score |
|---|---|---|---|
| | Likelihood of Occurrence | Consequences of Occurrence | |
| Knowledge Accuracy | 3 | 3 | 6 |
| Maintainability | 2 | 4 | 6 |
| S/W rel/qual/avail | 2 | 5 | 7 |
| Supportability | 2 | 2 | 4 |
| H/W durability | 1 | 4 | 5 |
| Documentation | 1 | 3 | 4 |
| Data Gathering | 3 | 2 | 5 |
| | | | |
| Computer Literacy | 1 | 2 | 3 |
| Tech Rep Resistance | 5 | 4 | 9 |
| FC Tech Resistance | 2 | 4 | 6 |
| Hierarchical Resistance | 3 | 5 | 8 |
| Attitude Towards Change | 3 | 3 | 6 |
| | | | |
| Chain-of-Command Support | 3 | 5 | 8 |
| Training Center Acceptance and Adoption | 1 | 4 | 5 |
| FTSC Endorsement | 3 | 5 | 8 |
| System Use by FC's | 3 | 5 | 8 |
| MAES Deployment Training | 4 | 4 | 8 |
| Deployment Funding | 3 | 5 | 8 |

**Table I. MAES Risk Element Ratings**

| Risk Category | Risk | Classification |
|---|---|---|
| Technical | Knowledge Accuracy | II |
| | Maintainability | II |
| | S/W reliability/quality/availability | II |
| | Supportability | I |
| | H/W durability | I |
| | Documentation | I |
| | Data Gathering | I |
| People | Computer Literacy | I |
| | Technical Representative Resistance | III |
| | Fire Control Technician Resistance | II |
| | Hierarchical Resistance | III |
| | Attitude Towards Change | II |
| Organizational | Chain-of-Command Support | III |
| | Training Center Acceptance and Adoption | II |
| | FTSC Endorsement | III |
| | System Use by FC's | III |
| | MAES Deployment Training | III |
| | Deployment Funding | III |

**Table II. MAES Risk Classification Table**

Class III Risks:

- Technical Representative (Tech Rep) Resistance. Already a reality to some extent, tech rep resistance remains a volatile issue. Several tech reps at both FTSCLANT and FTSCPAC are skeptical of MAES because it professes to perform skills similar to their own yet they were largely excluded from the initial MAES development process.

  If MAES proves itself on the ships then this risk can be expected to gradually erode; however, if MAES turns out to be riddled with errors or controversial procedures, tech rep resistance will likely solidify against MAES. If tech rep resistance grows then fleet use of MAES will probably suffer and future support for MAES will diminish.

  The best way to counter this risk is to establish open and honest communications with the FTSC tech reps. As important links to the fleet, tech reps should be aggressively pursued for their opinions of MAES. Whether positive or negative, their comments are valuable. Their criticisms can be used to improve MAES and their positive comments will help MAES gain fleet acceptance.

  In addition, seeking the active involvement of the tech reps in expanding the knowledge of MAES would include them as part of the development process. This could significantly reduce their resistance to MAES. Long-term, the tech reps could become the best source for updates and changes to MAES.

- Hierarchical Resistance. Minor issues or peripheral considerations may heavily impact the way that MAES is eventually implemented. Sensitivity to the special concerns of all involved activities, even those just remotely involved, will be important during the early implementation stages. Should someone feel that they have not been properly informed on some matter the entire implementation effort could be stalled and further support could be jeopardized.

  As one example, an early conversation about implementation issues with a CINCLANTFLT representative indicated that CINCLANTFLT was not familiar with the MAES project and should be fully informed prior to fielding the system to any east coast ships. Another conversation with a FTSC representative indicated concerns about the accuracy of MAES. This concern surfaced during casual conversation and could have easily gone unvoiced. Its ramifications are potentially very serious.

  This risk can be handled by first identifying all commands that might have an interest in MAES. These commands should be kept informed about the project and periodically solicited for comments and concerns.

- Chain-of-Command support. NAVSEA, FCTC Dam Neck, FTC, San Diego, FTSCLANT, FTSCPAC, CINCLANTFLT, CINCPACFLT, COMNAVSURFLANT, COMNAVSURFPAC, NSWC PHD, and the various ships are all players in the fielding of this system. Each command has its own expectations of MAES. When MAES software development and fielding studies migrated from NSWC PHD to the Naval Postgraduate School (NPS) a paradigm shift occurred.

  Internally, little changed; but externally the shift created new relationships founded on unfamiliar turf. The type commanders' staffs, the technical support commands, and even the training centers were familiar with NAVSEA and NSWC and understood their relationship. Since NPS rarely develops production level systems our involvement has created a new inlet to an old, well-established pipeline.

  This situation creates risks which may have been resolved long ago between the established players but resurface as the MAES development team attempts to build support and enthusiasm for the system. If one or more of these commands withholds support for MAES, the project could be placed in jeopardy.

  One way to counter this risk is to more actively associate the project with NSWC PHD instead of NPS. With NPS as the software developer, individuals from various commands might silently wonder where NPS gets the technical expertise to be involved in the MAES project. While this seems absurd to someone with full information about the MAES effort, it may seem like a completely valid concern to someone with limited knowledge about MAES. Silent concerns like these pose a significant risk but can be overcome by aggressive marketing and education. Presentations should discuss the roles of NAVSEA, NSWC PHD, and NPS.

- FTSC Endorsement. This is perhaps the most influential risk of the entire project. This organizational risk is closely coupled to the people risk, tech rep resistance, discussed above. Without FTSC acceptance, adoption, and advocacy, it is unlikely that the sailors will assimilate MAES into their troubleshooting repertoire. This will occur for at least two reasons.

  First, if the FTSCs do not accept MAES, then other commands, such as the type commanders, might be reluctant to fully support MAES. Second, if the FTSCs do not endorse MAES, sailors may be reluctant to use the system.

- System Use by FC's. The risk lies with the older more experienced FC's who may not trust MAES or may feel that they do not need MAES. Negative attitudes on the part of experienced FC's may create sufficient pressure to keep junior FC's from using MAES. If this risk becomes reality then the benefits of MAES will never be realized.

The most effective way to deal with this risk is to aggressively build support throughout the chain-of-command by emphasizing the many benefits of MAES. Gaining FTSC's endorsement of MAES also reduces the risk. The most effective way to mitigate both the FTSC endorsement and the system use risks would be for the FTSC representatives to ask sailors if they used MAES prior to calling for assistance.

- MAES Deployment Training. Much effort will be focused on providing quality training to each ship as MAES is introduced. Unfortunately, due to the transient nature of shipboard personnel, much of this training may not be passed on to newcomers who might have been transferred from a command without MAES or deployed during the MAES fielding. As the FC's with MAES experience and training transfer, the "corporate" knowledge about how to use MAES may lapse.

  To decrease this risk, MAES deployment training must be designed so that it perpetuates itself. Simply providing initial implementation training and then including MAES training in the work center's training plan may be inadequate to ensure that MAES training and experience are passed down to remaining technicians as others transfer.

  To ensure system use and to encourage ongoing training, some expert systems have been listed as tools to be used during routine Preventive Maintenance System (PMS) checks,. (Pandit, 1996) Another solution might be to require Casualty Report (CASREP) comments concerning the use or non-use of MAES.

- Deployment Funding. Deployment funding risk arises if after the evaluation period funding is not forthcoming to deploy the production version of MAES. Without adequate deployment funding, the MAES project will end, depriving the fleet of a valuable troubleshooting tool.

  An effective marketing campaign that emphasizes the benefits and cost savings of MAES, while highlighting the results from evaluation tests of the calibration module at FTC, San Diego, provides the best approach for handling this risk. This project's long history of austere funding suggests that deployment funding will be obtained only after great expenditure of time and effort. Optimistic hope is the only thing preventing deployment funding from being a Class IV risk.

Class II Risks:

- Knowledge Accuracy. Due to the complexity of the knowledge contained in MAES, it is likely that there will be errors. Even without errors, different experts will propose different ways to accomplish the same tasks. The consequences of knowledge inaccuracies depend on the frequency and seriousness of the discrepancies. Numerous minor problems or a few serious problems could jeopardize the program's credibility and greatly frustrate users especially if feedback channels are not responsive to problem reports.

This risk can be minimized by encouraging close scrutiny of MAES during the prototype phase. In the long-term, this risk should be dealt with by establishing responsive, user-friendly feedback channels connecting all MAES users.

A configuration management board, comprised of representatives from NSWC PHD, FTSCLANT, and FTSCPAC, could be convened on an semi-annual or annual basis to groom the MAES program. With NSWC PHD as the coordinator, e-mail between the board members could support an ongoing dialogue about MAES.

- Maintainability. Identified as one of the elements which killed off expert systems, maintainability problems could cripple MAES if the system becomes either too expensive or too time consuming to maintain. (Davenport, 1995) Maintainability applies to the time, effort, and expense required to keep the expert system software updated with the changes pertinent to all of the various versions for different equipment configurations.

  Fortunately, the maintainability risk has already been mitigated by several factors. First, MAES has been designed with maintainability in mind. Multi-media features, such as videos, were not incorporated into MAES because of the time and expense required to update them.

  Second, MK 92 Mod 2 FCS is expected to have few modifications to the system. This greatly reduces the potential software maintenance tasks by effectively restricting maintenance issues to the program as fielded.

  Third, the graphical displays developed with the expert system developmental shell closely resemble the structure of the knowledge documentation provided by the domain expert. These close ties make it easier for someone performing maintenance to correlate program changes with supporting software documentation.

  Last, the modular design of MAES simplifies maintenance by limiting the scope of the updates or corrections. Beyond these considerations, maintainability risk can be decreased by ensuring that the fielded system's annual maintenance budget is adequately funded. NPS estimates annual life-cycle support costs at $50,000 to $100,000.

- Software Reliability/Quality/Availability. If software reliability, quality and/or availability becomes a problem then MAES will likely be discarded by sailors as they lose trust in the system. Measures such as prototype evaluations, independent validation and verifications, and reasonable developmental scheduling have been employed to diminish this risk.

Feedback from the prototype version, which has been in use by several activities for over a year, indicates that the reliability/quality/availability risk may be minimal. As more activities begin to use MAES on a more frequent basis, this risk could increase.

If feedback shows that this risk is increasing, then aggressive steps should be taken to publicize known problems and to provide timely corrections. As Intel learned from their Pentium® chip error fiasco, even minor problems can explode into damaging episodes if not properly handled.

- Fleet Training Center Acceptance and Adoption. An important link to the fleet will be jeopardized if this risk becomes reality. Much has already been done to mitigate this risk. FTC San Diego continues to be an active participant in this project which provides sailors with very early exposure to MAES.

  Some risk still exists here since FCTC Dam Neck has only recently begun working with MAES. Failure to win FCTC Dam Neck's endorsement could be a fatal blow to the MAES project since the training center will be one of the activities to which SURFLANT looks for input about MAES.

  Close liaison should continue with the training centers to ensure that any concerns they have about MAES are properly addressed. Since the training centers offer junior FC's their first exposure to MAES, they are in an ideal position to identify problems that first time users of MAES might have.

- Fire Control Technician Resistance. For this risk to pose a serious threat to MAES, other factors such as lack of support from the chain-of-command or poor FTSC acceptance would have to occur. Given that MAES performs as advertised and absent any negatively contributing factors, this risk could be expected to gradually diminish as positive information from the users of MAES spreads to others.

  The timesaving aspects of MAES should be discussed during implementation training. One of the few incentives available to motivate sailors is liberty. If MAES saves them time, they will use it.

- Attitude Towards Change. This risk ties into the other risks concerning resistance but provides a more general approach to the problem. Though seemingly trivial, people's attitudes towards change can pose a significant risk to this project. The best way to deal with this risk is to include a plan for facilitating change in the implementation strategy.

Class I Risks:

- Supportability. Uncertainty surrounds the supportability of MAES both because of the volatile nature of many software companies and because of the decreased funding and billets assigned to support MK 92.

  There are no assurances that, SoftSell, the company that designed the expert system shell will continue to support their older products. If this risk arises then MAES may become locked into the Windows® 3.1 or Windows 95® operating environment where over time software problems may be identified but are unrepairable.

  Similarly, there are no guarantees that NSWC will have the software personnel to support MAES in the long-term.
  Depending on the effort required to support MAES, there may not be adequate funding to fully support MAES's upkeep.

  The risk with SoftSell should be dealt with by obtaining all available information and documentation about the developmental tool from SoftSell and by vigorously tracking all trouble reports submitted to them. The risk with NSWC support can be decreased, but not eliminated, by ensuring that MAES maintenance is included in the tasking for overall MK 92 support.

- Hardware Durability. If COTS laptops prove to be too fragile for the harsh elements found in a shipboard environment, then MAES users could become prejudiced against MAES based on hardware problems rather than software performance. In short, frustration with the hardware could lead to non-use.

  This risk might be diminished by fielding MAES on ruggedized computers. While ruggedized computers might be more durable than COTS computers, especially in a shipboard environment, the high cost of ruggedized computers might be prohibitive for the activity that funds MAES's deployment.

  One alternative approach would be for the In-service Support Engineering Activity (ISEA), NSWC PHD, to purchase replacement COTS laptops with funds that would have been used for ruggedized computers. This would allow for a phased replacement type of laptop purchase rather than a one-time expenditure for ruggedized computers that may be no more reliable than COTS computers. As the failure rate of the COTS laptops becomes known then additional replacement computers could be purchased. Based on personal experience, COTS laptops will prove to be far sturdier than one would expect.

  The intent of this approach would be to ensure that hardware problems do not jeopardize the successful deployment of MAES. This would not be a long-term commitment on the part of the ISEA. After an introductory period of six to nine months, hardware maintenance responsibilities would shift to the ships. The fielding plan calls for the laptops to be designated as test equipment with replacement responsibilities residing with the ships.

- Documentation. This risk ties not only to short-term program accuracy but also to long-term maintainability. Without adequate documentation, MAES will be difficult to update/upgrade which will hinder life cycle support efforts.

  The most desirable way to deal with this risk is to ensure that adequate documentation exists before the MAES software is transitioned to NSWC. Documentation is discussed in Chapter V of this paper.

- Data Gathering. If data gathering materializes as a risk, it could affect future MAES enhancements or the development of other expert systems, as benefits of the system will be hard to prove.

  An inexpensive way to deal with this risk would be to have thesis students analyze MK 92 Mod 2 maintenance data before and after MAES. Another method would be to look at repair parts demand information for MK 92 Mod 2 before and after MAES implementation. Repair parts demand information is available from the Naval Inventory Control Point (NAVICP), Mechanicsburg, Pennsylvania.

- Computer Literacy. While FC's are some of the most technically oriented people on a ship, there are no guarantees that they will all feel comfortable using a computer. If some of the FC's feel uncomfortable using the computer, MAES use may suffer or the tool may be monopolized by those FC's familiar with computers.

  The ways to counter this risk are to provide brief computer training during implementation training and to include explicit instructions in the users' manual about computer basics. Over time this risk will diminish as new MK 92 Mod 2 FCS "C" school graduates, who have received introductory computer training at one of the fleet training centers, reach the fleet.

Review of the above risks and their classifications reveals that many of the risks, especially Class III risks, are highly interdependent. They are interdependent in terms of how they should be handled and in that success or failure in one area can lead to a similar outcome in another area . For example, the tech reps' opinions of MAES will impact whether the FTSC's endorse MAES. The tech reps' opinions could also influence whether or not the sailors use MAES. Without the backing of the FTSC's, COMNAVSURFLANT and COMNAVSURFPAC are unlikely to support MAES. If the type commanders do not support MAES then the fleet commanders will certainly not support MAES.

