RADC-TR-90-31
Final Technical Report
April 1990

A CONTRACTOR PROGRAM MANAGER'S TESTABILITY/DIAGNOSTICS GUIDE

Giordano Associates

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RADC-TR-90-31 has been reviewed and is approved for publication.

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REPORT DOCUMENTATION PAGE

Form Approved
OPM No. 0704-0188

1. AGENCY USE ONLY (Leave Blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	April 1990	Final Jun 87 to Mar 89

4. TITLE AND SUBTITLE

A CONTRACTOR PROGRAM MANAGER'S TESTABILITY/DIAGNOSTICS GUIDE

5. FUNDING NUMBERS

C - F30602-87-C-0099
PE - 62702F
PR - 2338
TA - 02
WU - 3B

6. AUTHOR(S)

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7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

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8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

Rome Air Development Center (RBET)
Griffiss AFB NY 13441-5700

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

RADC-TR-90-31

11. SUPPLEMENTARY NOTES

RADC Project Engineer: Frank H. Born/RBET/(315) 330-4726

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

The military services have been experiencing problems in the adequacy of their weapon systems' diagnostic capabilities. There are available a variety of techniques, procedures, standards, and devices which can be applied to the acquisition of a system's diagnostic capability. However, this type of information appears in a variety of reports, military standards, specifications and other documents. The objective of this guide is to transform such individual and diverse pieces of information into a logical organized approach which a contractor program manager can follow to structure and control the various diagnostic activities and needs associated with the development of a weapon system with an adequate diagnostic capability. This guide is one of the three guides aimed at the government program manager, the contractor program manager, and the system designer. This guide is specifically designed to help the contractor program manager meet or exceed the diagnostic requirements imposed on the system he is developing.

14. SUBJECT TERMS	15. NUMBER OF PAGES
Diagnostics; Testability; Diagnostics Capability; Integrated Diagnostics, Guidance	252
	16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UL

REFERENCES

Although this report references the following limited documents, no limited information has been extracted.

RADC-TR-84-57 - Reliability, Testability, Design Considerations for Fault Tolerant Systems; Apr 84. USGO agencies and their contractors; Other requests RADC (RBET) Griffiss AFB NY 13441-5700.

RADC-TR-85-148- Smart BIT; Aug 85. USGO agencies and their contractors; Other requests RADC (RBET) Griffiss AFB NY 13441-5700.

Built-in-Test Design Guide, Joint AMC/CNO/AFLC/AFSC Commanders, Apr 87. Subject to Export Control.

PREFACE

One of the major missions of the Rome Air Development Center (RADC) is the development of procedures and techniques for improving the readiness and supportability of weapon systems. In support of this mission, RADC has sponsored a myriad of studies, analyses, and developments that have resulted in techniques, standards, and procedures aimed at reaching this goal.

In the 1980s all the military services have recognized the importance of improving the diagnostic capability of weapon systems as a means for rapid troubleshooting and repair of these systems. The research and development efforts conducted by RADC are reflected in this guide by synthesizing the results of these many efforts and filling gaps to provide both government and industry with a compendium of procedures and techniques which may be used to improve the fielded weapon systems' diagnostic capability.

Many other programs have made the contributions that are included in these guides. Information has been freely included from various military service and industry work. Among these is the Air Force's Generic Integrated Maintenance Diagnostics Program (GIMADS). The Navy's Integrated Diagnostic Support System (IDSS) and the Army's Integrated Diagnostics in the Maintenance Environment (AIDME) have also made valuable contributions to this guide. In this manner, material from all of the other service organizations is now available for Joint Service use.

Three (3) guides have been written which are aimed at the following users:

- o Government Program Manager
- o Contractor Program Manager
- o System Designer.

Thus, the guidance material required by a specific user will be included in one of these three (3) guides.

It is believed that this guidance material represents a comprehensive look at the problems in fielding a satisfactory diagnostic

capability and a structured system engineering approach to solving these problems. RADC solicits comments on this guidance material, as a means for improvements in the coming years.

These guides have been prepared under contract by Giordano Associates, Inc., with subcontractor assistance from Grumman Aerospace Corporation and Rockwell International.

Contractor Program Managers Guide

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WHY ALL THIS WORRY ABOUT DIAGNOSTICS?

Let's put the diagnostic problem in its proper perspective. You've got a problem with your automobile and you turn to a mechanic for help. Historically, you realize that the problem may be fixed or indeed, for some reason, you may have to go back one or more times before the problem is corrected, or you give up. We are talking about automobiles. Automobiles, which a manufacturer has produced tens of thousands of times, have a historical record of their reliability and maintainability and have been redesigned and reengineered many times.

When comparing your automobile to an extremely complex weapon system that is pushing the state of the art and produced in limited numbers, with questionable historical data on their operation, one can easily understand the magnitude of the problem.

It is not the purpose of this guide to provide a comprehensive discussion of the diagnostic problems, but rather to furnish guidance for government and industry people in circumventing known problem areas. However, to understand the magnitude of the problem a few examples follow.

In one six-month period, at one F-16 tactical fighter wing, over 13,600 maintenance manhours were reported for the processing of unnecessary removals. This equals about 20 people just working on troubleshooting these "good" items.

A DoD Task Force on Productivity in Support Operations (1986) found that 20 to 50 percent of avionics maintenance actions resulted in removal of items with no evidence of failures.

The deployment of an avionics Intermediate shop for fighter aircraft to a remote location can require anywhere from three to 11 C-141B equivalent loads. In wartime, there just will not be enough cargo aircraft to respond to this need. In peacetime, it's just plain costly.

The diagnostic problem is not unique to any one service, nor to any one type of weapon system. It manifests itself throughout the military services. The problem can be an engineering or a field problem. It can be a man or a machine problem. It can be a wartime or a peacetime problem. It can be a prime system or a supportability problem. The problem manifests itself in different ways for different types of weapon systems, but the consequences are all the same--long times to

troubleshoot, removal of items which have not failed, long logistic tails, and an overall lack of confidence in the entire diagnostic capability. Obviously, the result is lack of readiness and a waste of dollars and manpower.

There are a multitude of reports which adequately describe the problem. Two of these reports give a comprehensive picture of the problem and possible solutions. These are:

"Isolation of Faults in Air Force Weapon and Support Systems," Committee on Isolation of Faults in Air Force Weapon and Support Systems, Air Force Studies Board, Commission on Engineering and Technical Systems, National Research Council.

"Report for the Department of Defense on the Implementation of Integrated Diagnostics," prepared by the National Security Industrial Association's Integrated Diagnostics Working Group, September 1984.

HISTORICALLY THE FIELDED DIAGNOSTIC CAPABILITY HAS NOT LIVED UP TO THE PROMISES

Government and industry must share the responsibility for what has happened in the past. On the government's side, there tends to be a lack of knowledge on how to specify what is needed and how to make sure the government gets what it needs. On the contractor's side is a lack of understanding of the importance of fielding a satisfactory diagnostic capability and still maintain schedule and cost limitations. Hopefully, the series of guides produced under this program will help to alleviate this situation.

The military services, as well as the Office of the Secretary of Defense, understand the urgency of this problem and have established multimillion dollar programs to help alleviate this situation, both from a technology and a management perspective. For the most part, these programs are generic--applicable to a variety of weapon systems.

DIAGNOSTIC IMPROVEMENT PROGRAMS ARE UNDERWAY

HOW CAN THIS GUIDE HELP YOU?

The outputs from many of the government-sponsored programs are a variety of techniques, procedures, standards, and devices which can be applied to the acquisition of a system's diagnostic capability. However, this type of information appears in a variety of reports, military standards, specifications, and other documents. The major focus of this guide is to bring together this knowledge in a usable form and tie this to the various diagnostic activities which occur during the acquisition and deployment of a weapon system. In addition, where holes exist in this acquisition process, the guide attempts to fill them. Following this procedure will help you in doing a better job of acquiring a weapon system diagnostic capability.

This guide is for **THE CONTRACTOR PROGRAM MANAGER** --to help him to prepare an adequate response to a government RFP and to properly manage the development of the diagnostic capability for a weapon system, once a contract is underway. This is the second in a series of three guides. The first guide is a Government Program Manager's Guide which helps him to specify the required diagnostic capability and take the steps to assure that the requirements are met. The third guide is a comprehensive Design Encyclopedia, which provides detailed methods, procedures, tools, and trade-off information which can be applied to the design and demonstration of a weapon system's diagnostic capability. This third guide is aimed at the designer and analyst.

THREE GUIDES - ONE FOR EACH TYPE OF USER. THIS ONE IS FOR THE CONTRACTOR PROGRAM MANAGER

WHAT ARE THE MAIN THRUSTS OF THIS GUIDE?

Historically, the development, test, and evaluation of the diagnostic capability for a weapon system often have been more or less an afterthought. For many seemingly logical reasons, satisfying prime system "performance" requirements has taken precedence over diagnostic requirements. Simply, the goal of this guide is to promote a realization that diagnostic requirements are indeed system performance requirements, and thus are an integral part of weapon systems'

development, test, and evaluation. Thus this guide has the following attributes in relation to the development of this diagnostic capability:

- Describes a system engineering approach
- Gives guidance for the preparation of diagnostic portions of proposals and specifications
- Delineates a usable diagnostic allocation procedure
- Describes a design procedure for the integration of all diagnostic elements
- Suggests organizational responsibilities and relationships be established for development of the entire diagnostic capability
- Encourages concurrent design, test, and evaluation of the entire diagnostic capability with the prime hardware and software
- Allows for the a comprehensive maturation period to meet diagnostic requirements

A SYSTEMS ENGINEERING APPROACH IS KEY!

WHAT DO WE MEAN BY INTEGRATED DIAGNOSTICS?

Before using this guide it is imperative that you understand the definition of a few words. The first term is **"testability,"** which is defined as "a design characteristic which allows the status (operable, inoperable, or degraded) of an item to be confidently determined and the isolation of faults within the item to be performed in a timely manner." Therefore, testability may be regarded as inherent to the item's design.

"Diagnostics" is defined as "the hardware, software and/or other documented means used to determine a malfunction has occurred and to isolate the cause of the malfunction." It also refers to "the action of detecting and isolating failures."

"Integrated diagnostics" is defined as a "structured design and management process to achieve the maximum effectiveness of a weapon system's diagnostic capability by considering and integrating all related pertinent diagnostic elements." The process includes interfaces between design, engineering, testability, reliability, maintainability, human engineering, and logistic support analysis. The goal is a cost-effective capability to detect and unambiguously isolate all faults known or expected to occur in weapon systems and equipment in order to satisfy weapon system mission requirements.

"Diagnostic capability" refers to all the capabilities associated with the detection and isolation of faults, including automatic and manual testing, personnel, training, maintenance aiding, and technical information.

"Diagnostic element" is defined as one part of the diagnostic capability (e. g., ATE).