Thus, if the deployment team does not gain tech reps' support, the interdependencies among the risks including tech rep resistance, hierarchical resistance, chain-of-command support, FTSC endorsement, and system use by fire controlmen, could cause support for MAES to unravel. Any strategy to handle these risks should leverage the interdependencies to optimize risk mitigation outcomes while economizing project resources. In the above example, the tech reps represent the greatest leverage point.

### 3. Risk Handling

Risk handling is the final activity in the risk management process. Risk handling involves techniques such as avoidance, control, assumption, and transfer to mitigate or eliminate the unwanted results of risks. (DSMC, 1989)

As a brief review of these terms, risk avoidance involves selecting a lower risk choice from several alternatives. Risk control includes the continual monitoring and adjustment of a program, while risk assumption suggests that some consequences will be accepted. Finally, risk transfer entails reducing risk exposure by sharing the risk with another activity.

Applying these four handling techniques to MAES risks would show that all of the Class II and Class III risks fall under the risk control handling technique. By definition, Class II and Class III risks require close management attention and monitoring which are essential elements of the risk control handling technique. Controlling risk includes "the use of reviews, risk reduction milestones, development of fallback positions," and other management actions which should be part of an overall risk reduction plan. (DSMC, 1989)

The underlying assumption about risk control is that an awareness exists about certain risks and there is a flexible plan for dealing with those risks. Preliminary quantification provides the initial "awareness" of the risks while extracting the common elements generates the starting point for a risk reduction plan.

With respect to risk control, Class III risks share two common leverage points: communication and perception. Essential to mitigating Class III risks, open communications serve to build alliances and uncover negative undercurrents before they become threats. Perceptions influence such risks as tech rep and FC resistance, chain-of-command support, FTSC endorsement, and attitude towards change. An effective marketing campaign can cultivate beneficial perceptions about MAES and breakdown the silent barriers created by perceptions which might threaten the project. Experts throughout the software development industry agree that marketing is a crucial part of any implementation plan. (Dart, 1996; Fowler, 1996) In this case, it can also be an important part of the MAES risk reduction plan.

Risk assumption can be appropriate in some situations. For MAES, some risk assumption occurs in the areas of knowledge accuracy, software reliability/quality/availability, supportability, hardware durability, and data gathering. Risk control and risk assumption techniques are actually combined to handle knowledge accuracy and software reliability/quality/availability risks. This happens because despite our best efforts at controlling these risks, some risk will persist that we must eventually accept.

Computer literacy risk and perhaps hardware durability risk could be handled with risk avoidance techniques. Computer literacy risk could be avoided by providing more extensive computer training. Hardware durability risk might be avoided by procuring ruggedized rather than COTS laptop computers.

### 4. The Risk Management Plan

The activities described above form the foundation for the risk management plan which will be integrated into the overall MAES implementation plan. Identification of those factors important to implementation success is the next step in developing an implementation plan.

Because of the many definitions of risk, one could argue that risks and factors important to implementation success are closely related. For this analysis, factors differ from risks in that factors are more system specific and risks are more project specific.

## D. FACTORS IMPORTANT TO IMPLEMENTATION SUCCESS

Some information systems professionals suggest that Expert Systems (ES) are dead. At least three factors including maintainability, justifying the use of dedicated platforms, and implementation are cited as problem areas. (Davenport, 1995) Experience has shown that implementing new technology is usually more difficult than we expect. (Davenport, 1995) Given the importance of implementation, this section will explore the various factors which determine an implementation plan's success or failure.

### 1. Framework for the Implementation Strategy

If a generic implementation strategy existed for deploying technological innovations, such as expert systems, it would likely need to be tailored to the particular characteristics of the specific system (Meyer and Curley, 1991). Meyer and Curley (1991) have built a two dimensional framework for evaluating the characteristics of various expert systems. They classify expert systems based on knowledge complexity and technological complexity.

Measures of complexity are determined by incorporating a number of factors into each dimension. Knowledge complexity includes such factors as the number of separate areas of expertise needed to deal with a problem, the amount of training and experience required of an expert, and the nature of the system's output. Technological complexity considers such factors as the number of rules or the size of the knowledge base, the diversity of information sources, and the degree of diffusion of users of the system. (Meyer & Curley, 1991)

Based on the measure of complexity for the two dimensions, Meyer and Curley (1991) classify expert systems (ES) into one of four quadrants. Figure 2-2 graphically depicts the classification. The four quadrants are described below:

I. Low knowledge/low technology. Since these ES contain the lowest levels of both technology and knowledge, they can often be developed by end users and deployed on stand-alone PC's. They generally represent a few hundred rules at most.

II. High knowledge/low technology. Based on "deep" knowledge, these ES capture detailed knowledge from domain experts that can cover several complex domains. Nonetheless, they can be deployed on stand-alone PC's which might support small databases.

III. Low knowledge/high technology. These ES are based on simple knowledge requirements. The complexity in these systems comes from the considerable system integration challenges which can involve hundreds of different locations.

IV. High knowledge/high technology. Based on knowledge that is both "broad" and "deep" these ES often require complex efforts in areas like database management and systems integration.

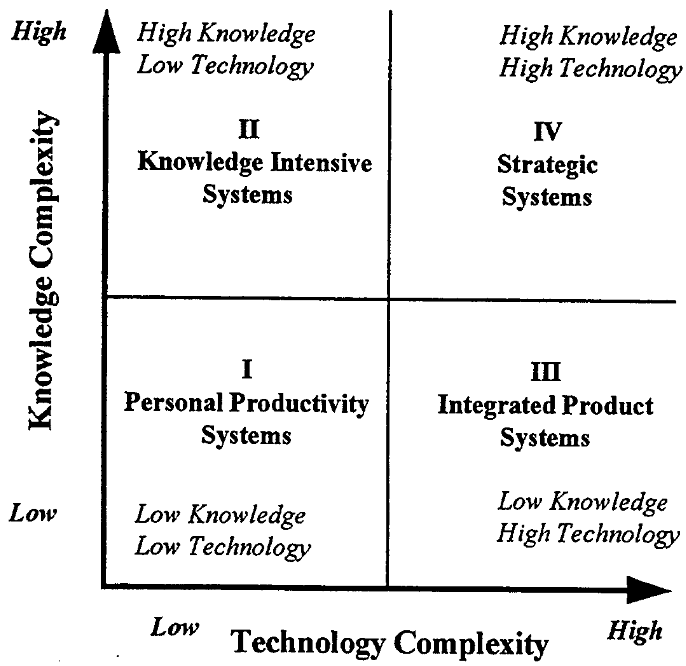


**Figure 2-2. Information Systems Complexity Matrix**
**(From Meyer and Curley, 1991)**

Efforts aimed at categorizing a number (50 in this example) of different knowledge-based systems indicate that these systems fall into all four categories. (Meyer and Curley, 1991) Given this tendency, a single implementation plan would not be appropriate for all systems. (Bradley and Hauser, 1995)

## 2. Implementation Factors

An important element in implementation planning appears to be correctly categorizing the ES as early as possible so that implementation efforts can be customized to fit the system. A precursor to categorization would be identifying key factors and activities within the four categories which are important to ES implementation success. Factors expected to influence user acceptance of a technological innovation, such as an ES, can be classified based on innovation characteristics, organizational influences, and individual differences. (Bradley and Hauser, 1995)

Innovation characteristics concern the users' perceptions of the innovation. A person who has a strong negative attitude about computer technology could be expected to have a negative attitudes towards an expert system. (Bradley and Hauser, 1995) Similarly, if something in the implementation process creates unrealistic expectations in the users, they can become resistant to change and jeopardize the implementation. (Bradley and Hauser, 1995)

Organizational influences include such factors as user participation in development and implementation, rewards for using the system, training, and informal and formal organizational support. From these factors, user involvement in the development process and availability of training have been shown to be very positive influences on implementation success. (Bradley and Hauser, 1995) However, not everyone agrees that user participation in development or implementation plays a significant role in implementation success (Ginzberg, 1981; Markus and Keil, 1994).

While the support of top management is important to implementation success, supervisor's desires and peer influences can also be controlling factors in the implementation process. (Leonard-Barton, 1987) Supervisors' attitudes towards a new ES can either accelerate or hinder the diffusion of the innovation among users. (Bradley and Hauser, 1995) In situations where peers are actively involved, they can help speed acceptance of the ES if they hold positive beliefs about the ES. (Leonard-Barton, 1987)

With regard to individual differences and their impact on implementation success, factors from job tenure to cosmopolitanism have been shown to have an effect on the implementation process. The degree to which individual differences influence users of ES depends on the perceived change created by the ES. User resistance might be expected to be high based on a particular set of individual characteristics, but user perceptions of the change could completely invalidate expectations. (Bradley and Hauser, 1995).

Bradley and Hauser (1995) state that "the manner in which the implementation is managed impacts both the users' perceptions of the system and the speed of its diffusion among the user group." Borrowing from Meyer and Curley (1991) and incorporating the factors described above, Bradley and Hauser (1995) offer a framework for determining which factors should be emphasized for each of the four classes of ES. Table III provides an overview of this framework.

The success of any implementation plan aimed at introducing new technology depends heavily on an effective marketing or sales campaign (Leonard-Barton, 1987; Dart, 1996; Fowler, 1996). A practical way to approach a new implementation challenge is to identify those factors which will most influence user acceptance of the innovation and then focus on those factors. In resource constrained organizations this approach can help narrow the scope of the project to an economically feasible level. (Bradley and Hauser, 1995)

| Factors | Expert System Classification | | | |
|---|---|---|---|---|
| | I | II | III | IV |
| **Innovation Characteristics** | | | | |
| User perception of computing technology | H | H | H | H |
| User perception of expert systems | L | M | M | H |
| **Organizational influences** | | | | |
| User involvement in ES design | H | H | H | H |
| User involvement in ES implementation | H | H | H | H |
| Reward structure | L | M | M | H |
| Training | L | M | M | H |
| Top management support | L | M | M | H |
| Supervisor support | H | H | H | H |
| Advocates | L | M | M | H |
| Consulting aids | L | M | M | M |
| **Individual differences** | | | | |
| User perception of change | H | H | H | H |

L = Low emphasis in the implementation plan
M = Medium emphasis in the implementation plan
H = High emphasis in the implementation plan

**Table III. Relative Importance of ES Implementation Factors (From Bradley and Hauser, 1995)**

Importance values of high, medium, and low were determined for the factors within each category of ES by analyzing the characteristics of each ES and by applying information from existing implementation literature (Bradley and Hauser, 1995). The key to this framework is not in the methods that were used to develop it but in the analytical tools it provides for developing an implementation plan.

As an example of how this process might work, consider developing an implementation plan for a category II expert system. At a minimum, the plan should focus on those factors which are rated as being highly influential. Based on Table III, those factors include the user's perceptions of computing technology, user involvement in the ES design and implementation, supervisor support, and the user's perception of change.

Referring to Figure 2-2, MAES would be considered a category II expert system because it captures detailed or "deep" knowledge from a domain expert but can be deployed on a standalone computer. Category II expert systems are described as knowledge intensive systems. (Meyer and Curley, 1991) The implementation factors for a category II expert system, shown in Table III, should be considered when developing the MAES implementation plan.

The implementation factors offered throughout the implementation literature as being critical to successful implementation generally parallel those factors described above (Ginzberg, 1981; Tyran and George, 1993; Markus and Keil, 1994). A few of these factors are described below.

Based on a study of 45 different ES projects, Tyran and George (1993) found that the five implementation factors with the most perceived importance were assessment of user needs, commitment of the human expert, ease of ES use, commitment of the user, and top management support. These five factors closely resemble the implementation factors outlined by Bradley and Hauser (1995).

Historically, management support and user involvement have been identified as common success factors in MIS implementation projects. (Ginzberg, 1981) In an attempt to further refine generic implementation issues, Ginzberg (1981) found through statistical analysis three factors which were most significant in determining implementation success.

The first factor is commitment to the project, which involves doing everything necessary to ensure that the problem is understood and that the system developed solves the problem. The next factor is commitment to change, which entails the willingness of those involved to make the changes that are necessary for the system to work. The last critical factor is the extent of project definition and planning, which concerns the detailed analysis of issues such as organizational needs, project impacts, training requirements, and role identification. (Ginzberg, 1981)

Though generic in nature these implementation issues provide another set of factors which should be analyzed together with previously discussed factors to isolate those issues deserving the most attention during the implementation process. This approach acts as an early warning system helping to track impending failures (Ginzberg, 1981). We want to be able to focus implementation efforts to save resources, but knowing the issues helps us shift the likelihood of success in our favor by giving us guidelines for detecting problems which might lead to failure.

Another factor that can influence implementation success is business system design. Tragically, systems that work well technically can go unused if they are not designed for "implementability." Making an information system good enough, does not ensure that people will use it. System users must be motivated to do what the system enables them to do and the system can not make it harder for them to do what they were motivated to do. (Markus and Keil, 1994)

When systems are not used the temptation is to mandate use. Unfortunately, mandated use can lead people to use a system in ways that do not improve their performance. Generally, when a system's design conflicts with the users' motivations and incentives, managers will not force them to use the system. (Markus and Keil, 1994) For the purposes of MAES's implementation, the development process is too far along to consider building implementability into the business system design; however, some of the issues related to business system design, such as motivation and incentives, will be discussed later in the context of performance measures and rewards.

Considering all of the factors described above, the goal for building an ES is organizational improvement (Markus and Keil, 1994). With MAES organizational improvement occurs if No-Fault Evident (NFE) repair parts are decreased or if the mean time to repair (MTTR) casualties is decreased. To achieve organizational improvement or implementation success, the system must be used.

Three subgoals comprise the overall goal of organizational improvement. First, when people use the system as they are intended to, they will achieve the goal. Second, the system must have the functionality and user interface, so that users can easily use it to accomplish a goal. And, third, people must actually use the system in the intended manner which means management has to measure, monitor, and reward their progress toward the goal. (Markus and Keil, 1994)

## E. INTEGRATING IMPLEMENTATION FACTORS AND RISKS

One method for simplifying the complex task of integrating implementation factors and risks into a successful implementation plan is to begin with a detailed scenario of what the ideal implementation plan would look like. From there, identify the current state and then target the deficient areas. (Fowler, 1996) Using the framework provided by Bradley and Hauser (1995) shown as Table III, we begin constructing the ideal implementation scenario by stating the desired outcomes from emphasizing the factors important to the implementation success of a type II expert system.

In addressing implementation factors, the ideal implementation plan would:

- Reinforce positive attitudes about computer technology and reverse negative attitudes about computer technology.
- Create realistic expectations about the capabilities of MAES.
- Involve the users in the implementation plan to the degree that they feel they have influence in the process.
- Promote system usage through appropriate organizational rewards.
- Provide a system of training that instills confidence in the users and offers the opportunity for additional instruction on request.
- Build enthusiastic support at all levels of management, from the Commanding Officer to work center personnel.
- Establish several consulting aids in the form of a help desk or points of contact of MAES advocates.
- Condition MAES users so that they will be amenable to the changes that MAES will bring to their work environment.

In addressing implementation risks, the ideal implementation plan would mitigate risks by:

- Creating feedback channels flowing from the ships, the fleet training centers, and the fleet technical support centers, so that as errors are discovered in the knowledge base, corrections can be made.
- Obligating the maker of the expert system shell to a 3-5 year support contract and obligating appropriate funds for NSWC personnel to maintain and support MAES.
- Providing hardware from reputable companies and supporting the hardware with appropriate equipage such as carrying cases and surge protectors.
- Including basic computer training in the initial MAES familiarization training.
- Winning FTSC technical representatives' support.
- Dissolving resistance to change among fire controlmen.
- Identifying and properly handling politically sensitive issues.
- Developing ardent chain-of-command support at all levels.
- Promoting continued excellent relations with the Fleet Training Centers.
- Building a quality training plan that reaches all of the targeted audiences and then perpetuates itself so that MAES use is not jeopardized by the transient assignment of Navy personnel.

The ideal implementation plan should handle the implementation factors and risks as described above. Factor consideration and risk mitigation, comprise two significant pillars of this plan. Common threads running through the risks and factors include training in various forms, overcoming resistance to change, building positive perceptions and developing pervasive support of MAES. Having created the ideal implementation plan, the next step is to assess the current state and then focus on the selected areas.

## F. SUMMARY

"An important key to the acceptance and use of expert systems in organizations lies in effective implementation." (Bradley and Hauser, 1995) Effective implementation hinges on how well the implementation plan addresses the key implementation factors and anticipates the "show stopping" risks. Effective implementation also depends on how well the plan is executed. A great plan that is too expensive or too difficult to carry out has minimal value.

Based on the analysis provided in this chapter, the MAES implementation team should begin by focusing their efforts on the "high emphasis" factors for a Category II expert system as shown in Table II. The important factors include emphasis on the user's perceptions of computing technology, user involvement in the ES design and implementation, supervisor support, and user's perception of change.

The team should also begin by addressing the Class II and Class III risks. These risks pose the most serious threats to MAES's success. The Class III risks are hierarchical resistance, tech rep resistance, FTSC endorsement, training, chain-of-command support, and deployment funding. Because of the overlap between risks and factors, this process should be a concurrent effort rather than separate endeavors.

A comprehensive implementation plan built on the factors and risks described above is not provided. Instead, the next three chapters will offer individual implementation plans dealing with the deployment of MAES to the ships, the integration of MAES into the formal training pipeline, and the transition of MAES to NSWC PHD for life cycle support. Each of these three plans will use the ideal implementation scenario as their benchmark. From there, the "current state" will be assessed which will help the deployment team target the deficient areas.

# III. DEPLOYING MAES TO ALL MK 92 MOD 2 FCS SHIPS

## A. OVERVIEW

This chapter discusses the long-term implementation plan for deploying MAES to all MK 92 Mod 2 FCS ships. The core issues covered by this chapter include the hardware, documentation, training, and support requirements necessary to successfully deploy MAES.

Before discussing the core implementation issues, two subsidiary issues are addressed. The first subsidiary issue concerns "lessons learned" from the initial deployment of the MAES prototype. Additionally, "lessons learned" from initial efforts to schedule the full-scale deployment of the updated MAES prototype are discussed. The second subsidiary issue concerns the MAES software approval process. These two subsidiary issues provide a background for consideration of the core issues mentioned above.

## B. LESSONS LEARNED FROM INITIAL DEPLOYMENT

This section discusses the "lessons learned" both from the initial deployment of the MAES prototype and from the type commander scheduling process that might help shape the long-term implementation of MAES. Due to funding constraints, the MAES prototype was not implemented as planned. Thus, empirical information about full-scale prototype implementation is limited. Regardless, there are still "lessons learned" to convey that might be useful in the eventual deployment of MAES.

From the deployment of an early prototype version of the MAES calibration module aboard a COMNAVSURFPAC ship lessons were learned about how sailors may or may not use MAES and the laptop computer on which MAES is loaded. Sailors loaded their preventive maintenance system (PMS) schedules, their training plans, and their evaluations onto the MAES laptop. Based on this experience, one should expect that the uses for the laptop will expand to the laptop's capacity unless measures are taken to restrict use.

Other lessons learned from the prototype were that more experienced FC's were reluctant to use MAES because they did not feel that they needed it and familiarity with MAES centered around one or two FC's. One must keep in mind, however, that this was an early prototype of the first module. The experienced fire control technicians had excellent knowledge of the troubleshooting procedures in this domain. Also, many of the enhancement features (such as pictures and "how" procedures) designed to encourage the use of MAES, were not implemented in the prototype. Both of these lessons learned fall into risk categories discussed in Chapter II.

Even though full-scale prototype deployment has not occurred, prospective implementation dates and requests for three to six Atlantic Fleet ships were submitted to the Atlantic Fleet scheduling conference. Several things were learned from this process. First, the scheduling process must be initiated one quarter prior to the planned implementation quarter so that inputs are available for the applicable scheduling conference.

Second, even though inputs are submitted to the scheduling conference through NSWC, who sends a representative to the conference, other involved activities, such as the Naval Science Advisor's Program, must also be notified of the deployment team's intentions. The final lesson learned from the scheduling process is that ships are hard to catch inport. Finding three ships inport at the same time is unlikely. This point will have a significant bearing on how full-scale implementation efforts are conducted.

## C. MAES SOFTWARE APPROVAL PROCESS

The software approval process involves at least four steps. The first step involves obtaining ISEA approval. The second step involves obtaining NAVSEA approval. The third step entails establishing a Memorandum of Understanding (MOU) between NAVSEA and the fleet commanders and the fourth step involves obtaining the approval of the type commanders to deploy MAES aboard their ships. Details of these four steps should be explored and negotiated after completion of the production version of MAES.

As McGaha noted, standard Navy procedures for deploying diagnostic software to the fleet have not been established. (McGaha, 1994) Until a policy is established, developers must seek implementation authority from the type commanders. For MAES, the NAVSEA project manager for the MK 92 FCS must obtain written authority from the type commanders (step four) to deploy MAES to the ships. This written authority will be in the form of a message from the type commanders to all ships with MK 92 Mod 2 FCS. (McGaha, 1994) Recent conversations with type commanders' staff members indicate that these requirements are still intact. (Whitman, 1996; Simino, 1996)

While this approval process might be administratively burdensome it accomplishes several objectives. It establishes implied command support for MAES. It advertises MAES up and down the chain-of-command, and it provides authoritative guidance for ship's Commanding Officers concerning the use of MAES.

NAVSEA's request to the type commanders should contain a recommended draft of the approval message that includes MAES points of contact and various reporting procedures. The deployment team should work closely with NAVSEA and the type commanders' staffs concerning the content of the approval message. If carefully drafted, the type commanders' approval message could give MAES a huge boost during the early days of implementation.

## D. HARDWARE IMPLEMENTATION ISSUES

Many of the issues in this section were previously examined by McGaha (1994). Rather than restating previous findings, this section will draw on McGaha's research to make recommendations pertinent to the long-term implementation of MAES.

### 1. Dedicated Laptop Versus Ship's Existing Resources

Ship's existing computer resources can be placed into three categories - desktop computers, portable computers, and personally owned computers. The inventory of these resources varies among ships and ship classes, but as one might expect, the FFG's have the fewest computer resources. While installing MAES on existing shipboard computers might be the cheapest way to deploy MAES, this option introduces undesirable variables into the implementation plan.

Experience using MAES on various laptops and desktop computers indicates that different hardware and software configurations can complicate the initial loading and use of MAES. In one case, a desktop computer loaded with MAES would not properly display the program because of incorrect video drivers. In another case, one laptop and a desktop loaded with MAES, both running Windows® 95, would not properly display several MAES screens. These complications may not be easy to overcome for people who are unfamiliar with computers. Furthermore, variation across the wide spectrum of computers that might be found on ships would create a maintenance nightmare for the MAES configuration manager.

Deploying MAES on a dedicated laptop computer accomplishes the following:

- Minimizes the range of potential hardware and software compatibility problems which in the long-term should make the systems easier to maintain.
- Creates the best assurance that computer resources will be available for fire control technicians when they need it.
- Acts as a marketing tool for MAES. This new "toy" will invite experimentation and use.

Most FFG's have no more than two laptop computers on board. (Simino, 1996). Given their scarcity, it is unlikely an existing laptop computer would be transferred to the FC's for their exclusive use. Using an existing desktop computer might be an option but that would limit MAES's functionality as pictures and "Hows" would not be readily available to technicians. (McGaha, 1994) Additionally, as with the laptops, there are no guarantees that a desktop, convenient to the FC's, would be available. This area is to be evaluated in more detail during the COMNAVSURFLANT evaluation.

An added benefit of providing the ships with a laptop computer is that a new computer comes with a warranty. This is especially important since there are no Navy operated computer repair facilities available to Atlantic Fleet ships. The east coast Shore Intermediate Maintenance Activities (SIMA) no longer provide computer repair support to the ships. (Simino, 1996) With the protection of a warranty, dedicated laptop computers provide the best hardware solution for successfully deploying MAES.

There is no standard laptop computer designated for shipboard use; however, any laptop procurement strategy should include consideration of future shipboard support issues. (Orchard, 1996; Curtis, 1996) One approach to ensure future supportability is to purchase computers from contracts that are accessible by the ships. Purchasing the laptop computers from an existing GSA contract or one of the Navy's Indefinite Delivery Indefinite Quantity (IDIQ) contracts offers the most practical approach. Since the ships have access to these contracts, this approach ensures consistency between what the ships can purchase and what is purchased for the ships.

#### 2. Commercial-Off-The-Shelf (COTS) Versus Ruggedized Computers

This comparison weighs lower prices for COTS computers against greater reliability for ruggedized computers. As mentioned in Chapter II, unreliable hardware can pose a risk to successful implementation. Of course, increased reliability comes at a price. Based on information provided by the U. S. Army, ruggedized computers do not always provide greater reliability. (Army, 1996)

At today's prices, ruggedized computers are roughly three to four times as expensive as COTS laptop computers. Fielding MAES on ruggedized computers would require significantly higher upfront expenditures and would also burden ships with higher replacement costs than for COTS laptops. Presently, there is no funding available to purchase ruggedized computers for evaluation.

One alternative to leverage the lower prices and perhaps comparable reliability of COTS laptops would be to initially purchase extra COTS laptops. These extra laptops could be used to quickly replace failed computers. This strategy might save money upfront as computer buys could be made incrementally based on failure rates. In addition to saving money, this strategy could improve the chances for implementation success by simplifying users' maintenance responsibilities.

### 3. Government Procurement

In addition to the procurement options proposed by McGaha (1994), the option of purchasing the laptop computers using a General Services Administration (GSA) contract should be considered. The combination of the National Performance Review and the Federal Acquisition Streamlining Act of 1994, perpetuated by the effective repeal of the Brooks Act, gave GSA the incentive to change many of its old restrictive policies. GSA prices and services are now more competitive with Indefinite Delivery Indefinite Quantity (IDIQ) contracts. (GCN, 1996)

For purchases over $2,500, GSA customers select the "best value" from three competitors. GSA customers have the flexibility to negotiate prices with the vendors to get the lowest available price. Maximum order limitations that might have prevented purchasing MAES laptops through GSA have been eliminated. Further, the requirement to synopsize orders over $50,000 has been abolished by GSA. (GCN, 1996) GSA reforms have made this procurement alternative worth investigating for the MAES laptops' purchase.

### 4. Accountability and Security

Implementing the MAES laptop as a piece of MK 92 FCS test equipment offers the best assurances that the computer will be used for its intended purpose, that there will be a reduced susceptibility to viruses, and that it will be inventoried frequently. (McGaha, 1994) Another option would be to classify the MAES laptop as controlled equipage. While this option would impose regular inventory guidelines and place the laptop in the signed custody of MK 92 FCS work center personnel it would also open up the computer for uses other than MAES.

Controlled equipage designations do not imply the same type of use restrictions that test equipment designations do. Based on the time and expense required to develop MAES, restricted use of the laptop by designating it as test equipment is justified. An NSWC representative is currently evaluating the requirements to include the MAES laptop as a piece of test equipment on an allowance equipage list (AEL). (Edozie, 1996)

### 5. Fielding, Maintenance, and Replacement

McGaha (1994) suggested three alternatives for fielding computers to the ships. The alternatives were that NAVSEA, the type commanders, or the ships would purchase or provide the laptop computers. (McGaha, 1994) Due to funding limitations, two of those options should be eliminated. Neither the type commanders nor the ships have the budgeted funding to procure dedicated laptops for the initial deployment of MAES. (Curtis, 1996) If MAES will be deployed on laptop computers, then NAVSEA should fund the purchase of the computers for initial system deployment.

Maintenance responsibilities for the computers should rest with the ships. They would be supported by computer warranties. As mentioned above, computer maintenance support from Navy activities is no longer available on the east coast (Simino, 1996) Computer maintenance support is available on the west coast at the Shore Intermediate Maintenance Activity (SIMA), San Diego, but their experience shows that replacing defective laptops is normally more economical than repairing them. (Tan, 1996)

Providing reliable hardware will be an important element in the successful implementation of MAES. The reliability of COTS laptop computers aboard ships is unknown. Based on personal experience, personal computers are much more durable in the harsh shipboard environment than one would expect but the hardware still represents a risk. Durable, hard shelled carrying cases and surge protectors would further reduce the risk.

This risk can be further mitigated by providing responsive support to MAES users who encounter problems with their computers. One alternative is that the system configuration manager at NSWC could be responsible for replacing defective computers during the first year of MAES's deployment. Damaged computers would be the responsibility of the ships to repair or replace. Computers infected by viruses would also be the responsibility of the ships to repair or replace.

## E. DOCUMENTATION REQUIREMENTS

The MAES implementation package should include a MAES user's manual (see Cepek, 1996), user's manuals for all prebundled software such as Microsoft DOS® and Microsoft Windows®, and user's manuals for the hardware. In addition to preloading the MAES software, two copies of the MAES software diskettes should be provided. One copy should remain in the work center and the other copy should be turned over to the ship's ADP security officer.

Elements of the MAES maintenance manual described by McGaha including the knowledge diagnostic trees; procedure diagrams; and testing, validation and verification forms are not necessary to support MAES at the shipboard level. (McGaha, 1994) Transfer of these items to the software life cycle manager will be discussed in Chapter V.

## F. TRAINING REQUIREMENTS

The nucleus of MAES training contains three major elements: the trainers, the methods and media used to deliver training, and the students. This section discusses each of these elements.

### 1. The Trainers

NSWC PHD, the Fleet Training Centers (FTC), and the Fleet Technical Support Centers (FTSC) represent the spectrum of MAES trainers. After the full-scale deployment of MAES, NSWC will probably not be involved in further training efforts.

On-going training for MAES will be conducted by the FTC's but this training differs from implementation training. With NSWC at one end of the spectrum and the FTCs at the other, FTSC's involvement falls somewhere between these two ends. FTSC involvement could provide an important connecting bond between the initial implementation training provided by NSWC and the on-going classroom training provided by the FTC's.

As mentioned in Chapter II, deployment training is susceptible to several risks. Sailors who transfer from a command without MAES may not receive adequate training. At the same time, those sailors who receive the training may transfer causing MAES knowledge to lapse. Developers of shipboard information systems have found that personnel turnover can leave a ship with no corporate knowledge of a system and no traceability for what has happened with the system. (Williams, 1996; Pandit; 1996) From personal experience aboard one of the first ships equipped with Shipboard Non-tactical Automated Program II (SNAP II), this risk seems largely ignored by some implementation teams.

FTSC representatives' participation in on-going shipboard MAES training could mitigate this risk by perpetuating implementation training. FTSC representatives are in a perfect position to become the guardians of shipboard MAES corporate knowledge. Their expertise combined with their frequent visits to most of the MK 92 Mod 2 FCS ships place them in a position to monitor MAES usage and training with minimal effort.

### 2. Methods and Media Used to Deliver Training

Several methods and media are available to disseminate MAES training. The various methods and media are listed below from the most preferred to the least preferred:

- On-site training by a deployment team from NSWC.
- On-site training by FTSC representatives.
- Training by a deployment team at a central site such as the FTC's.
- Training at a central site using video-teleconferencing capabilities.
- Videotaped training with videotapes mailed to the ships.
- Written training mailed to the ships with the program.

The optimal training plan would include on-site training at each of the ships. This training could be conducted by NSWC or FTSC representatives. If performed by NSWC representatives, this could be the most expensive and time consuming training method. As pierside residents, the FTSC representatives could save money in terms of travel expenses if they implement the software and perform the training during "windows of opportunity" created by routine technical assist visits.