"Diagnostic Subsystem" is defined as all the diagnostic elements, which constitute a weapon system's diagnostic capability.

"Embedded diagnostics" is defined as any portion of the weapon system's diagnostic capability which is an integral part of the prime system or support system. "Integral" implies that the embedded portion is physically enclosed in the prime system and/or permanently attached--physically or electrically.

"External diagnostics" is defined as any portion of the weapon system's diagnostic capability which is not embedded.

HOW TO USE THIS GUIDE

For a better understanding of the various diagnostic activities that take place during the acquisition and deployment of a weapon system, a Roadmap has been prepared for your use. The Roadmap depicts all of the diagnostic activities that take place during each phase of weapon system acquisition and deployment. The Roadmap is shown in Figure 1, with inputs and outputs for each activity. This Roadmap gives the reader the entire picture of both government and industry diagnostic activities which are aimed at developing an adequate diagnostic capability. It is recognized that there is no single Roadmap that can apply to all situations. Thus the Roadmap is designed with multiple entry points to provide flexibility.

THE ROADMAP GIVES YOU THE BIG PICTURE

The structure of the guide is built around this Roadmap. The activities on the Roadmap relate to seven basic requirements listed in Table 1. This document is a structured accordingly to these seven requirements.

Reference to a specific requirement is shown on the Roadmap, so the reader can quickly relate a diagnostic activity on the Roadmap to specific guidance information contained in this guide.

TABLE 1. ESTABLISHED REQUIREMENTS

REQUIREMENT #	REQUIREMENT
1	ESTABLISHING AND JUSTIFYING A PROGRAM FOR ACQUIRING A DIAGNOSTIC CAPABILITY
2	ESTABLISHING AND ALLOCATING DIAGNOSTIC REQUIREMENTS
3	DESIGNING THE DIAGNOSTIC CAPABILITY
4	ANALYSIS AND ASSESSMENT OF THE PERFORMANCE OF THE DIAGNOSTIC CAPABILITY
5	CONDUCTING DESIGN REVIEWS
6	CONDUCTING TEST AND EVALUATION
7	MATURATION OF THE DIAGNOSTIC CAPABILITY

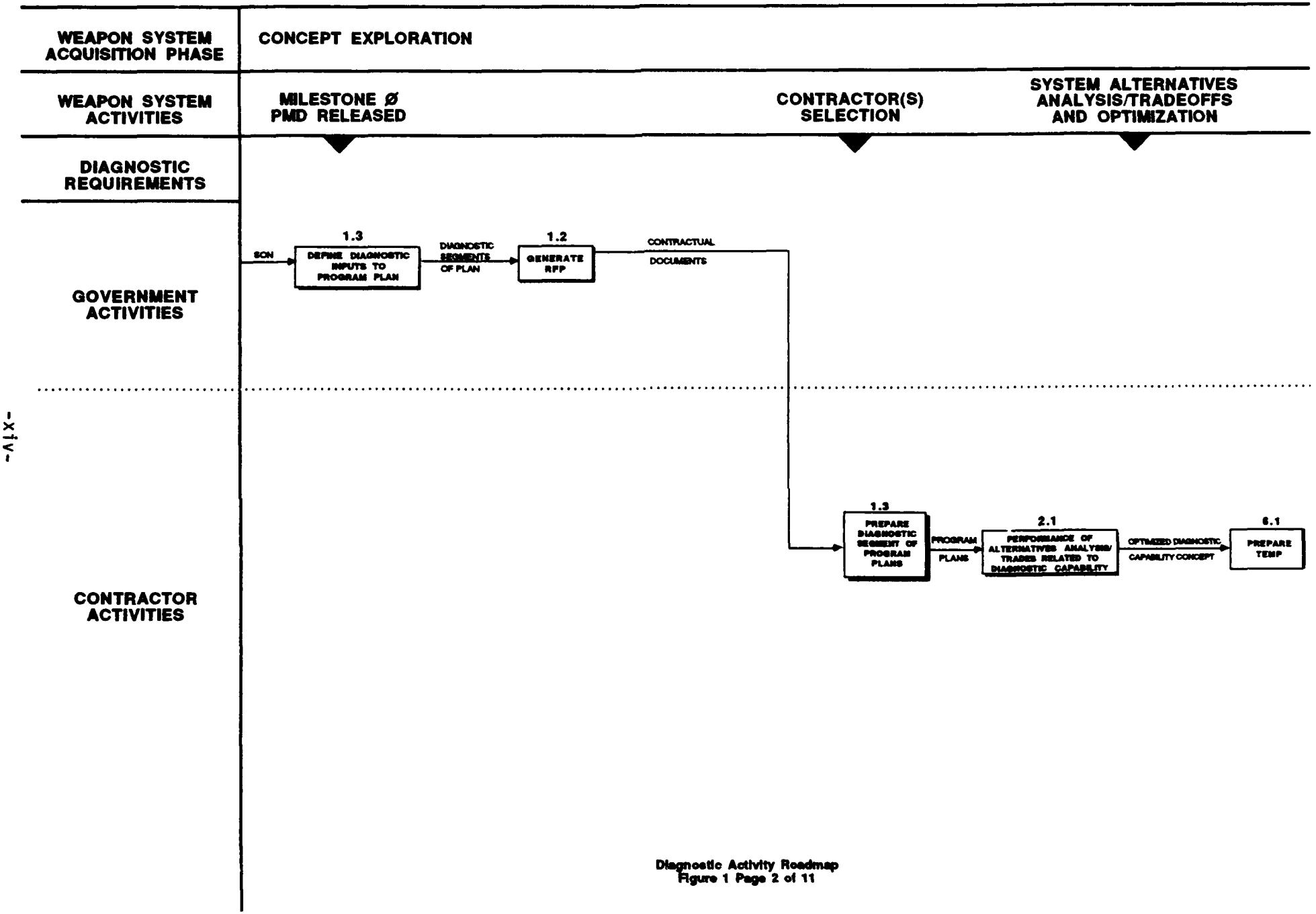
Each one of these basic requirements is followed by detailed requirements (e. g., Requirement 1.2, Preparing an RFP/SOW/ Specification). Each of these detailed requirements is tied to a weapon system activity and a weapon system acquisition phase.

The three guides are structured in essentially the same way--the difference being the guidance material supplied is tailored for the USER of each specific guide. Each requirement is color coded or highlighted for easy access to the information the user requires.

Each of the guides contains a Lessons Learned Appendix, (Appendix A) which will help the user to understand how this guidance information applies to real-world acquisitions. Appendix B lists the acronyms used.

WEAPON SYSTEM ACQUISITION PHASE	OPERATIONAL REQUIREMENTS	CONCEPT EXPLORATION
WEAPON SYSTEM ACTIVITIES	SON /MNS/PPBS PROCESS	
DIAGNOSTIC REQUIREMENTS		
GOVERNMENT ACTIVITIES		
CONTRACTOR ACTIVITIES		

Diagnostic Activity Roadmap
Figure 1 Page 1 Of 11



Diagnostic Activity Roadmap
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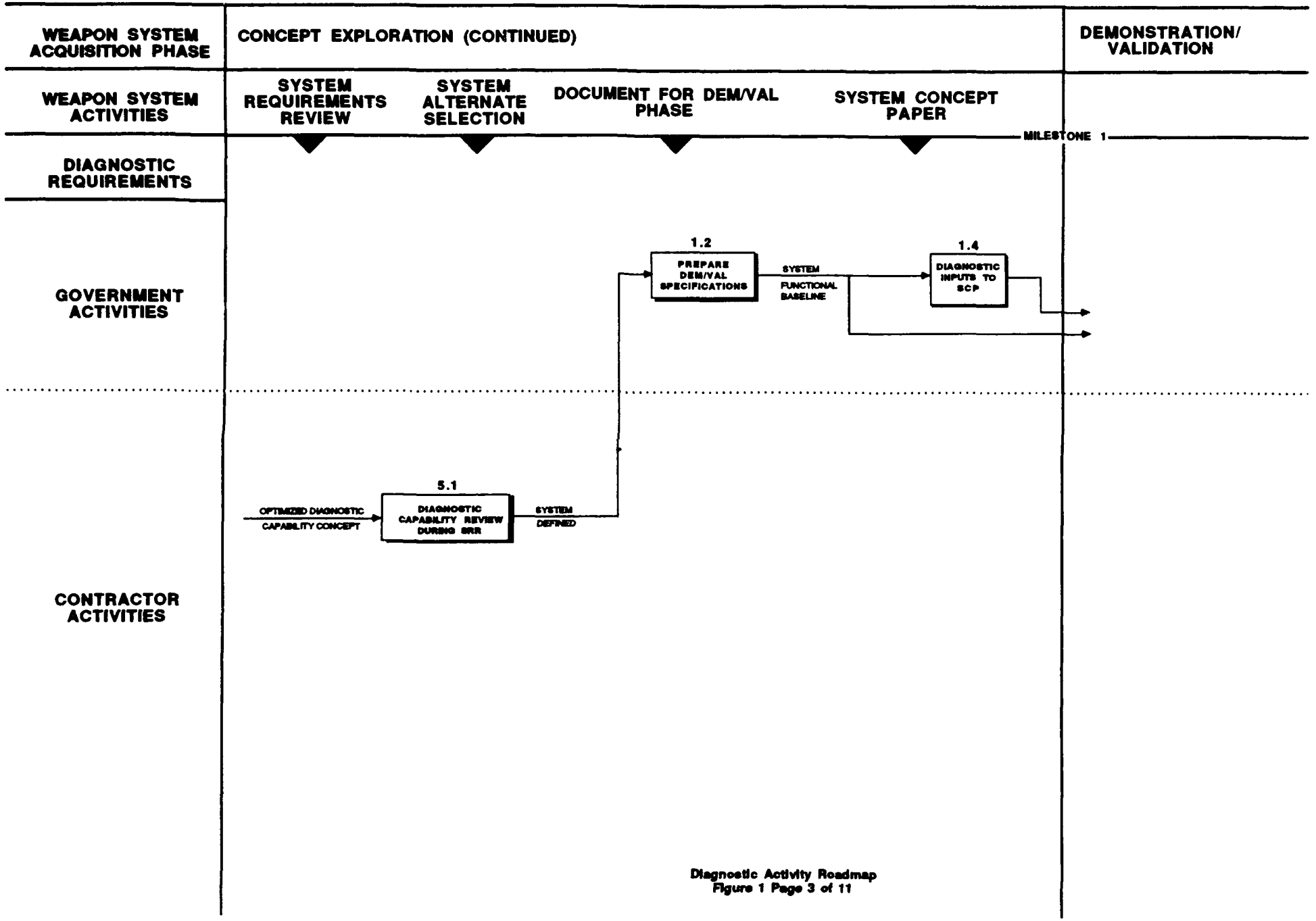