Another approach would be to train several ships at once at a central site such as a fleet training center. This method has advantages in that it saves time and travel money and may offer the fewest distractions for the students. A variation of this training method would be to conduct the training at a central site in each homeport using video-teleconferencing capabilities. One of the disadvantages to this method might be the one-hour time restriction normally imposed on video teleconferences.

Under strict funding and time constraints, videotaped training should be considered. While not the optimal method, videotaped training offers the deployment team the opportunity to carefully structure the presentation's content and delivery. As a last resort, a written MAES training guide based on the user's manual could be included in the MAES implementation package.

The training plan for full-scale MAES implementation should be tailored based on the findings from the prototype deployment. It may be discovered that a combination of the above methods offers the best chance for successful implementation training. For specific information about the prototype deployment training plan refer to Cepek (1996).

### 3. The Students

The population of potential MAES students includes everyone from Commanding Officers to software maintenance engineers. Of course, the most important students are the shipboard FC's. The deployment team must be prepared to train all the potential MAES students.

The trainers will be the first students. This means that new members of the deployment team must train themselves with regards to MAES before they can train others. For tips about the most effective training techniques for introducing MAES, the trainers should contact the FTC instructors who have experience with MAES. They should also refer to the lessons learned from the prototype deployment training.

## G. SUPPORT REQUIREMENTS AND PROCEDURES

This section describes the support requirements and procedures that should be addressed during MAES implementation training. Areas of concern include hardware support, software support and various reporting procedures.

### 1. Hardware Support

To minimize hardware risks, the MAES configuration manager at NSWC PHD should fully checkout all deployable laptops prior to issue. Even though they will be covered by warranties, defective laptops pose a risk to successful implementation because unreliable hardware can prejudice users against MAES. A complementary alternative to minimize hardware risk would be for NSWC PHD to replace problem hardware and assume responsibility for pursuing warranty work during the initial implementation phase. As a part of this plan, replacement computers could be staged at the FTSC's or at the ships' squadron offices.

### 2. Software Support

Software support issues fall into two categories, prebundled software and MAES software. Within this context, software support can be further divided into immediate "help" related support and non-urgent support. Prebundled software includes software such as Microsoft Windows® that may be pre-loaded on the laptop computer. Support for prebundled software should be pursued by the ships through the applicable software company. The MAES configuration manager should stay current on prebundled software issues and provide timely guidance to the users.

Support for MAES software should be provided by the MAES configuration manager and the MAES software engineer. This support should be available by telephone, Naval message, or SALTS message. Current addresses and points of contact should be either in the user's manual or in an addendum to the user's manual.

### 3. Reporting and Updating Procedures

Beyond "help" related questions, issues arise related to reporting errors, submitting trouble reports, and recommending changes that are serious but not urgent. Existing reports such as the NSWC PHD Software Trouble Report, the Digital Systems Feedback Report (NSWSES-3142/1), and the Engineering Change Proposal (DD 1692) provide a solid foundation for addressing these issues.

The Software Trouble Report (STR) provides a communications channel for reporting problems in the software or for proposing enhancements to the software. It is used mainly by engineers, such as the In-Service Engineering Agent (ISEA), Software Support Agent, Design Agent, System Integration Agent, Technical Direction Agent, and the Independent Verification and Validation (IV&V) agent, who are familiar with the software and the MK 92 Mod 2 FCS. The STR is the medium by which problems/enhancements are entered into the Configuration Control System (PC-CCS). PC-CCS is a database used to document and track configuration related data. (Gorham, 1996)

Designed for use by sailors and support personnel, the Digital Systems Feedback Report (DSFR) serves the same function as the STR, but uses a simpler format. When a DSFR is received by the ISEA (NSWC PHD for MAES), the problem is validated through a preliminary investigation, and if valid, the DSFR is rewritten as an STR for submission to PC-CCS. (Gorham, 1996)

Periodically, open STRs are segregated into functionally related groups and Engineering Change Proposals (ECPs) are written. ECPs describe each problem in the group, the design of the proposed solution, the interactions between the fixes, and the impacts on other hardware, software, or documentation. (Gorham, 1996b) The software update process might proceed as follows (Gorham, 1996b):

- DSFRs are submitted by users, validated, and rewritten as STRs by the ISEA/SSA. Designers, ISEA/SSA, users, and other involved agencies also submit STRs.
- The Configuration Manager (CM) enters the STRs into the PC-CCS database.
- STRs are periodically reviewed by the Software Configuration Management Board (SCCB) and assigned a priority, category, and status. Priorities range from high to low. Categories are assigned codes of S (software implementation error, no impact on requirements documentation), E (design error, affects code and requirements specifications), or D (affects requirements documents only) depending on the type of error and its affect on requirements documentation. Status can be indicated by a variety of codes meaning open, under investigation, closed, etc.
- After approval by the SCCB, certain ECPs are selected for a software build referred to as a version release. A test/project plan is written and an estimate is provided.
- When funded, the designs in the ECPs are coded and tested. Using PC-CCS, the CM documents and tracks implementation of these corrections.
- When fully and successfully tested, the software version is delivered to the Fleet.

The DSFR provides fire controlmen with a simple form that they can use for a variety of purposes. Whether reporting software errors, submitting trouble reports, or recommending enhancements, sailors can use the DSFR as their link to the software configuration managers. The User's Manual includes a copy of a DSFR. The communications channels required to support the DSFR reporting process will be discussed in Chapter V.

## H. SUMMARY - THE IMPLEMENTATION PLAN

The hardware, documentation, training, and support issues discussed in this chapter will be influenced by the experiences gained from the full-scale deployment of the MAES prototype. While the various alliances and agreements needed to ensure successful long-term implementation can not be solidified yet, the deployment team should begin to identify and pursue the relationships, activities, and policies important to a successful implementation.

The MAES long-term implementation plan is included as Appendix B. The framework for this plan was adapted from the Fleet Material Support Office's (FMSO) *Implementation Planning Guide*. (Moran, 1996; FMSO, 1994) The reader should understand that this implementation plan is subject to change based on "lessons learned" from the MAES prototype deployment. This implementation plan should be viewed as a working document rather than as a definitive implementation guide.

# IV. INTEGRATION OF MAES INTO THE MK 92 MOD 2 FCS "C" SCHOOL CURRICULUM

## A. OVERVIEW

MAES was introduced to the first group of MK 92 Mod 2 FCS students in January 1996. Through the cooperation and support of FTC San Diego, laboratory experiments were conducted with these students which provided the first empirical evidence that MAES performs as promised. These test results are summarized in Appendix A.

The Fleet Combat Training Center (FCTC), Dam Neck, the east coast equivalent of FTC San Diego, received MAES software and a familiarization presentation in June 1996. At this writing, FCTC instructors are just beginning to learn how to use MAES and to appreciate the power of this program.

While MAES has not been formally integrated into the MK 92 Mod 2 FCS curriculum, FTC San Diego's experiences with the program over the past two years provides valuable insight into the integration process. The guidance received from FTC San Diego will serve as the basis for the MAES integration plan.

## B. DOCUMENTATION REQUIREMENTS

Though the training centers will not perform life cycle maintenance functions on the MAES software, system knowledge diagrams that were developed by the domain expert should be provided to them. This will allow the training centers to analyze the knowledge diagrams if the need or desire arises. Additional documentation, such as a user's manual, complete with information about obtaining and loading upgrades, submitting a change proposal or error report, and receiving help, should also be provided to the training centers. Sometimes forgotten, the training centers should receive all follow-on documentation that is distributed to the ships so that they can keep their MAES training current with fleet developments.

Manufacturers' user's manuals for the hardware, including warranty information, and users' manuals for the supporting software, such as Microsoft Windows® and Microsoft DOS® 6.2, should be provided to the training centers. Documentation pertaining to the expert system shell should not be required by the schools as they will not have the development system.

## C. HARDWARE/SOFTWARE REQUIREMENTS

Both of the training centers have been provided with at least one laptop computer for dedicated MAES use. Concurrent with the deployment of MAES to the ships, each training center should receive a software and hardware package identical to the versions sent to the ships. Ideally, each training center should receive three laptop computers. Two of the laptops would be used in the laboratory and the other one would be connected to a personal computer compatible overhead projector for use in the classroom. Procedures should be in place to ensure that the training centers are on the distribution list for future software updates.

## D. IMPACT ON THE CURRICULUM

Introducing new material into a course usually involves modifications to various training materials ranging from the formal training plan to instructor guides. Even a simple change to a curriculum can result in hours of administrative work to ensure that all affected parts of the curriculum have been changed.

MAES's integration into the MK 92 Mod 2 FCS curriculum will not require extensive changes to the course documentation since the curriculum is currently under review. (Heidenreich, 1995) Any changes initiated by the introduction of MAES can be written into the new course rather than treated as a modification to the old course.

Experience has shown that classroom training does not need to change to accommodate MAES. By learning about MAES after the Daily Systems Operability Test (DSOT) module, students do not need additional classroom training to understand MAES. A simple demonstration in the lab on how to use MAES for fault isolation is all that students need to get started. Hands-on experience is the best way to learn how to use MAES. (Myers, 1996)

Based on FTC San Diego's work, the only changes to the course may be in a couple of the lab assignments. Modifications to the allotted course hours will not be required to support MAES training.

## E. COURSE MATERIALS REQUIREMENTS

Existing course materials that provide fault isolation scenarios for laboratory troubleshooting practice will support the inclusion of MAES into the laboratory assignments. Given a laptop computer loaded with MAES, the training centers should not require any additional course materials.

## F. SUMMARY - INTEGRATION PLAN

The integration of MAES into the MK 92 Mod 2 FCS curriculum will not require the same extensive implementation effort necessary for fielding MAES to the ships. By the time the production version of MAES reaches the ships FCTC Dam Neck will have worked with MAES for almost a year and FTC San Diego will have over two years experience with MAES. This simplifies the integration process and allows the deployment team to narrowly target long-term support related issues rather than familiarization issues.

A plan for integrating MAES into the MK 92 Mod 2 FCS curriculum is provided as Appendix C.

# V. TRANSITIONING LIFE CYCLE SUPPORT FOR MAES TO NSWC PHD

## A. OVERVIEW

This chapter discusses the activities and supporting documentation required to transition life cycle support for MAES to NSWC PHD. This process, while completing the Naval Postgraduate School's involvement in MAES, establishes the foundation for the future of MAES. The quality of the documentation passed to NSWC will be a key determinant in the maintainability of MAES. This will impact the long-term success of the system.

As was done with the shipboard MAES implementation plan and the fleet training centers' MAES integration plan, risk mitigation will be considered in the MAES transfer plan. Maintainability and documentation are just two of the risks that the MAES deployment team must consider when transferring this system. Other risks include attitude towards change, supportability, and training.

This section begins with a discussion of the documentation needed for NSWC PHD to maintain MAES. Next, training requirements are described. An analysis of the communications channels required to maintain MAES follows. The chapter concludes with a description of annual support costs.

## B. DOCUMENTATION REQUIREMENTS

The documentation package for MAES will be based on the guidelines provided by military standard 498 (MIL-STD-498), *Software Development and Documentation.*

These guidelines will be tailored as necessary to accommodate the visual programming environment which was used to develop MAES. Elements of the documentation package will include a system level description, a software design document, the MAES user's manual, and a version description document. (Lester, 1996)

The system level description will provide an overview of the system's purpose, the system development environment, the target operational environment, and the system architecture. Providing greater detail than the system level description, the software design document will focus on the system architecture, the methods used to generate problem analysis trees, and descriptions of the problem analysis diagnostic trees.

The MAES user's manual will offer users information on how to install, initialize, and operate MAES. Procedures for getting help, reporting problems, or recommending changes will also be provided as an addendum to the user's manual.

The version description document will list the version of tools used to develop MAES, version numbers of MAES modules, versions of commercial software which are compatible with this release of MAES, any known problems with this release of MAES, operator work-arounds for any known problems, and points of contact for MAES.

The system level description of MAES is included as Appendix D and the user's manual is provided by Cepek's Master's Thesis. (Cepek, 1996) The software design document and the version description document are being developed for the calibration and performance modules of MAES by the respective contractors and the NSWC project engineer.

## C. TRAINING REQUIREMENTS

Training requirements must be considered for both the MAES configuration manager and the MAES software engineers. As an active participant in the development of MAES, the configuration manager at NSWC PHD has experience with the development tool (Adept), prototype versions of MAES, and the knowledge documentation. Additional training for the configuration manager should not be required.

Written using a visual programming language, MAES will likely pose a new challenge to software engineers at NSWC who have minimal experience with such a tool. Transferring MAES to the NSWC software engineers will bring change to their work environment because MAES was developed with SoftSell Adept. A visual programming language, Adept is somewhat different from the languages normally used by NSWC software engineers. (Smith, 1994) Their attitudes towards this change pose significant potential risks to the successful transfer of MAES. Formal Adept training, discussed below, may offer the best opportunity to positively influence their attitudes.

Even for seasoned software engineers, training represents a serious risk when introducing a new tool. To mitigate the training risk and to ensure the successful transfer of MAES, NSWC software engineers should, like other MAES users, receive training but of a more specialized nature.

Formal Adept training should be provided to at least one of the software engineers who will maintain MAES. (Gorham, 1996a) This will minimize the learning curve for this tool and hopefully decrease the time it takes to perform maintenance on MAES. It will also provide key points of contact with SoftSell should questions arise.

## D. MAINTAINING MAES

MAES maintenance is a broad based function involving the efforts of personnel from NSWC, the FTSC's, the training centers, and the ships. Communication is the key to a successful maintenance program. Communication channels must be established to facilitate feedback from the ships, to encourage critical review and input from the ships, the FTSC's and the training centers, and to coordinate the ongoing improvement of MAES through updates by NSWC.

As discussed in Chapter II, many of the serious risks threatening the success of MAES can be mitigated by developing effective communications. The long-term success of the MAES maintenance program will depend on active and open communications among all involved activities. The communication channels needed to support MAES include feedback channels, configuration management channels, and update channels.

### 1. Feedback Channels

Before the transfer of MAES to NSWC, responsive feedback channels must be in place to support maintenance efforts and to assist MAES users. These communication channels must support activities such as error reporting, recommending changes, placing trouble calls, and requesting help.

Rather than creating new MAES specific procedures and reports, existing feedback mechanisms should be adapted as necessary to support MAES. This minimizes the number of different reporting channels which essentially accomplish similar tasks. Standard reporting procedures for different systems simplifies the process for the sailors. (Curtis, 1996)

Existing reports such as the NSWC PHD Software Trouble Report (SFR), the Digital Systems Feedback Report (DSFR) (NSWSES-3142/1), and the Engineering Change Proposal (ECP), DD Form 1692, provide mechanisms for reporting trouble, getting help, and recommending changes. Discussed in Chapter III, these forms are included as Appendix E. The MAES User's Manual includes a copy of a DSFR. ECPs and STRs are forms routinely used by MK 92 FCS engineers and should not require additional distribution to support MAES feedback.

While these feedback channels can be used by the ships, the FTSC's, or the training centers, they are primarily designed to support the ships. Other channels are required to support long-term configuration management issues which are best handled by the technical experts.

### 2. Configuration Management Channels

The objective of configuration management channels should be to link the technical experts together in a cooperative effort. This can be accomplished informally by promoting e-mail correspondence between the technical experts and formally by including MAES as a new program covered by the existing MK 92 Software Configuration Control Board (SCCB). (Gorham, 1996b)

Membership on the board might initially include NPS as the Design Agent, NSWC PHD 4C45 as ISEA and Software Support Agent, NSWC PHD 4C46 as System Integration Agent, and NAVSEA 91W3PT, the MK 92 Software Program Manager, as the Chair. (Gorham, 1996b) Proposed membership on the board does not include representatives from the FTSC's, the training centers, or the type commanders who are valuable sources of feedback concerning MAES. Their inputs would be channeled to the board through reports such as STRs or through other correspondence with the ISEA.

The board's main objective would be to provide long-range direction and planning for MAES software. In negotiating the details of the Software Transition Plan, the composition of the SCCB should be considered as well as the possibility of establishing a separate configuration control board to support MAES. The MK 92 Software Program Manager should determine the configuration control board's composition based on recommendations from the MAES configuration manager at NSWC PHD.

### 3. Update Channels

As updates are formalized based on inputs received through the feedback and configuration management channels, the task of making and distributing the updates arises. The SCCB will ultimately have responsibility for deciding the extent of the changes to MAES and how frequently updates will be sent. Everything will be contingent on adequate funding. Generally, updates should be provided once a year unless a major change to the system occurs that warrants more frequent updates. (Gorham, 1996) Once the changes have been made, the next task is distributing the updates.

Mail has been the traditional method used to send updates to the ships. (Gorham, 1996) The Streamlined Automated Logistics Transmission System (SALTS) offers a cheaper, faster, more efficient way to distribute updates to the ships. Through telephone lines inport and satellite links underway, all ships have SALTS capabilities.

SALTS provides users with a range of services from transmitting messages or passing e-mail to sending or receiving digital files. By posting MAES updates to the SALTS bulletin board, NSWC could save time and money while making the latest version of MAES immediately available for ships to download at their convenience.

To use SALTS, NSWC PHD would need to purchase the SALTS software, which costs about $1000, and install it on a computer with a modem access. NSWC PHD would receive their own SALTS address which could be used to communicate with the ships and about 2000 other government activities throughout the world. Since NSWC has about 20 existing SALTS locations, NSWC PHD may be able to share SALTS with an existing NSWC site. (Friedrichs, 1996) SALTS could prove to be an important link in the MAES communication network if the NSWC MAES configuration manager and software engineer elect to exploit this capability.

## E. ANNUAL SUPPORT COSTS

Annual support costs cover activities such as system configuration management and software configuration management. Hidden in the annual support costs are elements of risk. Risks such as knowledge accuracy, maintainability, documentation, and supportability will all impact annual support costs.

Qualitatively, the consequences from the occurrence of these events can be rated from minor to moderate threats requiring some management involvement. Quantitatively, the costs from the occurrence of these events can only be guessed. How much more will annual support costs be if the software is difficult to update or some of the knowledge is inaccurate? A range of annual support costs, as shown in Table IV, may provide the best answer.

| Position | Man-years | Hours | Hourly Rate | Subtotal | Total |
|---|---|---|---|---|---|
| Sys Config Mgr | **.25** | **440** | **$55** | **$24,200** | **Qtr Yr Option** |
| S/W Config Mgr | **.25** | **440** | **$55** | **$24,200** | **$48,400** |
| Sys Config Mgr | **.5** | **880** | **$55** | **$48,400** | **Half Yr Opt** |
| S/W Config Mgr | **.5** | **880** | **$55** | **$48,400** | **$96,800** |
| Sys Config Mgr | **1** | **1759** | **$55** | **$96,745** | **Full Yr Opt** |
| S/W Config Mgr | **1** | **1759** | **$55** | **$96,745** | **$193,490** |

**Table IV. Range of Annual Support Costs**

The hourly rate shown in Table IV is based on NSWC's stabilization rate for fiscal year 1996. The hours allotted per man-year were based on a 1759 hour federal work year. (Gassman, 1996) The stabilization rate includes: salary, station overhead, leave, holidays, retirement, and other fringe benefits.

Table IV illustrates that the range of annual support costs spans from about $48,400 to almost $193,500. Cost estimates in this range should be used with caution because they probably understate the actual salary costs. The understatement results from vacation time and other compensatory time-off that might extend the timeframe but not the number of hours expended to maintain MAES.

As an example, assume that MAES takes one quarter man-year to maintain. Also assume that the system configuration manager has six weeks of vacation time. If his vacation days are evenly distributed across four quarters then he will take about eight days off during each quarter. This means that his actual time spent on maintenance might be 440 hours but his actual time expended will be closer to 500 hours which will add another $3,300 to annual support costs.

Other costs such as the administrative expenses of distributing updated software might also be considered, but they will likely add little to the total expenses in comparison to salary expenses. Depending on the involvement of FTSCLANT and FTSCPAC representatives, their efforts might also be included in annual support cost estimates if significant time is required of them.

## F. SUMMARY - SOFTWARE TRANSITION PLAN

As defined in MIL-STD-498, "the Software Transition Plan (STrP) identifies the hardware, software, and other resources needed for life cycle support of deliverable software and describes the developer's plans for transitioning deliverable items to the support agency." (MIL-STD-498, 1994) The deliverable items include documents such as the system level description, the software design document, the MAES user's manual and the version control document.

The formal STrP includes major sections from all of these documents. It can also incorporate information about annual support costs and recommendations for establishing communication channels, discussed above. An STrP template (Data Item Description), DD Form 1664, taken from MIL-STD-498 is provided in Appendix F.

The major burden of providing adequate MAES documentation rests with the NSWC project manager, NPS staff, and the civilian software engineers who developed the calibration and performance modules of MAES. NSWC shares responsibility with NPS for building the communications infrastructure that will ensure the successful long-term support and maintenance of MAES.

# VI. SUMMARY AND CONCLUSIONS

## A. OVERVIEW

The implementation and deployment issues related to fielding MAES are divided into three separate but related areas. This three-tiered implementation plan includes MAES's deployment to the fleet, integration into the formal training pipeline, and transition of life cycle support to NSWC PHD. Within this framework, the research questions are examined as they relate to hardware, documentation, training, and support requirements. Important implementation factors and risks are incorporated into the answer for each of the research questions. This chapter provides a summary of the implementation factors, risks, and other issues important to a successful fielding of MAES.

## B. SUMMARY

This thesis answers three primary research questions which are analyzed according to hardware, documentation, training, and support requirements. This section summarizes the results of research aimed at responding to these questions. Restated from Chapter I, the primary research questions are considered below.

### 1. What are the implementation issues for deploying the MK 92 Mod 2 FCS MAES to all MK 92 Mod 2 ships?

The implementation issues for deploying MAES to the ships include topics such as approval of the production version software, selection of hardware, accummulation of appropriate documentation, development of a training plan, and establishment of support procedures. Associated with these issues are risks and implementation factors specifically related to implementing expert systems such as MAES.

Implementation factors such as user's perception of computing technology, user involvement in expert system implementation, supervisor support, and user perception of change, have all been identified as being highly important implementation factors for expert systems similar to MAES. Along with these implementation factors, project risks such as computer literacy, various levels of resistance, chain-of-command support, and successful deployment training should be incorporated in planning for MAES's full-scale deployment. Appendix B provides simple guidelines for the deployment team to follow with regards to these implementation factors and risks.

One tasking for the MAES deployment team will be to get the production version of the MAES software approved for distribution to the fleet. The approval process will involve coordination between NAVSEA, the ISEA, the fleet commanders, and the type commanders.

Next, the deployment team must consider fielding issues related to hardware selection, documentation, training, and support. Given adequate deployment funding, MAES should be deployed on COTS laptop computers provided to the ships with the hardware and prebundled software manufacturers' user's manuals. Appendix G provides a summary of the hardware, software, and documentation requirements needed to field MAES.

The ideal implementation training scenario would have the deployment team from NSWC PHD providing on-site training for each of the ships. Alternatives exist, such as video teleconferencing, if on-site training is too expensive or impractical. The MAES support plan, which establishes procedures for obtaining software and hardware support, should be in place prior to fielding the system.

**2. What are the requirements for integrating the MK 92 Mod 2 FCS MAES into the MK 92 Mod 2 "C" School curriculum at Fleet Training Center (FTC), San Diego and Fleet Combat Training Center (FCTC), Dam Neck?**

The long relationship between the software developers at NPS and the fleet training centers, especially FTC, San Diego, simplifies the process for integrating MK 92 Mod 2 FCS MAES into the MK 92 Mod 2 "C" School curriculum. Because of the training centers' prior experience with MAES, familiarization training should not be required. Instead, the implementation process should focus on post-implementation support issues which are important to the long-term viability of MAES.

As with deploying MAES to the fleet, implementation factors and risks should be considered when integrating MAES into the "C" school curriculum. Implementation factors such as user's perception of computing technology, user involvement in expert system implementation, supervisor support, and user perception of change, have all been identified as being highly important implementation factors for expert systems similar to MAES. Along with these implementation factors, project risks such as training center acceptance and advocacy, chain-of-command support, and deployment training should be given careful consideration. Appendix C provides simple guidelines for the deployment team to follow with regards to these implementation factors and risks.

The integration of MAES into the MK 92 Mod 2 FCS curriculum will not require the same extensive effort necessary for fielding MAES to the ships. Major changes to the curriculum are not expected as a result of including MAES training. Hardware, software, and documentation requirements for the training centers will parallel the fleet requirements with two minor exceptions. If funds permit, the training centers should be provided with a laptop and a compatible overhead projector for use in the classroom. Since the training environment encourages understanding the system, the training centers should also receive the MAES domain expert's knowledge documentation.

Initial implementation success at the training centers should be easy; however, the long-term success of MAES at the training centers will hinge on the life cycle manager's dedication to keeping the training centers current with fleet developments.

**3. What are the requirements for transitioning life cycle support for the MK 92 Mod 2 FCS MAES software to NSWC PHD?**

Maintainability, documentation, and training are the key issues related to transitioning life cycle support for MAES software to NSWC PHD. The quality of the documentation passed to NSWC will be important to the long-term maintainability of MAES software. Adequate training will also be important, as the NSWC software engineers have limited experience using visual programming tools such as SoftSell Adept. Formal training from SoftSell will likely be necessary.

The documentation required to support MAES should include a system level description, a software design document, the MAES user's manual, and a version description document. In addition, all of the domain expert's knowledge documentation should be transferred to the NSWC software engineers.

Long-term MAES maintenance will require establishment of communications channels for feedback, configuration management, and updates distribution. Existing reports such as the NSWC PHD Software Trouble Report (STR), the Digital Systems Feedback Report (DSFR), and the Engineering Change Proposal (ECP) can be adapted to accommodate MAES feedback requirements. The DSFR will be the most useful feedback mechanism for the ships.

Based on the information received through the feedback channels, a configuration control board should periodically review recommended changes to MAES. Composition of a configuration control board for MAES should be discussed between the ISEA and NAVSEA. Ultimately, MAES updates should be distributed to the ships using the most economical and efficient method available. The Streamlined Automated Logistics Transmission System (SALTS) may satisfy this requirement.

As with the deployment of MAES to the ships and the training centers, implementation factors and risks should be considered in transitioning life cycle support for MAES to NSWC PHD. The risks pertinent to MAES's transition include maintainability, documentation, supportability, training, and attitudes towards change.

## B. CONCLUSIONS

Almost five years after the idea for the Maintenance Advisor Expert System was born, the system has still not been deployed to the fleet. The fact is, MAES may never reach the fleet. Despite its many benefits, such as improved fault isolation capabilities, reduced reliance on outside technical assistance, and decreased replacement of perfectly good repair parts, MAES may not receive deployment funding because of the class of ships that it supports. The Oliver Hazard Perry class frigates are severely challenged by decreased funding levels and reduced maintenance support.

After deployment funding, resistance from competing experts poses the most significant risk to MAES. If identified and addressed early, even serious risks, like experts' resistance, can be controlled.

Consideration of implementation issues and factors from a risk management perspective offers the best opportunity for implementation success when deploying technological innovations such as MAES. The risk management process should begin the first day of the project and continue throughout the innovation's useful life.

In this author's opinion, obtaining funding and support for technological innovations in today's budgetary environment requires more than good technology and effective marketing. It also requires picking the right platform. If MAES receives deployment funding, the implementation and deployment issues discussed in this thesis provide a good foundation for a successful implementation plan.

# APPENDIX A: FTC LAB EXPERIMENTS WITH MAES

## A. OVERVIEW

This appendix shows the results of two laboratory experiments, using MAES, conducted at the MK 92 Mod 2 FCS "C" school in San Diego. The original cost/benefit study of MAES performed in 1993 promised reduced mean-time-to-repair, lower no-fault evident rates, reduced reliance on external technical assistance, and improved shipboard training and knowledge as a result of developing and deploying MAES. (Powell, 1993) Until these two experiments were conducted only anecdotal incidents with the prototype system provided support for these benefits.

The first experiment involved separating students who were in their final weeks of training into two groups. One group would use traditional troubleshooting methods and the other group would rely on MAES for troubleshooting assistance. Though not scientific, the experiment was structured to reveal the power of MAES as a fault isolation tool.

The second experiment attempted to show the power of MAES by evaluating the troubleshooting performance of students who had little or no knowledge of the MK 92 Mod 2 FCS. For this test, new students, with only "A" school training, were taken from the Phalanx Close-In Weapons Systems class.

## B. THE FIRST EXPERIMENT

### 1. Experiment Set-up

The class was first separated into two groups. Each group was further divided into teams composed of two or three members. In the first group, students used traditional manual troubleshooting methods to isolate the test faults. In the second group, students used MAES to isolate test faults. In each set of tests, both groups were given the same fault to isolate and repair. Three faults were selected that fell into three separate categories. The faults and the fault categories are described below:

**Faults:**

Fault #1: All CAS NoGo's; open pin on rigid coax W28 at end connecting output BANDPASS FILTER FL3.

Fault #2: CAS Track Target NoGo's; Ground TP15 of UD412/A1A4-A13 to inhibit CAS Track Target Gate.

Fault #3: All CAS NoGo's except ECM; Fault UD412/A1A4-A1 (Coho Assy) by removing +15VDC at A1-FL1.

**Fault Categories:**

| | |
|---|---|
| Category 1 | Problems everyone could be expected to solve. |
| Category 2 | Problems about 50% of the class could solve. |
| Category 3 | Problems that only a few or no one could solve. |

## 2. Experiment Results

The experiment results are displayed in Tables A-1, A-2, and A-3 shown below:

| Lab | Category | Fault | Class Rank | Time To Repair | NFEs Selected |
|---|---|---|---|---|---|
| 1. Traditional | 1 | 3 | 9 and 10 | 30 minutes | 0 |
| 1. Traditional | 1 | 3 | 1 and 6 | 28 minutes | 0 |
| 1. Traditional | 1 | 3 | 4 and 7 | 10 minutes | 0 |
| 1. MAES Team | 1 | 3 | 3, 5 and 8 | 4 minutes | 0 |

**Table A-1. Fault 3/Category 1 Results**

As illustrated in Table A-1, the students who used MAES isolated the fault faster than any of the traditional troubleshooting teams. With regards to the MAES team, the instructor commented that this was the "easiest lab ever." MAES picked the fault strictly from the calibration results requiring no additional troubleshooting steps. This was a category one problem which meant that everyone in the class was expected to successfully isolate this fault.

| | | | | | |
|---|---|---|---|---|---|
| 2. Traditional | 2 | 1 | 3, 5 and 8 | 62 minutes | 1 |
| 2. MAES Team | 2 | 1 | 1 and 7 | 62 minutes | 0 |
| 2. MAES Team | 2 | 1 | 9 and 10 | 40 minutes | 0 |

**Table A-2. Fault 1/Category 2 Results**

Table A-2 shows the results from the category two fault isolation efforts. The most significant data shown in this table is that the traditional team pulled a No-Fault Evident (NFE) repair part which was valued at about $4,000. Neither of the MAES teams pulled an NFE part and one of the teams finished about thirty percent faster than the other two teams.

| | | | | | |
|---|---|---|---|---|---|
| 3a. Traditional | 3 | 2 | 1 and 7 | 65 minutes | 1 |
| 3b. Traditional | 3 | 2 | 3, 5 and 8 | 100 minutes | 1 |
| 3a. MAES Team | 3 | 2 | 4 and 6 | 43 minutes | 0 |
| 3b. MAES Team | 3 | 2 | 9 and 10 | 55 minutes | 0 |

**Table A-3. Fault 2/Category 3 Results**

Table A-3 reveals the most significant results from this MAES performance evaluation. As shown in Table A-3, the Non-MAES team 3a could not isolate the fault and on board ship would have requested technical assistance. Both MAES teams isolated this fault while only one Non-MAES team solved the problem taking twice as much time as the MAES teams. Additionally, each of the Non-MAES teams pulled an NFE which cost approximately $7,000 each.