Diagnostic Activity Roadmap
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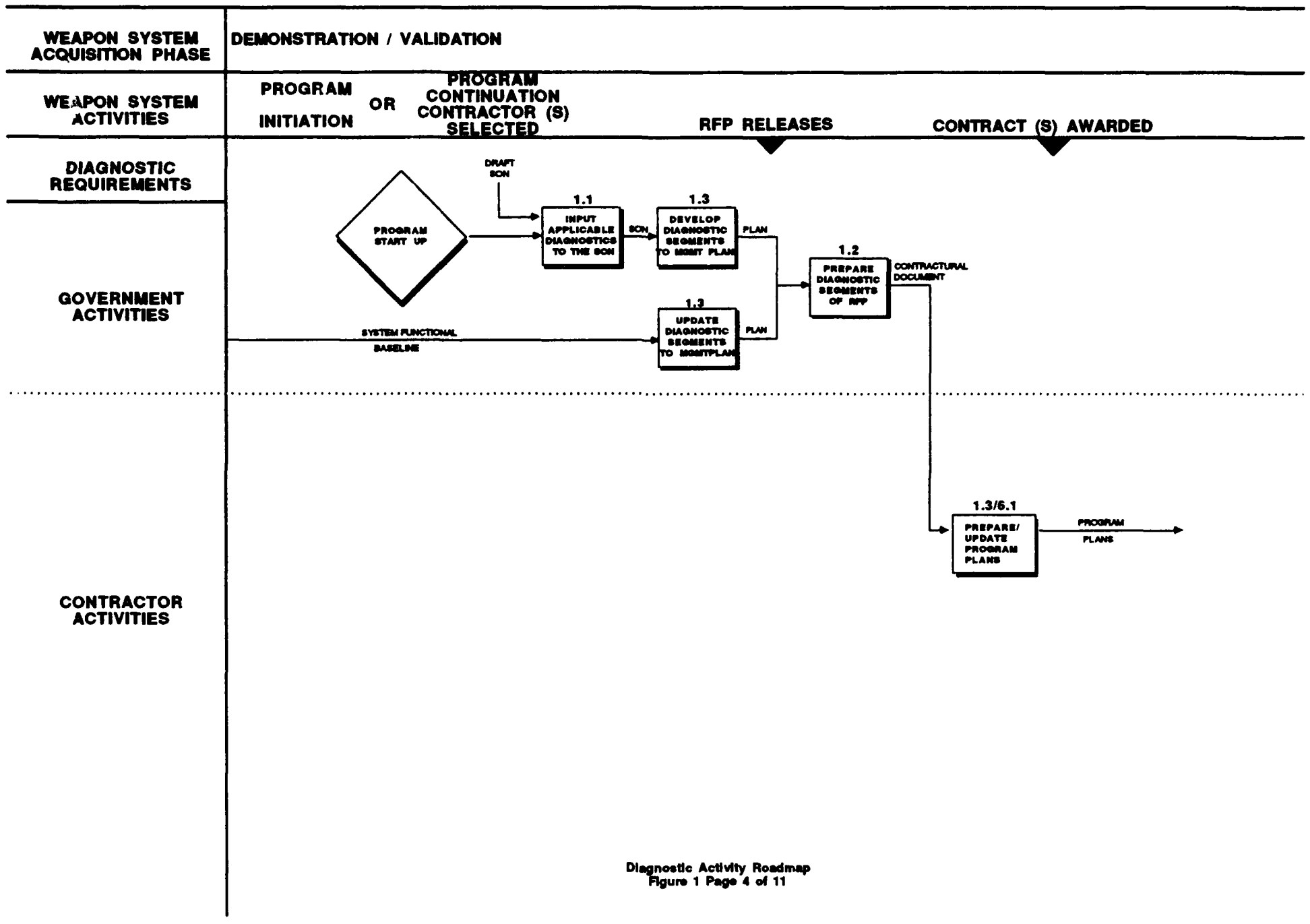
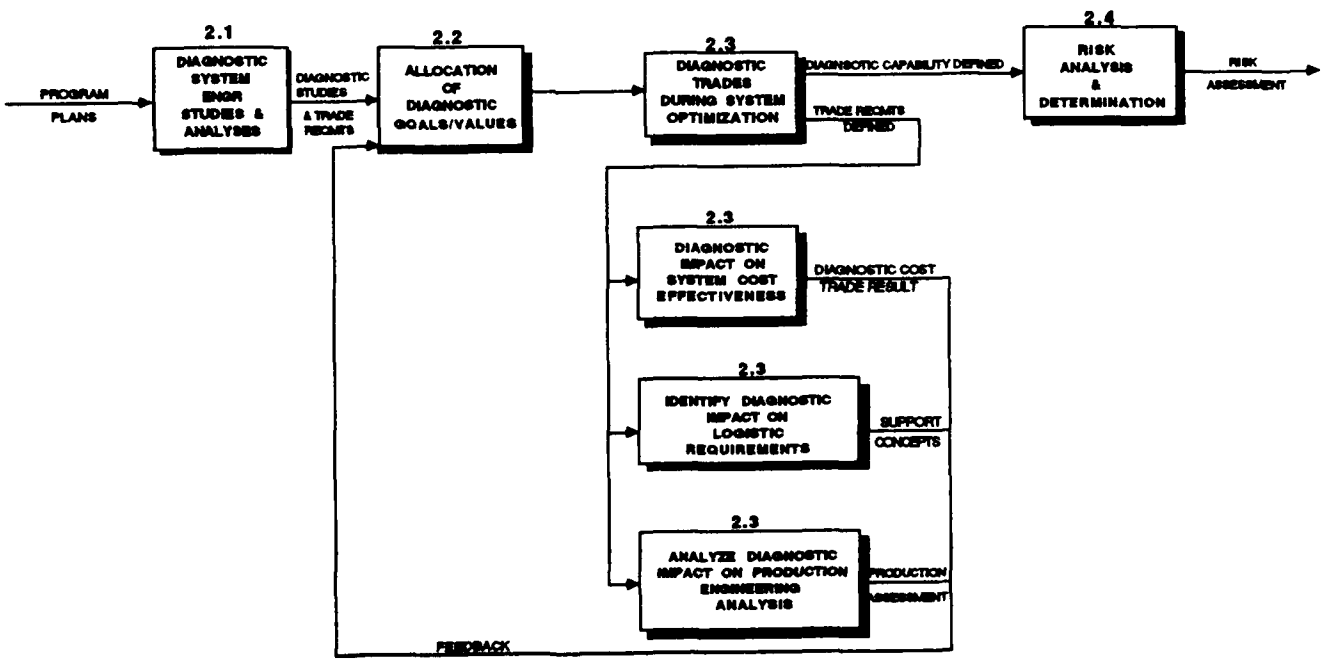


Diagnostic Activity Roadmap
Figure 1 Page 4 of 11

WEAPON SYSTEM ACQUISITION PHASE	**DEMONSTRATION / VALIDATION (CONTINUED)**
WEAPON SYSTEM ACTIVITIES	**SYSTEM ENGINEERING** **DESIGN** **PROOFING/PROTOTYPING** **LOGISTIC SUPPORT** **ANALYSIS** **REPAIR LEVEL ANALYSIS** **SUPPORT EQUIP. PLAN**
DIAGNOSTIC REQUIREMENTS	
GOVERNMENT ACTIVITIES	
CONTRACTOR ACTIVITIES	

Diagnostic Activity Roadmap
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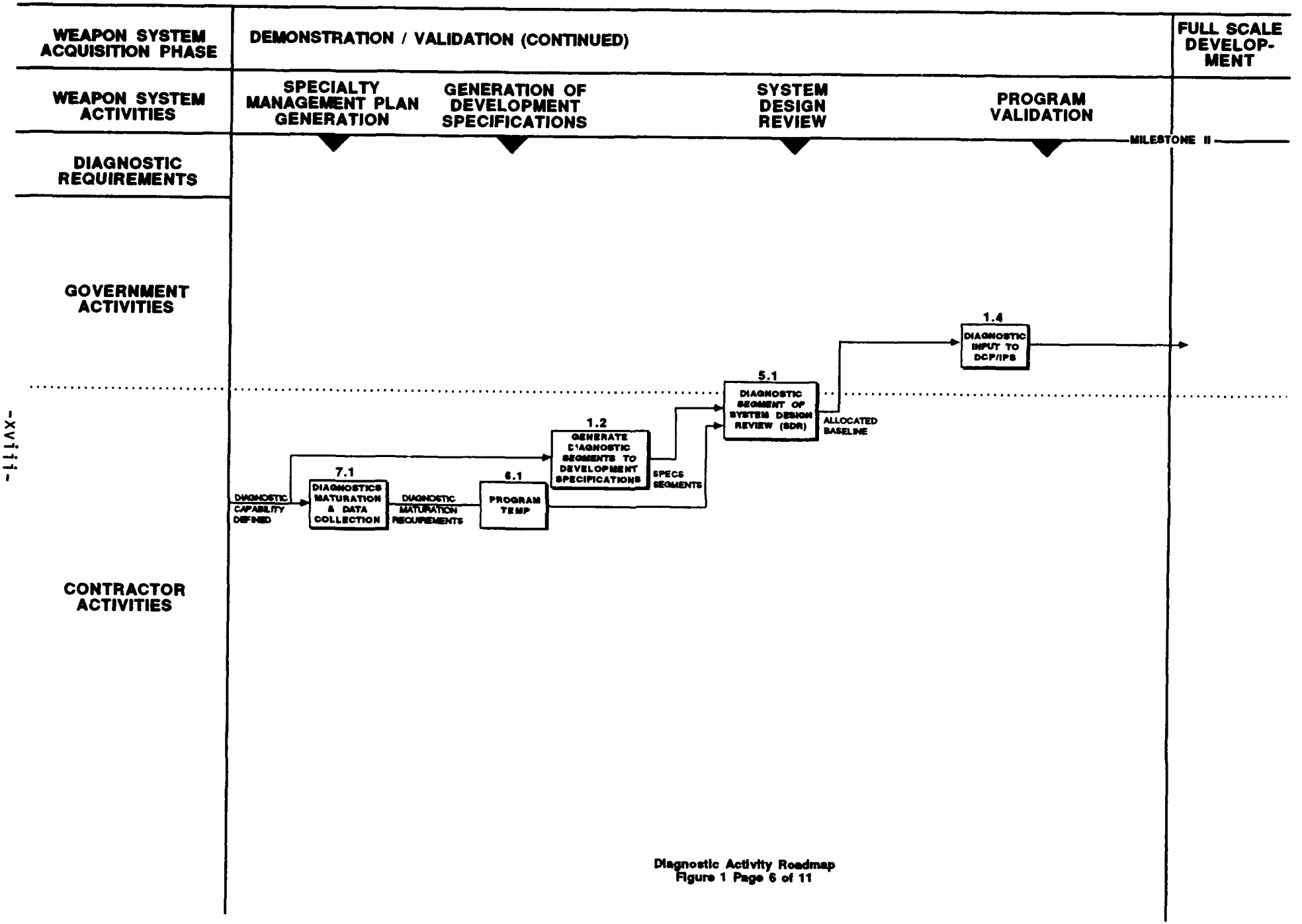