During this performance test and evaluation, MAES demonstrated that even an early prototype version has the power to improve mean-time-to-repair and reduce the number of NFE repair parts turned into the supply system. These results were encouraging.

## C. THE SECOND EXPERIMENT

The idea for the second experiment evolved from discussions about how Navy training might change in the future. Driven by smaller budgets, high training costs, and unacceptable attrition rates, the search for a new approach to training has begun. One new approach suggests that "Just-in-Time" training may be the way to cut costs and combat high attrition rates. Without going into detail, instead of emphasizing formal classroom training, this approach relies on focused job specific training for sailors on how to perform their jobs and a job performance aid (e.g. expert system) available aboard ship to assist in maintenance.

Viewing MAES as a "job performance aid" for the MK 92 Mod 2 FCS, Professor McCaffrey proposed that fire control technicians who were just starting the MK 92 Mod 2

FCS "C" school be taken into the lab and given a troubleshooting problem using MAES. The idea was to see how the students performed without the benefit of the 32 week school.

For the actual experiment, FTC instructors chose students who were from the Phalanx Close-In Weapons System class. These students, like the MK 92 Mod 2 FCS students, have an electronics background and a general knowledge of test equipment ("A" school). The test groups had no prior experience with MK 92 Mod 2 FCS.

Using MAES, the first group of students successfully isolated the test fault in about 25 minutes. The normally allotted time for this fault was 45 minutes. Two other groups followed with similar results. The use of control groups was considered but dismissed because the control groups would have no point of reference to begin their troubleshooting efforts.

The findings seem to suggest that a basic electronics background combined with a tool like MAES might reduce the required training time in "C" school for new technicians but allow them to function at an equivalent level of expertise. Further tests and analysis of the training syllabus are needed to substantiate this claim.

# APPENDIX B: IMPLEMENTATION PLAN FOR DEPLOYING MAES TO ALL MK 92 MOD 2 FCS SHIPS

This appendix provides a plan for deploying the production version of MAES to all MK 92 Mod 2 FCS ships. This implementation plan includes a brief discussion about the implementation factors and risks that will likely confront the MAES deployment team. In most cases, this plan does not assign specific individuals to tasks or activities. Assigning responsibilities should be one of the first tasks tackled by the deployment team.

This long-term implementation plan should be viewed as a working document since MAES prototype deployment has not been completed. Applicable sections in this implementation plan should be changed based on the "lessons learned" from the deployment of the MAES prototype.

## MAES IMPLEMENTATION PLAN

**1. Scope**. This implementation plan covers the deployment of the production version of the Maintenance Advisor Expert System (MAES) to all MK 92 Mod 2 Fire Control System (FCS) ships. The homeports include Mayport, Pascagoula, Norfolk, San Diego, Pearl Harbor, and Yokosuka.

**1.1 Identification**. MAES is a diagnostic tool that assists fire control technicians in isolating faults occurring in the MK 92 Mod 2 FCS. The current version of the MAES software is 0.0X. Your version of the software can be verified by checking the front label on the installation diskettes, by viewing the label at the bottom of the program icon, or by starting the program and checking the top bar on the introductory screen.

**1.2 System Overview.** The purpose of MAES is to put expert knowledge for diagnostics at the fingertips of shipboard fire control technicians. A cost/benefit study conducted early in the project's history showed that this expert knowledge could decrease the time it takes to isolate a fault and reduce the number of No-Fault Evident (NFE) repair parts selected by technicians.

Relying on the engineering expertise of the Naval Surface Warfare Center, Port Hueneme Division (NSWC PHD), the Naval Postgraduate School (NPS) managed the development of the MAES software. Funding for the project was received from NAVSEA and the Naval Science Advisors Program (NSAP). On completion of the project, NPS transitioned life cycle support for MAES to NSWC PHD in March 1997 (tentative).

**1.3 Document Overview.** This plan provides a description of those activities and materials that are needed to deploy MAES to all MK 92 Mod 2 FCS ships. The purpose of this plan is to frame the implementation process in terms of important implementation factors and project risks so that the deployment team accomplishes their goal of implementing MAES in a manner that promotes success. This plan is unclassified.

**2. Installation Overview**

**2.1 Description.** The deployment of MAES aboard ships involves several progressive phases. An introductory phase of the deployment process involves considering the implementation factors and risks that might influence the success of the MAES project. Implementation factors such as user's perception of computing technology, user involvement in expert system implementation, supervisor support, and user perception of change, have all been identified as being highly important implementation factors for expert systems similar to MAES.

Along with these implementation factors, project risks such as computer literacy, various levels of resistance, chain-of-command support, and successful deployment training should be incorporated in planning for the future implementation phases. As simple guidelines, the deployment team should:

- Be sensitive to the widely varying computer skills they are likely to encounter.
- Solicit and build support for MAES at all levels of the chain-of-command.
- Cultivate a positive relationship with the FTSC representatives.
- Focus on cultivating supportive "perceptions of change" at all levels of the chain-of-command.
- Realize that deployment training is a Class III risk and they should not be deceived by its apparent simplicity.
- Understand the importance of an effective marketing campaign when fielding MAES.

The first phase entails formally establishing the long-term support infrastructure and communications channels.

The second phase involves gaining the appropriate approval from the chain-of-command for the software to be deployed aboard ships. This will require liaison between the deployment team, NSWC PHD, the fleet commanders' staffs, and the type commanders' staffs. The deployment team should view the approval message as a marketing tool and as such should provide sample drafts to the type commanders' staffs.

The third phase involves scheduling and should commence two quarters prior to the desired implementation dates. Factors such as busy ships' schedules combined with six different homeport locations will make the scheduling process one of the more complex tasks for the deployment team.

The fourth phase involves conducting implementation training and the last phase involves providing life cycle support.

**2.1.1 Installation sites.** Twenty-eight ships homeported in six different locations are tentatively slated to receive MAES. The type commanders' should specify which ships will receive MAES in their approval message. The approval message should task each ship to provide the deployment team with primary and secondary installation dates, a point of contact for installation arrangements, and a phone number. The number of ships may change based on decommissionings, foreign military sales, and the number of prototype sites.

**2.1.2 Installation Dates.** The installation dates are undetermined.

**2.1.3 Method of Installation.** Preferably site visit but undetermined. The method of installation is directly related to the various deployment training options. The potential training alternatives include:

- On-site training by a deployment team from NSWC.
- On-site training by FTSC representatives.
- Training by a deployment team at a central site such as the training centers.
- Training at a central site in each homeport using video-teleconferencing capabilities.
- Videotaped training with videotapes and a deployment kit (laptop loaded with MAES software, user's manuals, etc.) mailed to the ships.
- Written training and a deployment kit mailed to the ships.
- For deployed ships, written training and a deployment kit could be mailed with a follow-up visit performed by NSWC or FTSC when the ships return to their homeport.

**2.2 Contact Point.** The contact points for this installation are:

Henry Seto, Project Engineer
Area Defense Systems Engineering Department
Naval Surface Warfare Center, Port Hueneme Division
Code 4W32
4363 Missile Way
Port Hueneme, California 93043
Phone: (805) 982-0141 DSN 551-
e-mail: Seto_Henry/4W00_AreaDefSysEngDept@om.nswses.navy.mil

Professor Martin J. McCaffrey
Systems Management Curricular Office (Code 36)
Naval Postgraduate School
555 Dyer Road, Room 220
Monterey, CA 93943-5104
Phone: (408) 656-2488 DSN 878-
e-mail: mjmccaff@nps.navy.mil

**2.3 Support Materials.**

- [ ] Prepackaged user's manuals for bundled software such as Microsoft® Windows and DOS 6.2.
- [ ] Laptop computer preloaded with MAES.
- [ ] User's manual for the laptop computer.
- [ ] Two copies of MAES software diskettes, Version 0.0X.
MAES installation instructions.

☐ MAES user's manual.

☐ Procedures for obtaining software updates, submitting change proposals or reporting errors.

☐ Procedures for receiving help.

**2.4 Training.** Based on information gathered from the deployment of the MAES prototype, this section should discuss the plans for training shipboard fire controlmen. This section should discuss a general orientation for both the software and hardware, classroom training (if required), and "hands-on" training.

**2.5 Tasks.** A general description of the tasks required to deploy MAES to the ships and the responsible organization or person is provided below:

a. Project Engineer from NSWC PHD will prepare the requests for authority to deploy MAES to the respective type commanders.

b. Project Engineer from NSWC PHD will draft recommended inputs to the type commanders' approval message.

c. Project Engineer from NSWC PHD will create a list of prospective installation sites and dates for submission to the applicable scheduling conference. Access to Atlantic Fleet ships is gained through scheduling conference inputs. Access requirements for Pacific Fleet ships may differ.

d. NPS will create a MAES marketing campaign which will include providing educational information to various commands and publishing articles in periodicals such as *Surface Warfare* or *Proceedings*.

e. The overall planning, coordination, and preparation for the installation visits will be the responsibility of (staff representative) from COMNAVSURLANT, (staff representative) from COMNAVSURPAC, and the project engineer from NSWC PHD.

f. The installation team will be comprised of at least one engineer from NSWC PHD.

g. Project Engineer from NSWC PHD will ensure that all documentation applicable to the implementations is available prior to the installation dates.

h. Project Engineer from NSWC PHD will ensure that all hardware and peripheral devices are available for transfer on the installation date.

i. Project Engineer from NSWC PHD will plan, coordinate, and conduct training as required.

j. (Ships' point-of-contact) will ensure that designated fire controlmen are available and attend MAES implementation training. This individual will also arrange an orientation briefing for the Commanding Officer and other interested command personnel.

k. Project Engineer from NSWC PHD will conduct post-implementation follow-up calls.

Note: NPS faculty and student participation may occur depending on tasking.

**2.6 Security and privacy.** Since this software is unclassified, special security procedures will not be required to protect MAES. The pilferable nature of the laptop computer will make it necessary to immediately serialize it and either include it on the applicable command's controlled equipage inventory or test equipment inventory.

**3. Site Specific Information.** This section provides a template for tracking implementation related information specific to each ship. This section assumes adoption of an on-site implementation strategy.

**3.1 Site, Schedule, and Contact Matrix.**

| Homeport | Ship | Point of Contact | Phone # | Primary Install date | Secondary Install Date |
|---|---|---|---|---|---|
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |

**3.2 Implementation Visit Tasks.** This section outlines the schedule of tasks to be accomplished during the installation. Some items may change or items may be added based on the NSAP evaluation deployment. This schedule should be presented as a Plan of Action and Milestones (POA&M) listing tasks in chronological order. Some of the activities that should be included are:

- T-120. Provide scheduling conference inputs.
- T-90. Order laptops/surge protectors/cases.
- T-45. Contact ships scheduled for installations. Establish points-of-contact and determine primary/secondary installation dates.
- T-14. Ensure that the laptops and supporting peripherals are available. If shipping computers, ensure that MAES software is preloaded and allow two weeks lead time for shipping.
- T-14. Load MAES software onto the laptop and test.
- T-14. Assemble all training materials and support documentation.
- T-7. Confirm all arrangements one week prior.
- T-3. Confirm security clearances have been received by ship.
- Conduct in-brief with the Commanding Officer and designated officers, chief petty officers, and work center representatives.
- Conduct computer orientation training.
- Conduct MAES software orientation training.
- Review all provided materials including user's manual for the hardware and software.
- Review special procedures for getting help, completing trouble reports, submitting error reports, etc.
- Conduct out-brief with the Commanding Officer and designated officers, chief petty officers, and work center representatives as necessary.
- T+14. Conduct follow-up survey by phone or SALTS.

**3.3 Facilities.** This section will describe the physical facilities and accommodations needed to support implementation training. This task will become important if the implementation training is held some place other than on the ship. Lessons learned from the NSAP deployment and evaluation will provide valuable details.

# APPENDIX C: INTEGRATION PLAN FOR INCLUDING MAES IN THE MK 92 MOD 2 FCS "C" SCHOOL CURRICULUM

This appendix provides a plan for integrating MAES into the MK 92 Mod 2 FCS "C" School curriculum. The integration plan includes a brief discussion about the implementation factors and risks that will likely confront the MAES deployment team. In most cases, this plan does not assign specific individuals to tasks or activities. Assigning responsibilities should be one of the first tasks tackled by the deployment team.

# MAES INTEGRATION PLAN

**1. Scope**. This integration plan covers the formal integration of the Maintenance Advisor Expert System (MAES) into the MK 92 Mod 2 Fire Control System (FCS) "C" school curriculum. This plan includes the fleet training centers in Dam Neck, Virginia and San Diego, California.

**1.1 Identification**. MAES is a diagnostic tool that assists fire control technicians in isolating faults occurring in the MK 92 Mod 2 FCS. The current version of the MAES software is 0.0X. Your version of the software can be verified by checking the front label on the installation diskettes, by viewing the label at the bottom of the program icon, or by starting the program and checking the top bar on the introductory screen.

**1.2 System Overview.** The purpose of MAES is to put expert knowledge at the fingertips of shipboard fire control technicians. A cost/benefit study conducted early in the project's history showed that this knowledge could decrease the time it takes to isolate a fault and reduce the number of No-Fault Evident (NFE) repair parts selected by technicians.

Relying on the engineering expertise of the Naval Surface Warface Center, Port Hueneme Division (NSWC PHD), the Naval Postgraduate School (NPS) managed the development of the MAES software. Funding for the project was received from NAVSEA and the Naval Science Advisors Program (NSAP). On completion of the project, NPS transitioned life cycle support for MAES software to NSWC PHD in March 1997 (tentative).

**1.3 Document Overview.** This plan provides a description of those activities and materials that are needed to integrate MAES into the MK 92 Mod 2 FCS "C" school curriculum. The purpose of this plan is to frame the integration process in terms of important implementation factors and project risks so that the deployment team accomplishes their goal of implementing MAES in a manner that promotes success. This plan is unclassified.

**2. Installation Overview**

**2.1 Description.** A standard implementation process might begin with an introduction to the system supported by familiarization training. This step will not be necessary for the integration of MAES into the MK 92 Mod 2 FCS "C" school curriculum because of the prior experience that the training centers have with MAES. Instead, this implementation process will focus on post-implementation support issues which are important to the long-term viability of MAES.

To set the stage, the deployment team should review those implementation factors and risks that might influence the success of the MAES project. Implementation factors such as user's perception of computing technology, user involvement in expert system implementation, supervisor support, and user perception of change, have all been identified as being highly important implementation factors for expert systems similar to MAES. Along with these implementation factors, project risks such as training center acceptance and advocacy, chain-of-command support, and deployment training should be given careful consideration.

As simple guidelines, the deployment team should:

- Emphasize to the training centers' instructors the importance of building positive perceptions of this technology in the opinions of the students.
- Describe to the instructors how their support and involvement are important.
- Understand that with the training centers there are actually two groups of users, the students and the instructors.
- Focus on cultivating supportive "perceptions of change" on the part of the instructors.
- Realize that deployment training is a Class III risk and they should not be deceived by its apparent simplicity.
- Understand the importance of an effective marketing campaign when fielding MAES.

**2.1.1 Installation sites.** The two training centers' addresses and points of contact are:

Fleet Combat Training Center Atlantic, Dam Neck
Code N723C
Weapons Training Department
1912 Regulus Avenue
Virginia Beach, Virginia 23461-2098
Points of contact: LT Tommy Johnson
(804) 433-6351 DSN 433-
(804) 433-7492 (fax)
or
FCC(SW) Ken Turman
(804) 433-6691 or e-mail
FCTCLANT.N723TKD@netpmsa.cnet.navy.mil

Fleet Training Center
Box 368035, FLEETTRACEN Code 424
3975 Norman Scott Road, Suite 1
San Diego, CA 92136-5588
Point of contact: FCC(SW) Myers
(619) 556-7577 DSN 526-

**2.1.2 Installation Dates.** The installation dates are undetermined.

**2.1.3 Method of Installation.** Site visit.

**2.2 Contact Point.** The contact points for this installation are:

Henry Seto, Project Engineer
Area Defense Systems Engineering Department
Naval Surface Warfare Center, Port Hueneme Division
Code 4W32
4363 Missile Way
Port Hueneme, California 93043
Phone: (805) 982-0141 DSN 551-
e-mail: Seto_Henry/4W00_AreaDefSysEngDept@om.nswses.navy.mil

Professor Martin J. McCaffrey
Systems Management Curricular Office (Code 36)
Naval Postgraduate School
555 Dyer Road, Room 220
Monterey, CA 93943-5104
Phone: (408) 656-2488 DSN 878-
e-mail: mjmccaff@nps.navy.mil

**2.3 Support Materials.**

- [ ] Prepackaged user's manuals for bundled software such as Microsoft® Windows and DOS 6.2.
- [ ] Laptop computers.
- [ ] User's manual for the laptop computer.
- [ ] MAES software diskettes, Version 0.0X
- [ ] MAES installation instructions.
- [ ] Laptop compatible overhead projector.
- [ ] A copy of MAES knowledge diagnostic trees.
- [ ] Procedures for obtaining software updates, submitting change proposals or reporting errors.

**2.4 Training.** Training will focus on familiarizing the fleet training centers' instructors with the various support materials described above. General orientation training and other forms of introductory training for first time users will not be required at the fleet training centers unless key training center contacts detach prior to the scheduled installations.

**2.5 Tasks.** A general description of the tasks required to deploy MAES to the training centers and the responsible organization or person is provided below:

a. The overall planning, coordination, and preparation for the installation will be the responsibility of the project engineer from NSWC PHD, Chief Petty Officer Myers from FTC, San Diego, and Chief Petty Officer Turman from FCTC, Dam Neck.

b. The installation team will be comprised of at least one engineer from NSWC PHD. NPS faculty and student participation may apply.

c. Project engineer from NSWC PHD will ensure that all documentation applicable to the implementations are available prior to the installation dates.

d. Project engineer from NSWC PHD will ensure that all hardware and peripheral devices are available for transfer on the installation date.

e. Project engineer from NSWC PHD will plan and conduct training as required.

f. Chief Myers and Chief Turman will identify those instructors who will receive MAES training at their respective training centers.

**2.6 Security and privacy.** Since this software is unclassified, special security procedures will not be required to protect MAES. The pilferable nature of the laptop computer will make it necessary to immediately serialize it and include it on the applicable command's minor property inventory.

Note: NPS faculty and student participation may occur depending on tasking.

## APPENDIX D: MAES SYSTEM LEVEL DESCRIPTION

The MAES system level description provides data that will be used to maintain the system. It will include a brief overview of the system's purpose, the system development environment, the target operational environment, the system architecture, and resulting products. As mentioned in Chapter V, the system level description is one of four documentation products that will be developed for MAES. Information from these documents will be integrated into a Software Transition Plan when all of the documents have been completed.

This is an initial outline for the system level description. Improvements to this document should be made as additional information about the production version of the MAES software becomes available. Information contained in this document has been drawn from a number of sources. Lawrence Scruggs, the software engineer for the Calibration module, provided the majority of the information comprising this system level description. The deliverable document will be developed as part of the production funded tasking.

# MK 92 Mod 2 Fire Control System Maintenance Advisor Expert System (MAES)

## SYSTEM LEVEL DESCRIPTION

Prepared By
Naval Postgraduate School
Monterey, California

Prepared For
Naval Surface Warfare Center
Port Hueneme Division

**13 September 1996**

I. Document Scope.

A. System Applicability. The Maintenance Advisor Expert System(MAES) is a diagnostic expert system designed to provide training and troubleshooting assistance to fire control technicians who maintain the MK 92 Mod 2 Fire Control System (FCS) installed aboard U.S. Navy Oliver Hazard Perry class guided missile frigates.

B. The purpose of this document is to describe the purpose of MAES, its development environment, the overall system architecture, and the products which form MAES.

II. Applicable Documentation.

A. List of MIL Specs used (if any) - None
B. List of government documents used - None
C. List of commercial documents used - Will be available after the integration of the performance and calibration modules.

III. System Overview.

A. Development Rationale. Repeatedly listed on the CINCLANTFLT/CINCPACFLT Fleet Troubled Combat Systems Reports, the MK 92 Mod 2 FCS is a maintenance intensive system that is plagued by excessive downtime and often requires outside technical assistance to repair. MAES attempts to provide shipboard Fire Control technicians with access to expert knowledge and troubleshooting expertise through a software program.

B. Purpose of MAES. The main purpose for developing MAES is to enhance the ability of MK 92 Mod 2 Fire Control technicians to better determine, diagnose, and resolve problems occurring within their systems without the assistance of outside technical representatives. (McGaha, 1994) While MAES provides diagnostic capabilities, it is not integrated into the MK 92 Mod 2 FCS and is best deployed on a standalone laptop computer.

C. Development Environment.

1. Naval Postgraduate School computer laboratory provides access to research and commercial software and hardware. Provided resources include internet access to support tools such as software updates.

2. Commercial Expert-System-Development Shell (Integrated Development Environment or IDE).

a) Terms used to describe the IDE and "programming language" include "graphical programming," "visual programming," and "iconic programming." One's first visual impression might remind one of formal structure charts used in software-engineering documentation.

b) MAES is currently two application files (Calibration and Performance) each containing sets of procedures. Each procedure is a set of nodes and arcs assembled to provide assistance in troubleshooting specific areas of the MK 92 Mod 2 FCS. The procedures generally follow the troubleshooting structure charts provided by the expert.

c) Nodes and arcs (represented in the IDE's GUI by icons and colored lines) do the work of traditional declarative and procedural code lines (as in Ada, C, Pascal, FORTRAN, SAS, etc.).

(1) Nodes represent reusable "packages" of code that generate CRT displays and accept user input, make decisions based on user-provided data and rules provided by experts, and link procedures.

(2) Arcs represent program-control flow.

(3) Data flow is not represented.

3. Personal Computer compatible desktop computer.

a) Intel 80486 compatible, 50 MHz, 8 MB RAM, 150 MB hard drive, 100 MB Iomega Zip drive, Hewlett Packard Laserjet IIP printer.

b) Intel 80586 compatible, 100 MHz, 16 MB RAM.

4. Support tools.

a) The internet provides communication among team members and access to maintenance items for development tools.

b) MS-Office provides administrative and documentation support.

c) Image management relies on COTS software.

D. Description of Target Operational Environment. Personal Computer compatible laptop computer.

1. Intel 80486/80586 compatible, 100 MHz, 16 MB RAM, 500 MB hard drive.

2. MAES Calibration and Performance modules currently require 20 megabytes of disk space. These modules can run in eight megabytes of RAM.

E. Description of System Architecture. The main Adept constructs are applications, procedures, and nodes/arcs. An application usually consists of several procedures, where each procedure is made up of nodes, displays, variables, and functions. An application typically corresponds to the overall program. (Smith, 1994)

Programs called procedures are used to build an application. A procedure consists of a series of visual objects called nodes. A node is a graphical object which represents a specific step or series of steps within any given procedure. It is a visual object that allows end users to design and implement an expert system without having to deal with traditional text-based programming code. (Smith, 1994)

The MAES program would be considered an application. Procedures supporting the application would presently be structured around two modules, the performance module and the calibration module. Nodes representing yes/no/unknown decisions are used to build procedures which are drawn from the domain expert's knowledge document.

F. Description of Validation Methodology. Validation has been performed through visual inspection of the product by experts and the target audience.

G. Description of MAES products. Loaded on a laptop computer, MAES software provides MK 92 Mod 2 FCS technicians access to expert knowledge to assist them in isolating faults discovered during MK 92 Mod 2 FCS Daily Systems Operability Tests (DSOT).

IV. Development Environment

A. Hardware Requirements. Personal Computer compatible desktop computer.

1. Intel 80486 compatible, 50 MHz, 8 MB RAM, 150 MB hard drive, 100 MB Iomega Zip drive, Hewlett Packard Laserjet IIP printer.

2. Additional computers are used for communications and demonstrations in support of the project.

B. Software Environment. The software environment for MAES includes Microsoft DOS® 6.2 and Microsoft Windows® 3.1.

C. Software tools which are MAES (or expert system) specific. SoftSell Adept® 2.21.

V. Target Operational Environment

A. Hardware Requirements. Intel 80586 compatible, 100 MHz, 16 MB RAM.

B. Software Environment. The user must interface through three levels of software - DOS, Windows, and Adept - to operate MAES.

VI. System Architecture

A. Basic System Structure. (Should show how the different software units interface with each other. Need to list everything required to run MAES including the operating system, commercial software packages, databases, etc.)

B. Structure of all units developed specifically for MAES. (Internal organization, data type requirements, unit interactions.)

VII. Validation Methodology

A. What type of validation is planned?

B. Scope of validation.

C. Location, schedule, equipment requirements, and personnel requirements.

VIII. Products

A. Documentation developed for MAES

1. System Level Description

2. Software Design Document

3. MAES User's Manual

4. Version Description Document

B. Software developed for MAES

# APPENDIX E: FORMS

This appendix contains three existing forms or reports that can be adapted to support MAES reporting procedures. Use of these forms will take advantage of existing reporting channels and procedures rather than creating new ones. These forms include the NSWC PHD Software Trouble Report, the Digital Systems Feedback Report (NSWSES-3142/1), and the Engineering Change Proposal (DD Form 1692). The function of these forms is described in Chapter III and summarized below:

NSWC PHD Software Trouble Report (STR): The STR should be used mainly by engineers who are familiar with the MAES software and the MK 92 Mod 2 FCS to report software problems or to propose software enhancements.

Digital Systems Feedback Report (DSFR): The DSFR serves the same purpose as the STR but it uses a simpler format. The DSFR is primarily intended for use by sailors and support personnel to report software errors, submit trouble reports, or recommend enhancements.

Engineering Change Proposals (ECPs): Open SFR's are periodically reviewed by the Software Configuration Control Board and rewritten as ECPs. Certain ECPs are selected for a software build referred to as a version release.

## NSWC PHD SOFTWARE TROUBLE REPORT

To: Port Hueneme Division, Naval Surface Warfare Center
Code 4W34
Port Hueneme, California 93043

| 1. Date | 2. Category<br>S D E | 3. Error Priority *<br>1 2 3 4 5 | 4a. SCCB No. * | 4b. ISEA No. * | 4c. Orig No. |
|---|---|---|---|---|---|
| 5. Title | | | | | |
| 6. Official Program Designation | | 7. Official Program Document | | 8. Unit/Site | |
| 9a. Program Medium | 9b. Serial No. | 10. Reference Document | | 11. Function Affected | |
| 12. Responsible Module(s) | | | 13. Test/Step | | |
| 14. Originator | | 15. Activity/Code | | 16. Tel/Ext | |
| 17. Run time | | 18. Simulation Used | | 19. Interface with | |
| 20. Configuration/Patches in Core | | | | | |

| 21. Problem Duplicated - Circle the required items | 22a. Enclosures- Circle the required items | 22b. Other Systems/Programs Affected |
|---|---|---|
| During Run Yes No N/A<br>After Restart Yes No N/A<br>After Reload Yes No N/A | Complication Typewriter O/P<br>Sample Program Memory Map<br>Object Program Memory Dump<br>Source Program Other | |

23. Trouble Description

24. Response

| Valid | Urgency | ECP Class | ECP Number |
|---|---|---|---|
| 25. V&V Date | 26. Navy SCCB Signature | | |

* TO BE FILLED IN BY SOFTWARE SUPPORT AGENT ONLY

# DIGITAL SYSTEMS FEEDBACK REPORT

# DIGITAL SYSTEMS FEEDBACK REPORT (DSFR)

| WEAPONS SYSTEM MK: MOD: | SHIP NAME | HULL NUMBER |
|---|---|---|
| SHIPBOARD POINT OF CONTACT | | DATE |
| PHONE NUMBER OR CONTACT METHOD | DELIVERY TAPE SERIAL NUMBER | |

**QUESTION OR PROBLEM:** PLEASE PROVIDE ALL AVAILABLE INFORMATION, ESPECIALLY WHAT PROGRAM WAS RUNNING, WHICH MODE (NORMAL, CASUALTY, LOCAL), ENGAGEMENT STATUS, LAMP INDICATIONS, AND WHAT HAPPENED

| SEND COMPLETED FORM TO: | OR FAX TO: |
|---|---|
| COMMANDING OFFICER<br>NAVAL SHIP WEAPON SYSTEMS ENGINEERING STATION<br>PORT HUENEME, CA 93043-5007<br>ATTENTION CODE 4W40 (CM) | NSWSES TARTAR DEPARTMENT<br>ATTENTION 4W40 (CM)<br>FAX NO. (805) 982-8546 |

NSWSES-3142/1 (10-90)

## ENGINEERING CHANGE PROPOSAL

**ENGINEERING CHANGE PROPOSAL, PAGE 1**
*(SEE MIL-STD-480 FOR INSTRUCTIONS)*

DATE PREPARED

PROCURING ACTIVITY NO.

1. ORIGINATOR NAME AND ADDRESS

2. CLASS OF ECP | 3. JUST. CODE | 4. PRIORITY

5. ECP DESIGNATION

| a. MODEL/TYPE | b. MFR. CODE | c. SYS. DESIG. | d. ECP NO. | e. TYPE | f. REV. | g. CORR. |
|---|---|---|---|---|---|---|
| | | | | | | |

6. BASELINE AFFECTED
☐ FUNCTIONAL ☐ ALLOCATED ☐ PRODUCT

7. OTHER SYS./CONFIG. ITEMS AFFECTED
☐ YES ☐ NO

8. SPECIFICATIONS AFFECTED - TEST PLAN

| | MFR CODE | SPEC./DOC. NO. | SCN |
|---|---|---|---|
| a. SYSTEM | | | |
| b. ITEM | | | |
| c. TEST PLAN | | | |

9. DRAWINGS AFFECTED

| MFR CODE | NUMBER | REV. | NOR NO. |
|---|---|---|---|
| | | | |
| | | | |
| | | | |

10. TITLE OF CHANGE

11. CONTRACT NO. & LINE ITEM

12. CONFIGURATION ITEM NOMENCLATURE

13. IN PRODUCTION
☐ YES ☐ NO

14. NAME OF PART OR LOWEST ASSEMBLY AFFECTED

15. PART NO. OR TYPE DESIGNATION

16. DESCRIPTION OF CHANGE

17. NEED FOR CHANGE

18. PRODUCTION EFFECTIVITY BY SERIAL NUMBER

19. EFFECT ON PRODUCTION DELIVERY SCHEDULE

20. RETROFIT

a. RECOMMENDED ITEM EFFECTIVITY

b. ESTIMATED KIT DELIVERY SCHEDULE

c. SHIP/VEHICLE CLASS AFFECTED

d. LOCATIONS OR SHIP/VEHICLE NUMBERS AFFECTED

21. ESTIMATED COSTS/SAVINGS UNDER CONTRACT

22. ESTIMATED NET TOTAL COSTS

23. SUBMITTING ACTIVITY AUTHORIZING SIGNATURE

TITLE

24. APPROVAL/DISAPPROVAL

a. CLASS I
☐ APPROVAL RECOMMENDED

b. CLASS II
☐ APPROVED ☐ DISAPPROVED ☐ CONCUR IN CLASSIFICATION OF CHANGE ☐ DO NOT CONCUR IN CLASSIFICATION OF CHANGE

c. GOVERNMENT ACTIVITY

SIGNATURE

DATE

DD FORM 1 DEC 68 1692 S/N-0102-020-8000

ENGINEERING CHANGE PROPOSAL, PAGE 2
*(SEE MIL-STD-480 FOR INSTRUCTIONS)*

PROCURING ACTIVITY NO.