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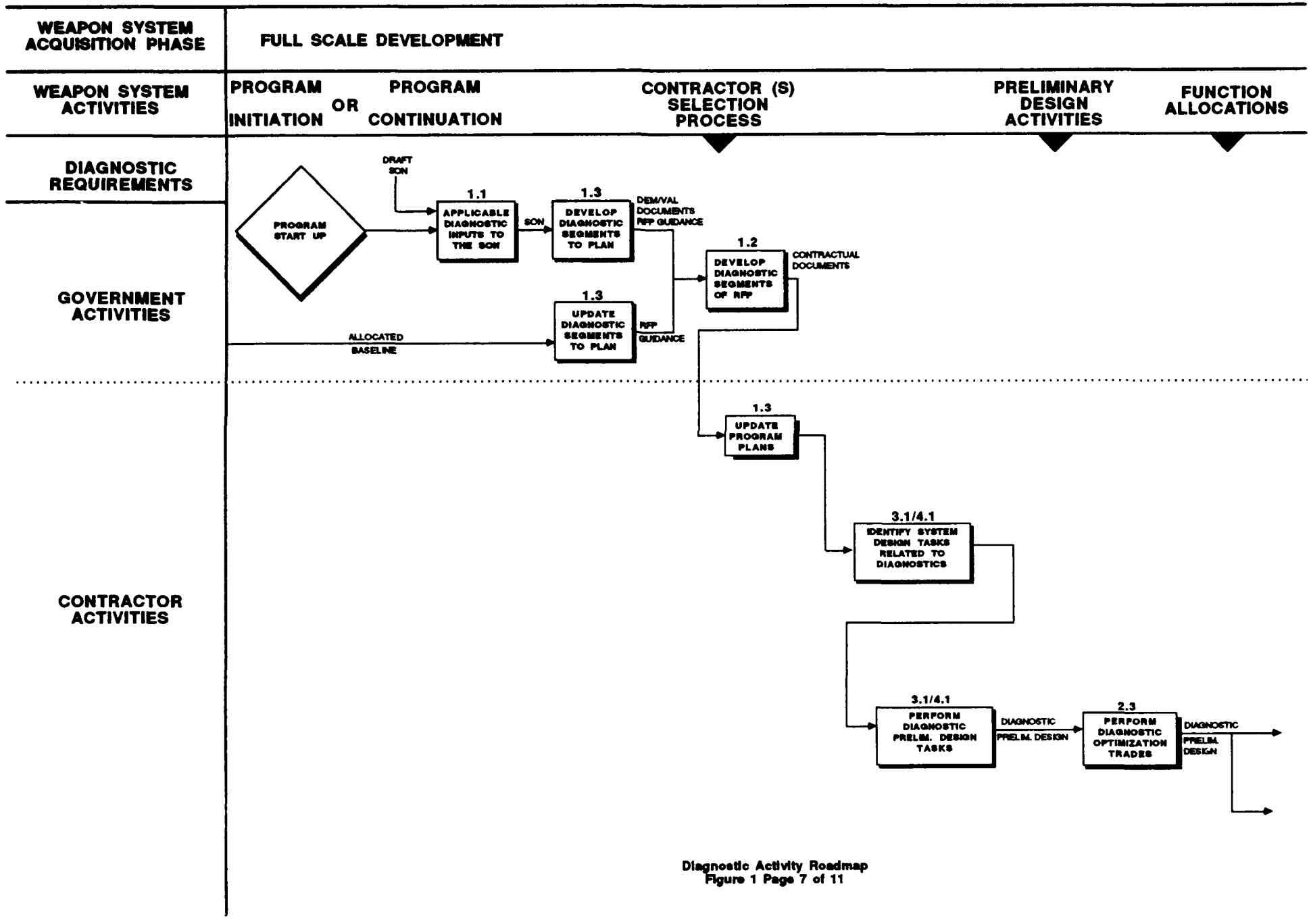

Diagnostic Activity Roadmap
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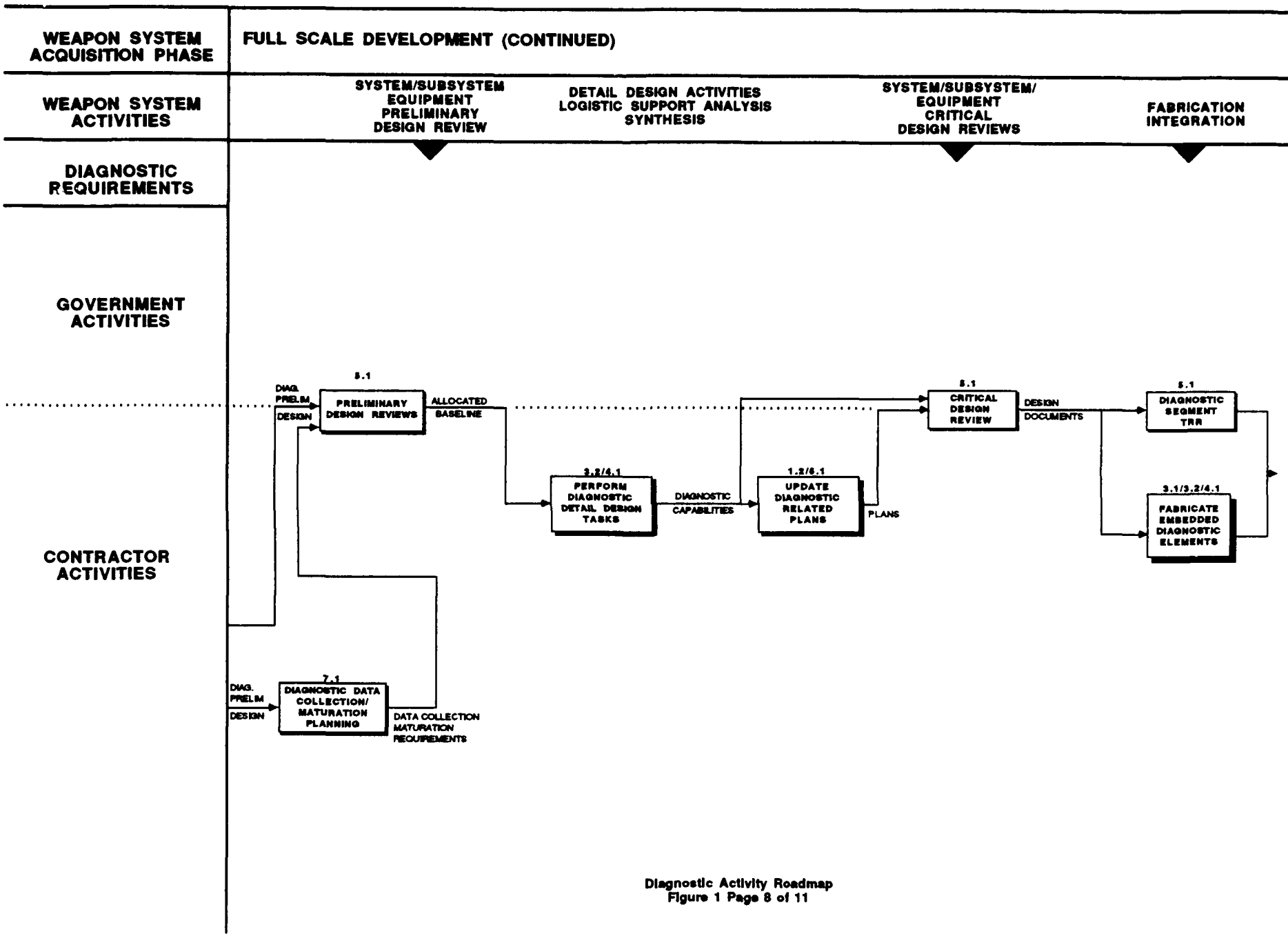

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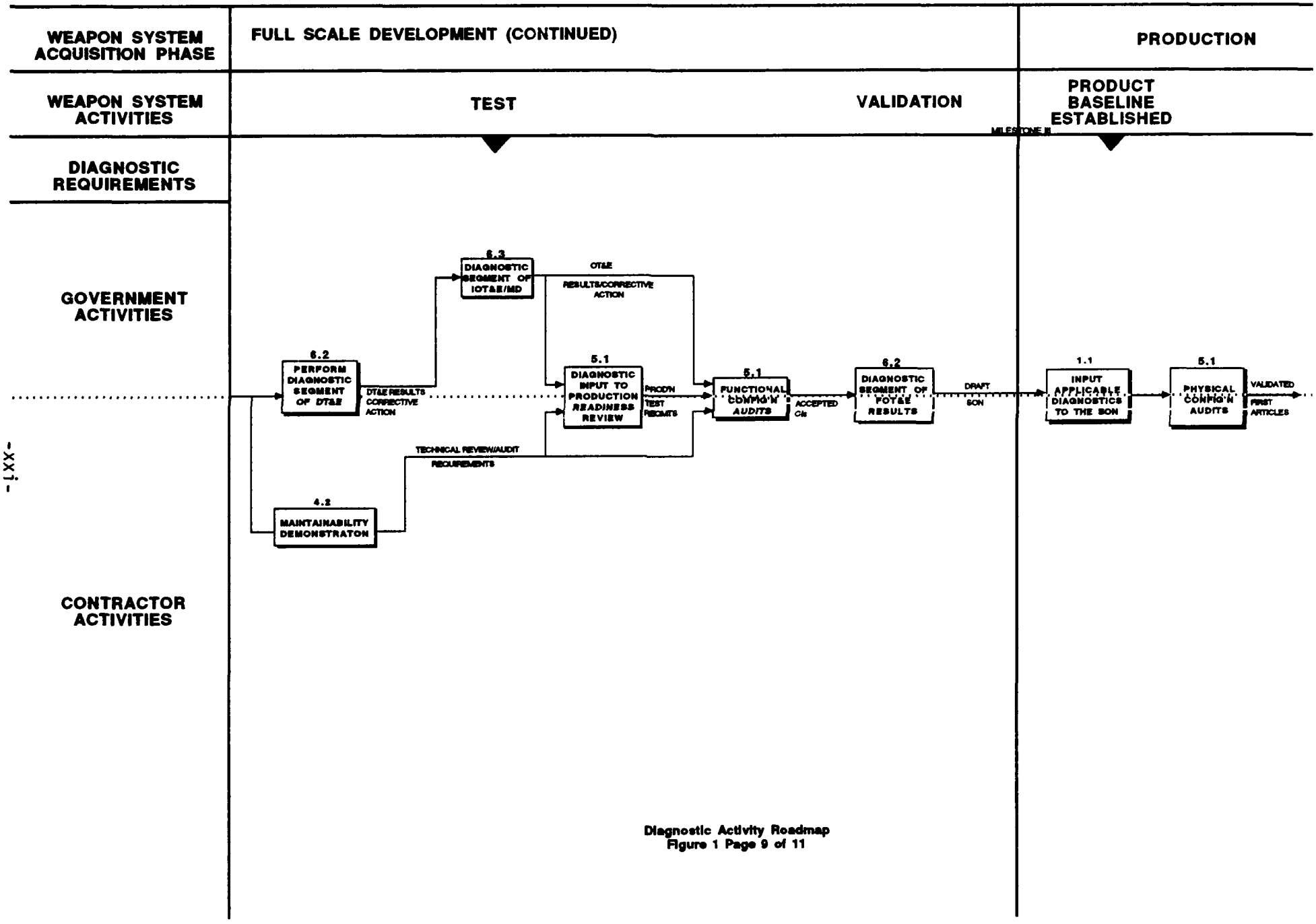