ORIGINATOR NAME AND ADDRESS

ECP NUMBER

EFFECTS ON FUNCTIONAL/ALLOCATED CONFIGURATION IDENTIFICATION

25. OTHER SYSTEMS AFFECTED

26. OTHER CONTRACTORS/ACTIVITIES AFFECTED

27. CONFIGURATION ITEMS AFFECTED

28. EFFECTS ON PERFORMANCE ALLOCATIONS AND INTERFACES IN SYSTEM SPECIFICATIONS

29. EFFECTS ON EMPLOYMENT, INTEGRATED LOGISTIC SUPPORT, TRAINING, OPERATIONAL EFFECTIVENESS, ETC.

30. EFFECTS ON CONFIGURATION ITEM SPECIFICATIONS

31. DEVELOPMENTAL REQUIREMENTS AND STATUS

32. TRADE OFFS AND ALTERNATIVE SOLUTIONS

33. DATE BY WHICH CONTRACTUAL AUTHORITY IS NEEDED

DD FORM 1 DEC 65 1692-1 S/N-0102-020-8010

☆ U.S. GOVERNMENT PRINTING OFFICE: 1974—713-653/3993 2-1

# APPENDIX F: SOFTWARE TRANSITION PLAN

This appendix provides the Software Transition Plan (STrP) Data Item Description (DID) from the Department of Defense's, *Software Development and Documentation Military Standard*, MIL-STD-498. The STrP identifies hardware, software, and other resources needed for life cycle support of deliverable software. It also describes the developer's plans for transitioning deliverable items to the support agency. In the case of MAES software, the deliverable items include documents such as the System Level Description, the Software Design Document, the MAES user's manual, and the Version Control Document.

# DATA ITEM DESCRIPTION

*Form Approved*
*OMB NO.0704-0188*



**1. TITLE**

**SOFTWARE TRANSITION PLAN (STrP)**

**2. IDENTIFICATION NUMBER**

**DI-IPSC-81429**

**3. DESCRIPTION/PURPOSE**

3.1 The Software Transition Plan (STrP) identifies the hardware, software, and other resources needed for life cycle support of deliverable software and describes the developer's plans for transitioning deliverable items to the support agency.

3.2 The STrP is developed if the software support concept calls for transition of responsibility from the developer to a separate support agency. The STrP may also be used by the acquirer for updating the Computer Resources Life Cycle Management Plan.

| 4. APPROVAL DATE (YYMMDD) | 5. OFFICE OF PRIMARY RESPONSIBILITY | 6a. DTIC APPLICABLE | 6b. GIDEP APPLICABLE |
|---|---|---|---|
| 941205 | EC | | |

**7. APPLICATION/INTERRELATIONSHIP**

7.1 This Data Item Description (DID) contains the format and content preparation instructions for the data product generated by specific and discrete task requirements as delineated in the contract.

7.2 This DID is used when the developer is tasked to develop and record plans for transitioning deliverable items to the support agency.

7.3 The Contract Data Requirements List (CDRL) (DD 1423) should specify whether deliverable data are to be delivered on paper or electronic media; are to be in a given electronic form (such as ASCII, CALS, or compatible with a specified word processor or other support software); may be delivered in developer format rather than in the format specified herein; and may reside in a computer-aided software engineering (CASE) or other automated tool rather than in the form of a traditional document.

7.4 This DID supersedes DI-MCCR-80024A.

| 8. APPROVAL LIMITATION | 9a. APPLICABLE FORMS | 9b. AMSC NUMBER |
|---|---|---|
| Limited Approval from 12/5/94 through 12/5/96 | | N7072 |

**10. PREPARATION INSTRUCTIONS**

10.1 General instructions.

a. Automated techniques. Use of automated techniques is encouraged. The term "document" in this DID means a collection of data regardless of its medium.

b. Alternate presentation styles. Diagrams, tables, matrices, and other presentation styles are acceptable substitutes for text when data required by this DID can be made more readable using these styles.

(Continued on Page 2)

**11. DISTRIBUTION STATEMENT**

DISTRIBUTION STATEMENT A. Approved for public release; distribution is unlimited.

10. PREPARATION INSTRUCTIONS -- 10.1 General Instructions (continued)

c. Title page or identifier. The document shall include a title page containing, as applicable: document number; volume number; version/revision indicator; security markings or other restrictions on the handling of the document; date; document title; name, abbreviation, and any other identifier for the system, subsystem, or item to which the document applies; contract number; CDRL item number; organization for which the document has been prepared; name and address of the preparing organization; and distribution statement. For data in a database or other alternative form, this information shall be included on external and internal labels or by equivalent identification methods.

d. Table of contents. The document shall contain a table of contents providing the number, title, and page number of each titled paragraph, figure, table, and appendix. For data in a database or other alternative form, this information shall consist of an internal or external table of contents containing pointers to, or instructions for accessing, each paragraph, figure, table, and appendix or their equivalents.

e. Page numbering/labeling. Each page shall contain a unique page number and display the document number, including version, volume, and date, as applicable. For data in a database or other alternative form, files, screens, or other entities shall be assigned names or numbers in such a way that desired data can be indexed and accessed.

f. Response to tailoring instructions. If a paragraph is tailored out of this DID, the resulting document shall contain the corresponding paragraph number and title, followed by "This paragraph has been tailored out." For data in a database or other alternative form, this representation need occur only in the table of contents or equivalent.

g. Multiple paragraphs and subparagraphs. Any section, paragraph, or subparagraph in this DID may be written as multiple paragraphs or subparagraphs to enhance readability.

h. Standard data descriptions. If a data description required by this DID has been published in a standard data element dictionary specified in the contract, reference to an entry in that dictionary is preferred over including the description itself.

i. Substitution of existing documents. Commercial or other existing documents may be substituted for all or part of the document if they contain the required data.

10.2 Content requirements. Content requirements begin on the following page. The numbers shown designate the paragraph numbers to be used in the document. Each such number is understood to have the prefix "10.2" within this DID. For example, the paragraph numbered 1.1 is understood to be paragraph 10.2.1.1 within this DID.

10. PREPARATION INSTRUCTIONS -- 10.2 Content Requirements (continued)

1. Scope. This section shall be divided into the following paragraphs.

1.1 Identification. This paragraph shall contain a full identification of the system and the software to which this document applies, including, as applicable, identification number(s), title(s), abbreviation(s), version number(s), and release number(s).

1.2 System overview. This paragraph shall briefly state the purpose of the system and the software to which this document applies. It shall describe the general nature of the system and software; summarize the history of system development, operation, and maintenance; identify the project sponsor, acquirer, user, developer, and support agencies; identify current and planned operating sites; and list other relevant documents.

1.3 Document overview. This paragraph shall summarize the purpose and contents of this document and shall describe any security or privacy considerations associated with its use.

1.4 Relationship to other plans. This paragraph shall describe the relationship, if any, of the STrP to other project management plans.

2. Referenced documents. This section shall list the number, title, revision, and date of all documents referenced in this document. This section shall also identify the source for all documents not available through normal Government stocking activities.

3. Software support resources. This section shall be divided into paragraphs to identify and describe the resources needed to support the deliverable software. These resources shall include items needed to control, copy, and distribute the software and its documentation, and to specify, design, implement, document, test, evaluate, control, copy, and distribute modifications to the software.

3.1 Facilities. This paragraph shall describe the facilities needed to support the deliverable software. These facilities may include special buildings, rooms, mock-ups, building features such as raised flooring or cabling; building features to support security and privacy requirements (TEMPEST shielding, vaults, etc.), building features to support safety requirements (smoke alarms, safety glass, etc.), special power requirements, and so on. The purpose of each item shall be described. Diagrams may be included as applicable.

3.2 Hardware. This paragraph shall identify and describe the hardware and associated documentation needed to support the deliverable software. This hardware may include computers, peripheral equipment, hardware simulators, stimulators, emulators, diagnostic equipment, and non-computer equipment. The description shall include:

a. Specific models, versions, and configurations
b. Rationale for the selected hardware
c. Reference to user/operator manuals or instructions for each item, as applicable
d. Identification of each hardware item and document as acquirer-furnished, an item that will be delivered to the support agency, an item the support agency is known to have, an item the support agency must acquire, or other description of status

10. PREPARATION INSTRUCTIONS -- 10.2 Content Requirements (continued)

e. If items must be acquired, information about a current source of supply, including whether the item is currently available and whether it is expected to be available at the time of delivery

f. Information about manufacturer support, licensing, and data rights, including whether the item is currently supported by the manufacturer, whether it is expected to be supported at the time of delivery, whether licenses will be assigned to the support agency, and the terms of such licenses

g. Security and privacy considerations, limitations, or other items of interest

3.3 Software. This paragraph shall identify and describe the software and associated documentation needed to support the deliverable software. This software may include computer-aided software engineering (CASE) tools, data in these tools, compilers, test tools, test data, simulations, emulations, utilities, configuration management tools, databases and data files, and other software. The description shall include:

a. Specific names, identification numbers, version numbers, release numbers, and configurations, as applicable

b. Rationale for the selected software

c. Reference to user/operator manuals or instructions for each item, as applicable

d. Identification of each software item and document as acquirer-furnished, an item that will be delivered to the support agency, an item the support agency is known to have, an item the support agency must acquire, or other description of status

e. If items must be acquired, information about a current source of supply, including whether the item is currently available and whether it is expected to be available at the time of delivery

f. Information about vendor support, licensing, and data rights, including whether the item is currently supported by the vendor, whether it is expected to be supported at the time of delivery, whether licenses will be assigned to the support agency, and the terms of such licenses

g. Security and privacy considerations, limitations, or other items of interest

3.4 Other documentation. This paragraph shall identify any other documentation needed to support the deliverable software. The list will include, for example, plans, reports, studies, specifications, design descriptions, test cases/procedures, test reports, user/operator manuals, and support manuals for the deliverable software. This paragraph shall provide:

a. Names, identification numbers, version numbers, and release numbers, as applicable

b. Rationale for including each document in the list

c. Identification of each document as acquirer-furnished, an item that will be delivered to the support agency, an item the support agency is known to have, an item the support agency must acquire, or other description of status

d. If a document must be acquired, information about where to acquire it

10. PREPARATION INSTRUCTIONS -- 10.2 Content Requirements (continued)

e. Information about licensing and data rights

f. Security and privacy considerations, limitations, or other items of interest

3.5 Personnel. This paragraph shall describe the personnel needed to support the deliverable software, including anticipated number of personnel, types and levels of skills and expertise, and security clearances. This paragraph shall cite, as applicable, actual staffing on the development project as a basis for the staffing needs cited.

3.6 Other resources. This paragraph shall identify any other resources needed to support the deliverable software. Included may be consumables such as magnetic tapes and diskettes, together with an estimate of the type and number that should be acquired.

3.7 Interrelationship of components. This paragraph shall identify the interrelationships of the components identified in the preceding paragraphs. A figure may be used to show the interrelationships.

4. Recommended procedures. This section shall be divided into paragraphs as needed to describe any procedures, including advice and lessons learned, that the developer may wish to recommend to the support agency for supporting the deliverable software and associated support environment.

5. Training. This section shall be divided into paragraphs as appropriate to describe the developer's plans for training support personnel to support of the deliverable software. This section shall include:

a. The schedule, duration, and location for the training

b. The delineation between classroom training and "hands-on" training

c. Provision (either directly or by reference) for:

   1) Familiarization with the operational software and target computer(s)

   2) Familiarization with the support software and host system

6. Anticipated areas of change. This section shall describe anticipated areas of change to the deliverable software.

7. Transition planning. This section shall be divided into paragraphs as needed to describe the developer's plans for transitioning the deliverable software to the support agency. This section shall address the following:

a. All activities to be performed to transition the deliverable software to the support agency. These activities may include planning/coordination meetings; preparation of items to be delivered to the support agency; packaging, shipment, installation, and checkout of the software support environment; packaging, shipment, installation, and checkout of the operational software; and training of support personnel.

b. Roles and responsibilities for each activity

10. PREPARATION INSTRUCTIONS -- 10.2 Content Requirements (continued)

c. The resources needed to carry out the transition activities and the source from which each resource will be provided

d. Schedules and milestones for conducting the transition activities. These schedules and milestones shall be compatible with the contract master schedule.

e. Procedures for installation and checkout of deliverable items in the support environment

8. Notes. This section shall contain any general information that aids in understanding this document (e.g., background information, glossary, rationale). This section shall include an alphabetical listing of all acronyms, abbreviations, and their meanings as used in this document and a list of any terms and definitions needed to understand this document.

A. Appendixes. Appendixes may be used to provide information published separately for convenience in document maintenance (e.g., charts, classified data). As applicable, each appendix shall be referenced in the main body of the document where the data would normally have been provided. Appendixes may be bound as separate documents for ease in handling. Appendixes shall be lettered alphabetically (A, B, etc.).

# APPENDIX G. HARDWARE, SOFTWARE, AND DOCUMENTATION REQUIREMENTS

This appendix summarizes the anticipated hardware, software, and documentation requirements necessary to deploy MAES to the ships, integrate it into the "C" school curriculum, and transition life cycle support for it to NSWC PHD. This matrix should be used as a working document for future planning.

| Activity Requirement | Fleet | NSWC | FTSC | FTC/FCTC | Other | Total |
|---|---|---|---|---|---|---|
| **Hardware**: | | | | | | |
| Laptop computers | 28 | 2 | 4 | 6 | 3 (note 1) | 43 |
| Carrying cases | 28 | 2 | 4 | 6 | 3 | 43 |
| Surge protectors | 28 | 0 | 4 | 6 | 0 | 38 |
| Overhead projector | 0 | 0 | 0 | 2 | 0 | 2 |
| **Software**: | | | | | | |
| Prebundled software | 28 | 2 | 4 | 6 | 3 | 43 |
| MAES runtime version | 56(note 2) | 4 | 8 | 12 | 6 | 86 |
| MAES development version | 0 | 1 | 0 | 0 | 0 | 1 |
| **Documentation**: | | | | | | |
| Hardware User's Manual | 28 | 2 | 4 | 6 | 3 | 43 |
| Prebundled S/W User's Manuals | 28 | 2 | 4 | 6 | 3 | 43 |
| Knowledge Documentation | 0 | 2 | 2 | 2 | 0 | 6 |
| MAES User's Manual | 28 | 4 | 4 | 6 | 3 | 45 |
| System Level Description | 0 | 1 | 0 | 0 | 0 | 1 |
| Software Design Document | 0 | 1 | 0 | 0 | 0 | 1 |
| Version Description Document | 0 | 1 | 0 | 0 | 0 | 1 |
| MAES Deployment Plan (Ships) | 0 | 1 | 2 | 0 | 0 | 3 |
| MAES Integration Plan (FTCs) | 0 | 1 | 0 | 2 | 0 | 3 |
| MAES Software Transition Plan | 0 | 3 | 0 | 0 | 0 | 3 |

**Table G-1. MAES H/W, S/W, and Documentation Requirements Matrix**

Note 1. One laptop would go to the NAVSEA MK 92 Program Manager and the other two would go to each of the type commanders' staffs.

Note 2. Two copies of the MAES software should be provided to each activity. One copy should remain with the users and the other copy should be transferred to the activity's ADP officer or software librarian.

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