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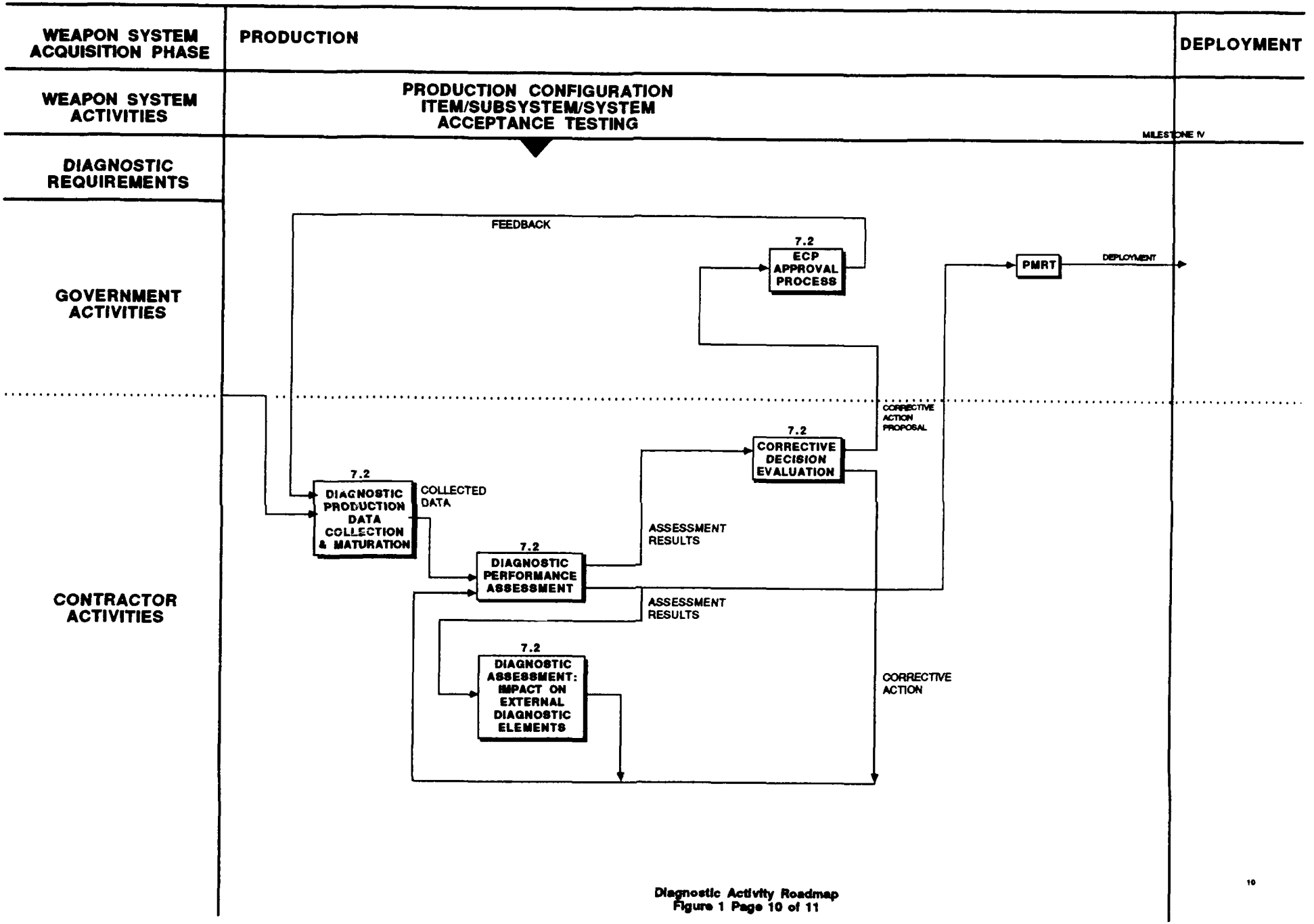

Diagnostic Activity Roadmap
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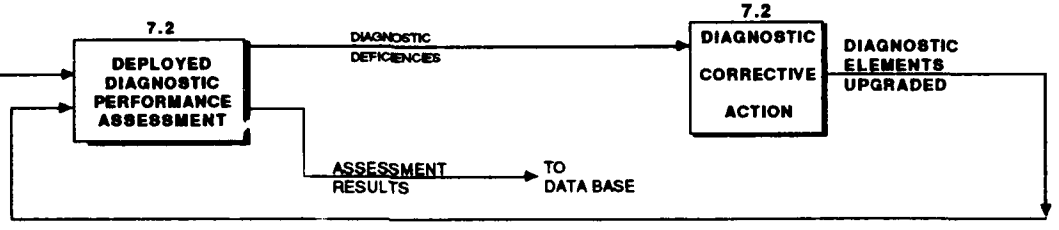
WEAPON SYSTEM ACQUISITION PHASE	DEPLOYMENT
WEAPON SYSTEM ACTIVITIES	MILESTONE IV
DIAGNOSTIC REQUIREMENTS	
GOVERNMENT ACTIVITIES	
CONTRACTOR ACTIVITIES	

Diagnostic Activity Roadmap
Figure 1 Page 11 of 11

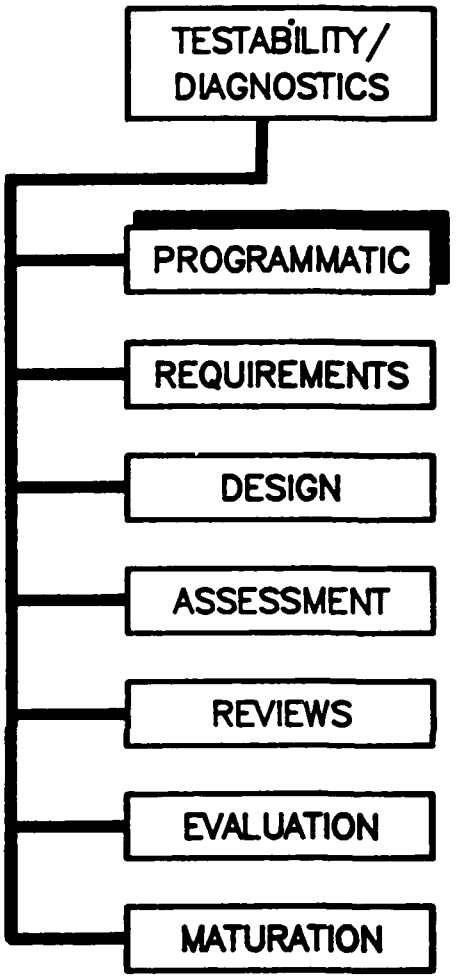
THE GUIDE IS STRUCTURED TO GIVE THE USER EASY ACCESS TO THE INFORMATION REQUIRED

It is recognized that a guide of this type cannot contain all the necessary information that the user requires. In these cases, an attempt has been made to cite reference documents, such as military standards, handbooks, and reports.

AN AUTOMATED VERSION OF THIS GUIDANCE PLUS SOME COMPUTERIZED TOOLS ARE AVAILABLE

To aid in the use of these guides, a computerized, interactive version of of all these guides has been developed. In addition, a number of computer-aided tools, suitable for inclusion in CAD modules, have been included for use by design engineers in the implementation of techniques, procedures, etc. These are contained in the Design Encyclopedia. If you are interested in obtaining these software programs, you may contact Rome Air Development Center, RADC/RBET, Griffiss Air Force Base, New York, 13441-5000, (telephone number: 315-330-4726, AV 587-4726).

ESTABLISHING AND JUSTIFYING A PROGRAM FOR ACQUIRING A DIAGNOSTIC CAPABILITY



OVERVIEW

DoD organizations are often disappointed at the performance of a weapon system's diagno c capability, once it is deployed. This disappointment often results in frustration by the user, an adversarial relationship between the acquirer and the producer, and costly engineering changes. The fact is that the quality of the acquired diagnostic capability is a two-way street. In the case of the government, careful consideration must be given to what you want the contractor to deliver. In the case of the contractor, he must be dedicated to producing a quality product. Specifying fault detection and isolation requirements is a difficult, complex job for the Government Program Manager. Justifying his program to a higher authority in clear, concise terms is essential. Establishing realistic and feasible plans for satisfying these requirements is a prime responsibility of the Contractor Program Manager. Implementing these plans is the responsibility of the weapon system designer. Without a clear understanding and close cooperation among these people, production of a less-than-satisfactory diagnostic capability is inevitable.

IMPORTANT CONSIDERATIONS TO BE ADDRESSED

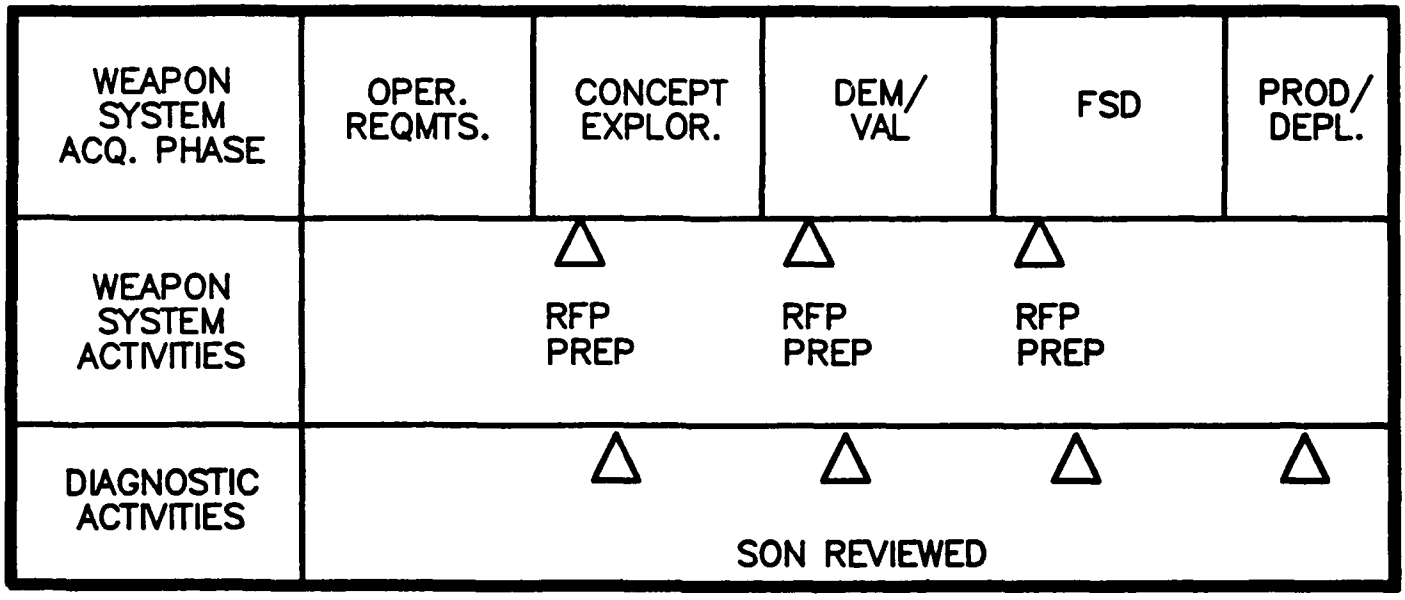
Reqmt.

1.1 Review the Statement of Need (SON) to assure a clear understanding of the basis for the development program.

1.2 Diagnostic considerations are a very important part of your proposal.

1.3 Tie diagnostic capability plans to the system engineering plans.

1.4 Make sure that specific information on diagnostic and capability issues are available for inclusion in SCPs and DCPs.



DIAGNOSTIC ACTIVITY

The major consideration in the initiation of a weapon system acquisition program is the preparation of a Statement of Need. Each of the services has its own designation for this document. For a major weapon system, DoD Instruction 5000.2 designates this document as a "Mission-Need Statement (MNS)." For less-than-major systems, the services use other terms, such as "Operational Requirements Document" and "Required Operational Capability." It is important that these documents reflect these operational requirements in terms which can be properly interpreted to produce diagnostic requirements. The contractor is not involved in the generation of this document but must be aware of it's content since it forms the baseline upon which the diagnostic requirements are derived.

PROCEDURE

Each of the military services has issued policy directives and guidance relating to the preparation of a Statement of Need. DoD Instruction 5000.2 delineates the format for an MNS. This format does not differ appreciably from the formats used for less-than-major new starts, thus the following guidance will be discussed in relation to the MNS.

The SON is issued prior to Concept Exploration. When the Concept Exploration Phase is not conducted, the SON should be issued prior to initiation of work. In addition, the validity of the SON can be reevaluated prior to the initiation of Dem/Val, FSD, and Production.

GUIDANCE

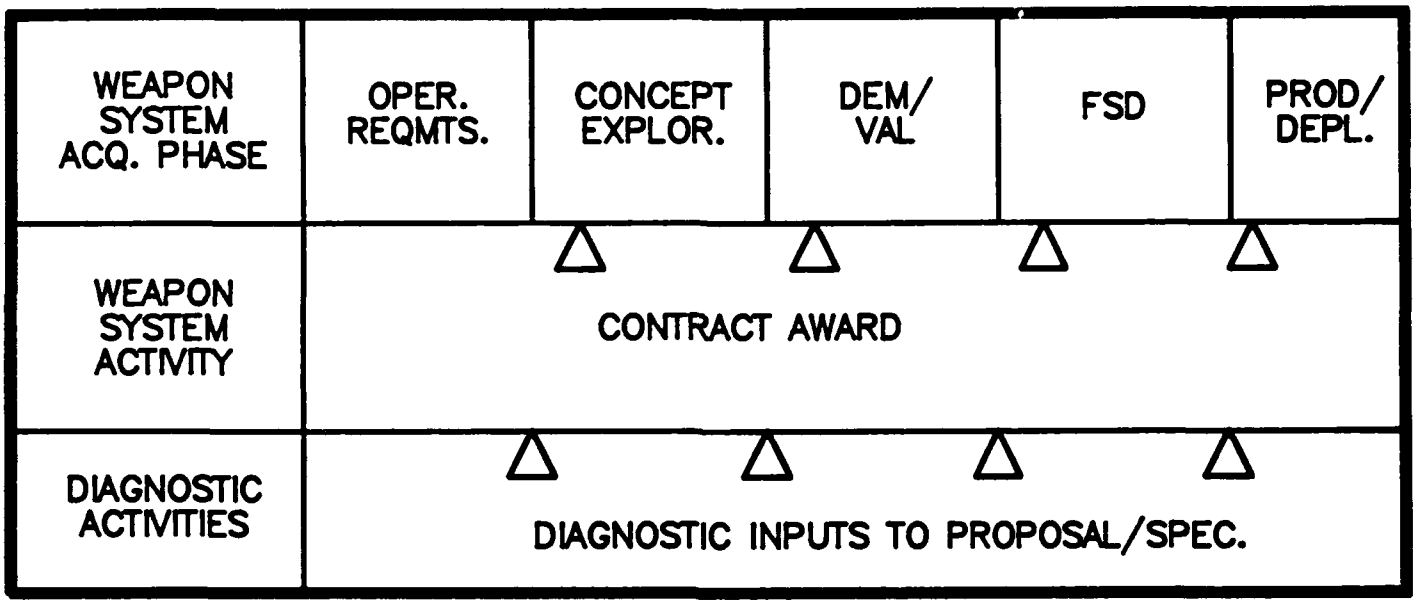
It is almost as important to ensure what should not be put into an SON as what should be put into an SON. From a diagnostic point of view, initially there are no diagnostic requirements per se, only requirements which reflect a threat and mission and operational needs, plus certain constraints put on the weapon system, such as resource limitations. At the initiation of a weapon system development, it is important that the Government Program Manager and his contractor not be limited by establishing premature diagnostic requirements, such as a certain percent fault detection/fault isolation to a given unit, or an MTTR. Rather, the contractor should be given the flexibility to derive the diagnostic requirements from mission needs, such as sortie rates, mobility requirements, and the mission scenario.

The Contractor Program Manager should examine the SON to make sure he and the Government Program Manager have a common understanding of its content. If the SON contains needs, which the Contractor Program manager believes unduly constrained the efficient and effective development and deployment of the diagnostic capability, he should inform the Government Program Manager so that he may take the action which he feels necessary. As the weapon system development progresses the Contractor Program Manager should periodically check the SON to assure compliance with the spirit of this document and to make sure all subsequent proposals reflect this concern.

CHECKLIST

- ☑ Does the SON adequately address mission and threat and refrain from prematurely including diagnostic requirements?
- ☑ Have you informed the Government Program Managers of any potential deficiencies in the SON?

RESPONDING TO AN RFP, SOW, SPECIFICATION	REQUIREMENT #1.2



DIAGNOSTIC ACTIVITY

Clear, concise, and feasible provisions must be inserted into the Request for Proposal (RFP), the Statement of Work (SOW), and the System Specification, as a means for assuring that the contractor and his subcontractors have a clear understanding of what is required of the diagnostic capability.

The Contractor Program Manager's job is to respond to the Government Program Manager's requirements with feasible and innovative diagnostic alternatives.

PROCEDURE

One of the initial tasks which must be undertaken by the Government Program Manager, at the beginning of each acquisition phase, is the development of the Request for Proposal, which will subsequently lead to a contractual document.

Often a draft RFP will be distributed by the Government Program Manager to all interested bidders as a means for assuring that the RFP will produce the most effective and efficient product. It is the job of the Contractor Program Managers to work directly with the Government Program Managers prior to the final issuance of an RFP to assure that the requirements can be met in a cost-effective manner. Once the RFP has been formally issued, it is the Contractor Program Manager's job to respond to the provisions contained in the RFP within the bounds of a competitive environment.

For the Concept Exploration Phase, normally the RFP contains a Statement of Work without an associated weapon system specification. The specification is usually

invoked no sooner than the Demonstration and Validation Phase. It is normally written by the contractor as a data deliverable, with final review by the Government Program Manager. The requirements for this diagnostic capability must appear in a variety of places throughout these documents to assure the acquisition of a satisfactory diagnostic capability. For the Concept Exploration Phase, these requirements are general in nature and allow the maximum flexibility for the contractor to do his job. As the weapon system design proceeds, these requirements become more and more specific. The thrust and content of the provisions contained in these documents varies, depending on the acquisition strategy developed by the Government Program Manager, the phase in which these documents are invoked, and the size and complexity of the weapon system.

GUIDANCE

The Contractor Program Manager is faced with somewhat of a dilemma of satisfying the Government Program Manager's diagnostic requirements, while placing his corporation in a realistic competitive environment. When working with the Government Program Manager prior to issuing a formal RFP, the Contractor Program Manager should stress the need for clear, concise, and feasible diagnostic requirements, which promote flexibility in the meeting of these requirements. Once the RFP is issued, the Contractor Program Manager's response must not only be directed at satisfying the diagnostic requirements, but should permit the utilization of the innovative diagnostic technology and techniques to satisfy these requirements. Integration of diagnostic elements is the central issue. Employment of innovative diagnostic technology can result in cost savings, not only after deployment but during design and manufacture. Thus it is possible to satisfy diagnostic requirements utilizing innovative techniques and still be competitive.

RESPONDING TO AN RFP:

Diagnostics impacts a number of sections within an RFP, as shown in the following paragraphs.

Special Contract Requirements (Section H) - Contractor incentives and warranties are contained in this section of the RFP. The type and content of these incentives and warranties are almost limitless, depending on the innovation of the RFP writer. The Defense System Management College has published a warranty handbook, which is a reference guide for use by DoD managers in developing, applying and administering warranties. This guide contains:

- o Warranty law and DoD Policy
- o Warranty concepts and issues
- o Warranty selection and structure
- o Warranty development
- o Warranty administration
- o Warranty cost benefit analysis
- o Case examples of warranties.

Several of these warranties are applicable to the fault detection, fault isolation process. These deal with reliability improvements, MTBF guaranties, availability guaranties, and logistic support costs guaranties. Copies of this document can be obtained from the Defense System Management College, who is the controlling agency for this handbook.

Instructions to Offerors (Section L) - The contractor's response to the Instructions to Offerors Section of the RFP is particularly important because it addresses the contractor's understanding of the integrated diagnostics process. Thus the proposal should address the management and technical approach relative to this process and the

meeting of the diagnostic requirements. The proposal should emphasize that the contractor understands that integrated diagnostics interfaces with logistics, reliability, maintainability, testability, human engineering, and safety requirements. The proposal will be judged on how well this integration is planned, organized, directed, and controlled and how advanced technology will facilitate this integration.

DoD's support of the Computer-Aided Acquisition and Logistics Support (CALS) Program report will be addressed in this section. One of the major parts of this program focuses on the automation of the diagnostic design process as a means for providing a more efficient and effective design process. Usually, the government will not dictate the use of design tools, but rather will encourage their use through various incentives. As a minimum, the contractor's proposal should address the following issues:

- o A discussion of design aids which will facilitate the design and integration of the diagnostic capability into the system engineering process
- o The development and use of a diagnostic data base which supports the application of these tools
- o Identification of how automation will reduce risk in the design of the diagnostic capability
- o Means for providing the government with appropriate documentation for understanding and validating the output of the automation process

Additional information on the implementation of CALS is contained in the CALS Implementation Guide, which will be issued as a military handbook.

Evaluation Factors for Award (Section M) - This section will be written to assure that the proposal writer understands that integrated diagnostics and diagnostic requirements have a significant impact on the selection of a contractor. The evaluation factors will most likely reflect the diagnostic content of the Instructions to Offerors (Section L) from both technical and management points of view. Thus the contractor's proposal should stress that testability and integrated diagnostics are part of the system engineering process and advanced technology will be applied in solving this problem.

The contractor should emphasize that a single person will be responsible for managing the development of the entire diagnostic capability. This person should have systems engineering experience because he is required to assure integration of the design of the diagnostic capability, which cuts across a multitude of design and supportability functions. Reliability, maintainability, testability, human engineering, logistics, etc. along with system, subsystem, and component diagnostics are all included. In addition, the proposal should stress:

- o The amount and type of specialized education and training given to both contractor program managers and designers which relate to testability and integrated diagnostics process

- o The independent research and development conducted by the contractor which relates to testability and diagnostic design tool development and demonstrations of the integration of diagnostic elements

- o Methods and scheduling to assure the concurrent delivery and evaluation of the entire diagnostic capability with the prime system itself

- o How the diagnostics for both GFE and CFE will be addressed by the contractor to assure that overall system diagnostic requirements are met

- o The quality of the diagnostic maturation program

Responding to a Statement of Work

The character of the Statement of Work will vary, depending on which weapon system acquisition phase is being addressed. The responses to these Statements of Work should address the factors described under one or more of these four phases (i.e., Concept Exploration, Demonstration and Validation, Full-Scale Development, and Production). The principal tasks that will be addressed throughout the development of a weapon system are:

1. An engineering analysis (including gathering of field data) from a previously fielded weapon system(s) to determine diagnostic capability performance deficiencies experienced

2. Identification of specific risk areas which require design attention

3. A requirement for preparation and implementation of a Diagnostic Capability Maturation Plan, including assets required, activities required, and data collection

4. Thorough analysis of the design of the embedded diagnostics to be completed by CDR

5. Design analysis and specification of the external diagnostic capability, including overlap, by CDR

6. A requirement for demonstration of the diagnostic capability, including a thorough, statistically valid sample in selected areas of the system.

The following are sample Statements of Work which may be included in the SOW Requirements section. When responding to an RFP it is important that the Contractor Program Manager address how he plans to accomplish these tasks. Even if these tasks are not called out in the SOW, it may still be crucial for these items to be addressed. In such a case, the initiative shown by the contractor could be the deciding factor in the government source selection process.

CONCEPT EXPLORATION PHASE

Diagnostic Approach

1. Establish overall diagnostic design objectives, strategies, goals, thresholds, and constraints which support mission requirements and operational constraints in support of the logistic support analysis process of MIL-STD-1388-1 and the system engineering process of MIL-STD-499. These include:

   a. Translation of weapon system mission and performance requirements into diagnostic requirements for each level of maintenance which support the mission scenario.

   b. Establishment of requirements which allow for diagnostic growth as design proceeds through the weapon system acquisition phases.

   c. Identification of diagnostics-related constraints driven by operational constraints of the system.

   d. Identification of technology advancements which can be exploited in system development and diagnostic element development and which have the potential for increasing diagnostic effectiveness; reducing the requirement for maintenance; reducing test equipment, technical manuals and manpower, and skill-level requirements; reducing diagnostic costs; or enhancing system availability.

   e. Identification of existing and planned diagnostic resources (e. g., family of testers, maintenance aids), which have potential benefits. Identification of resource limitations.

   f. Identification of diagnostics problems on similar systems which should be avoided.

2. Define what constitutes a system failure and establishing deferred maintenance, performance and safety monitoring, embedded diagnostic and external diagnostic objectives for the new system at the system and subsystem levels. Identifying the risks and uncertainties involved in achieving the objectives established.

3. Establish BIT, test equipment, technical information, and maintenance manpower and skill-level constraints for inclusion in System Specifications or other requirements documents. These constraints shall include both quantitative and qualitative factors.

4. Evaluate alternative diagnostic concepts to include varying degrees of BIT, manual and automatic testing, technical information format and delivery systems, personnel and

training, along with deferred, preventive, and scheduled maintenance concepts, and identify the selected concept. The evaluation includes:

a. A determination of the sensitivity of system mission performance and readiness parameters to variations in key diagnostic element parameters

b. A determination of the sensitivity of life cycle costs to variations in diagnostic element parameters

c. An estimation of the manpower and personnel implications of alternative diagnostic concepts in terms of direct maintenance manhours per operating hour, job classification, skill levels, and experience required at each level of maintenance

d. An estimation of the risk associated with each concept.

Diagnostic Program Planning

Develop a Diagnostic Capability Program Plan which describes how the program will be conducted. This program plan may be included as part of the System Engineering Management Plan (SEMP). The plan should describe the time phasing of each task including the contractual requirements and its relationship to other tasks.

The plan should also address the following:

a. Identify a single organizational element within the performing activity which has overall responsibility and authority for implementation of the program. Establish analyses and data interfaces among the organizational elements responsible for each of the elements of the diagnostic capability and other, related elements.

b. Develop a process by which diagnostic requirements are integrated with other design requirements and disseminated to design personnel and subcontractors. Establish controls for assuring that each subcontractor's diagnostic practices are consistent with overall system or equipment requirements.

c. Identify diagnostic design guides, analysis models and procedures to be imposed upon the design process. Plan for the review, verification, and utilization of diagnostic data submissions. Explain how computer-aided design tools will be utilized in this process.

Diagnostic Program Reviews

Describe the conduct of the diagnostic portion of the System Requirements Review (SRR), including how these reviews will interrelate with reliability, maintainability, human engineering, and logistic support reviews.

DEMONSTRATION AND VALIDATION PHASE

Diagnostic Specification Development

1. Perform detailed comparability and design analysis and risk reduction efforts necessary to develop a specification provision which allocates testability/diagnostic requirements. These are used for fault detection/isolation, repair verification, performance or safety monitoring, and damage assessment. This enables the weapon system to meet maintenance and operational goals with a minimum of unnecessary removals. Diagnostic capabilities should be selected from design techniques (including built-in test, fault tolerance, status monitoring, partitioning, test points); external hardware (e. g., automatic and manual test equipment and maintenance aids); technical information (e. g., technical manuals, information systems, and operator displays); and training manuals (e. g., formal schooling, on-the-job training). The capabilities selected may be designed into the system as part of the system and/or provided separately to maintenance personnel, as required, to meet mission and level-of-repair objectives.

2. Based on the results of the analyses and risk reduction efforts, the diagnostic capabilities to be provided with the system at each level of maintenance should be specified. This includes:

a. Mode of operation (e. g., status monitoring) in areas where there is diagnostic ambiguity or overlap

b. Operational test strategies, fault tolerance, prognostics, and fault model assumptions

c. Performance in terms of mean time to diagnose, fault coverage, false alarms, and false removals

d. Physical and functional equipment partitioning requirements

e. Physical (weight, volume) and functional (% memory) limitations

f. Diagnostic capability interface requirements

g. Options for augmenting government-furnished equipment (GFE) diagnostic capabilities

h. Reliability of the BIT and external diagnostic hardware.

Detailed Diagnostic Comparison Analysis

1. As part of the development of the diagnostic specification provisions, perform a comparison analysis, using the baseline fielded system at each level of field maintenance. This should include an analysis of the causes of diagnostic times, undetected faults, "false alarms," and "false removals" which are judged to be excessive. The sources of these causes need to be identified and the improvements of a new, proposed system diagnostic design must be delineated. As a minimum, this analysis characterizes whether the causes of diagnostic problems are inherent to the design (e. g., reliability, maintainability, partitioning, connectors, etc.), due to maintenance procedures, lack of "vertical" testability (e. g., cone of tolerance, compatibility between levels of maintenance), or transients.

2. Provide quantitative assessments of diagnostic capabilities identifying current capabilities, extrapolations to proposed capabilities, and the engineering analysis that is the basis for the extrapolation. Overlaps or ambiguities in diagnostic capabilities used for maintenance of fielded systems, must be identified and addressed for the proposed system. When deficiencies in the GFE preclude meeting the diagnostic requirements, alternatives need to be addressed. Weight and volume of the major external test equipment, type and extent of technical information, maintenance skill levels and training requirements for currently fielded systems should be identified and estimates of these quantities for the proposed diagnostic capability and explanation of the basis for this estimate need to be provided.

Diagnostic Risk Reduction

1. As part of the design, prototype, test, and demonstration activities proposed (the basis of the proposal shall be risk areas identified in Concept Exploration), determine the feasibility of achieving diagnostic capability performance improvements.

Diagnostic Maturation Planning

1. Develop a plan for next phase activities in the areas of analysis, growth, and demonstration of the entire diagnostic capability (hardware and software). The plan should also include the resources required for maturation activities (e. g., prime hardware, laboratory facilities).

2. Design a diagnostic data system which extends from Demonstration and Validation through Full-Scale Development, Production, and Deployment. The data system should be designed so that the performance of the diagnostic capability can be ascertained at any point during the acquisition, production, and deployment of the weapon system, and be compatible with the established DoD data system, which will be employed after the maintenance of the weapon system becomes the responsibility of the government.

Testability, Preliminary Design

1. Apply testability design criteria to the design of selected high-risk items, in accordance with MIL-STD-2165, Task 202.2.1. The testability design criteria to be considered should include selective implementation of system-level diagnostic strategies, partitioning to enhance fault isolation, initialization of circuitry under test control, module interface for test access and control, circuit controllability and observability, parts selection, test point placement, and BIT fault detection approaches.

Diagnostic Capability Planning

1. Develop a Diagnostic Capability Program Plan which describes how the program will be conducted. This program plan may be included as part of the System Engineering Management Plan. The plan should describe the time phasing of each task included in the contractual requirements and its relationship to other tasks. Diagnostic issues which relate to reliability, maintainability, logistics, human engineering, safety, etc., should be addressed in those individual plans.

The plan should address, but not be limited to, the following requirements:

a. Identify a single organizational element within the performing activity which has overall responsibility and authority for implementation of the program. Establish analyses and data interfaces among the organizational elements responsible for each of the elements of the diagnostic capability and other related elements.

b. Develop a process by which diagnostic requirements are integrated with other design requirements and disseminated to design personnel and subcontractors. Establish controls for assuring that each subcontractor's diagnostic practices are consistent with overall system or equipment requirements.

c. Identify diagnostic design guides, analysis models and procedures to be imposed on the design process. Plan for the review, verification, and utilization of diagnostic data submissions. Explain how computer-aided design tools will be utilized in this process.

Diagnostic Program Reviews

1. Describe the conduct of the diagnostic portion of the System Design Review (SDR) including how these reviews relate to reliability, maintainability, human engineering, and logistic support reviews.

FULL-SCALE DEVELOPMENT PHASE

Design of the Diagnostic Capability

1. Describe how the embedded diagnostics and testability features will be incorporated in the system and how the external diagnostics capabilities which will satisfy the diagnostic capability performance requirements will be provided.

Diagnostic Design Analysis

1. Implement a structured design analysis process to assess in detail the ability of the diagnostic capability design to meet the system diagnostic performance specification (e.g., fault coverage, mean time to diagnose, false removal, etc.); analyzing the inherent testability of the preliminary design; identifying the areas where the primary means of diagnostics may lead to an ambiguous result and ways the ambiguity will be resolved; identifying areas where there is a redundant (overlapping) diagnostic capability planned to be provided; and verifying that the detailed design of diagnostics is in accordance with the functional allocation established during the previous program phase. The analytical task should include:

a. Design Analysis of Diagnostics Built In the System

   Conduct a structured analysis of system design implementation to identify the functional areas in which diagnostics capabilities allocated in the previous phase to be built into the system provide an unambiguous capability to detect or isolate a fault to the appropriate replaceable unit at each level of maintenance.

b. Assessment of External Diagnostics

   Deliver at the Critical Design Review detailed requirements definition for external test equipment, troubleshooting approaches to be included in maintenance manuals, maintenance aids, and training requirements. These requirements should each be supported by a diagnostic ambiguity analysis to be delivered at the same time, which describes the degree to which diagnostic ambiguities are reduced and the areas where there is redundancy (overlap) of diagnostic capabilities.

Diagnostic Maturation Program

1. Establish and maintain a diagnostic performance data collection system and conducting diagnostic performance verification tests and demonstrations to evaluate the effectiveness of the diagnostic design. The total diagnostic capability, both embedded and external, should be evaluated concurrently with the weapon system itself for maintainability demonstrations as well as for test and evaluations.

2. Monitor diagnostic performance whenever the system is operating and performing an analysis to determine whether the diagnostic capabilities are operating in accordance with the design. Based on the maturation results, taking corrective action in order to meet diagnostic capability requirements.

3. Plan for the transition of responsibility to the government for the collection and analysis of diagnostics data. Field data collection and analysis should be automated to the maximum extent practical and cost effective; and integrated to the maximum extent practical with similar data collection requirements specified elsewhere.

Diagnostic Capability Program Planning

1. Develop and maintain a Diagnostic Capability Program Plan which describes how the program will be conducted. The program plan may be included as part of the SEMP. The plan should describe the time phasing of each task included in the contractual requirements and its relationship to other tasks. Diagnostic issues which relate to reliability, maintainability, logistics, human engineering, safety, etc., should be addressed in those individual plans.

The plan should address, but not be limited to, the following requirements:

a. Identify a single organizational element within the performing activity which has overall responsibility and authority for implementation of the program. Establish analyses and data interfaces among the organizational elements responsible for each of the elements of the diagnostic capability and other related elements.

b. Develop a process by which diagnostic requirements are integrated with other design requirements and disseminated to design personnel and subcontractors. Establish controls for assuring that each subcontractor's diagnostic practices are consistent with overall system or equipment requirements.

c. Identify diagnostic design guides, analysis models and procedures to be imposed upon the design process. Plan for the review, verification, and utilization of diagnostic data submissions. Explain how computer-aided design tools will be utilized in this process.

Diagnostic Program Reviews

1. Describe the conduct of the diagnostic portion of the formal reviews (e. g., PDR, CDR) which are conducted during FSD, including how these reviews relate to reliability, maintainability, human engineering, and logistic support reviews.

PRODUCTION PHASE

DIAGNOSTIC MATURATION

1. Mature the diagnostic capability in accordance with the established Maturation Plan to assure that required improvements are made toward satisfying the updated Diagnostics Performance Specification at each maintenance level. This includes:

   a. Maintaining and utilizing the diagnostic data system to measure performance of the diagnostic capability and take required corrective action, in accordance with the incentive and warranty provisions

   b. Planning and transitioning of the data analyses and system to the government

   c. Demonstrating that the diagnostic capability satisfies the diagnostic requirements.

PREPARING A SPECIFICATION:

Preparation of the diagnostic portion of a weapon system specification is a job which necessitates a full understanding of the design and fielding of the diagnostic capability. When preparing this specification, the Contractor Program Manager must recognize the intricacies of this job to ensure that the specifications utilized to acquire a weapon system clearly define the diagnostic requirements.

What is a Failure?

An initial requirement in the specification is to establish the definition of a failure at system, subsystem, and unit levels. This requirement is essential in demonstrating graceful degradation through the use of fault-tolerant design, reconfigurability, redundancy, and performance monitoring. A failure may be defined as causing the mission and performance requirements of the prime system to be compromised.

What Means are Available to Perform Diagnostics?

Too often the word "diagnostic" is used interchangeably with "test." The specification must recognize the different types of diagnostics, which include:

- o Sensory observations (e.g., the display isn't on!)
- o Symptomatic (e.g., usually this means the power supply isn't working!)
- o Test (e.g., an output voltage measures zero!)

Means through which systems' diagnostics can be addressed include:

- o Automatic testing (i.e., embedded or external)
- o Manual troubleshooting, utilizing technical manuals, troubleshooting procedures, manual test equipment
- o Operator and maintenance technicians' observations and various forms of performance monitoring
- o A combination of the above.

What Terms Can be Used in Specifying Diagnostic Requirements?

As indicated previously, various terms may be used to specify diagnostic requirements. A preferred set is contained in an RADC report, "A Rationale and Approach for Defining and Structuring Testability Requirements," (RADC-TR-85-150), August 1985. The set includes the following:

Fraction of Faults Detected (FFD)

FFD can be defined as that fraction of failures which occur over operating time which can be correctly identified through direct observation or other specified means by an operator and/or other specified personnel under a given set of conditions. The quantitative definition of FFD is:

$$FFD = \frac{F_D}{F_A}$$

Where:

F_A = Number of actual failures (faults) which (will) occur over operating time, T.

F_D = Number of actual failures correctly identified through direct observation and other specified means by an operator and/or other specified personnel under a given set(s) of conditions.

In specifying FFD, all the various means which can be used to detect faults must be taken into consideration. The requirement for FFD should be stringent enough to exclude the application of the types of detection means which are unsatisfactory/unacceptable for the system needs/objectives/philosophies, but flexible enough to allow the contractor to tailor his design cost effectively. In general, the specific nature and mix of the means to be employed to achieve a given minimum FFD should be dependent on results of an analysis of each such alternative and its cost and performance effectiveness, in conjunction with other system/equipment design factors and requirements. The contractor should be tasked to perform such analyses and provide results/recommendations to the procuring activity based on these factors.

The FFD specification parameter must be specifically defined to take into account frequency of failure (failure rates) of the components making up the system. It is only in this way that FFD will be representative of what occurs during operational life.

In specifying FFD, care must be taken to define that set of detection conditions which are acceptable: for example, who can perform the detection function; what are the acceptable means through which detection can be performed; during which equipment status modes can detection be performed (operation, pre- or post-mission checks, etc.); and whether or not a failure must be detected within a certain period of time? It should also be noted that the fraction of faults detected will have a significant effect on the reliability of the fault-tolerant system if diagnostics are an essential part of the system's failure/recovery mechanism.

Fraction of Faults Isolated (FFI)

FFI can be defined as that fraction of failures which occur over operating time which can be correctly isolated to x units, or fewer, at a given maintenance echelon through use of specified means, by a maintenance technician or other specified personnel. The quantitative definition for FFI is:

$$FFI = \frac{F_I}{\overline{F_A}}$$

Where:

F_A = Number of actual failures (faults) which (will) occur over operating time T.

F_I = Number of actual failures (faults) which (will) occur over operating time T that can be correctly isolated to x units, or fewer, at a given maintenance echelon through use of specified diagnostic scheme(s)/ procedure(s) (or a defined set of such), by a maintenance technician or other specified personnel.

In specifying FFI, all the various generic means acceptable in general for the mission/operational/maintenance environment which can be used to isolate faults must be taken into consideration. The requirement for FFI should be stringent enough to exclude the application of isolation means which are known in general to be *unsatisfactory/unacceptable to the system needs/maintenance philosophy/objectives but* are flexible enough to allow the contractor to tailor his design cost effectively. The specific nature and mix of the means to be employed should be dependent on the results of an analysis task (levied on, and performed by, the contractor) of each fault isolation alternative, in conjunction with system/equipment design factors, maintainability requirements, and support system needs. Generally speaking, unless there is clear evidence that unacceptable weight, volume, or cost penalties would accrue, primary diagnostic means based on: (1) signal tracing and analyses through the use of schematics and test equipment, and (2) repetitive item remove/replacement/performance check actions should be avoided.

In specifying FFI care must be taken to indicate the conditions under which isolation must take place:

- Where it takes place (i.e., Organizational Level, Shop Level)

- o What are the acceptable means of isolation (i.e., built-in test, external testers, general-purpose testers, peculiar testers, manual means, degree of manual means)
- o Who will perform the isolation (i.e., operator or maintenance technician)
- o Its constraints (i.e., prohibition of wholesale removal of units, time allowable)
- o Its second isolation tier requirements (what happens after isolation to proper ambiguity level)
- o The time constraints levied by the maintainability requirement.

The FFI parameter must be specifically defined to take into account frequency of failure (failure rates) of the components making up the system. It is only in this way that FFI will be representative of what occurs during operational life.

False Alarm Rate

A false alarm is defined as an apparent indication of failure when, in fact, no failure exists. The false alarm rate is the number of false alarms per unit of time.

Intermittent faults can be difficult to distinguish from false alarms during operational test and in use. A properly structured qualification test, however, can exclude the influence of intermittent faults.

False alarm rates are controllable through the use of such design techniques and features as:

- o Scope and magnitude of performance monitoring
- o Definition of test tolerances
- o Transient monitoring and control
- o Multiple-run decision logic
- o Environmental effects filtering and identification.

Fraction of Erroneous Fault Isolation Results (FEFI)

FEFI is the fraction of BIT or external tester isolations that identify the wrong removable unit (subunit) or group of units (subunits) as failed. FEFI is primarily a design problem resulting either from test system design error or low sensitivity thresholds and tolerance levels of system/equipment components and/or signals. It can have serious

consequences by creating confusion during fault isolation and by eroding maintenance technician confidence in the test system. The quantitative definition is:

$$FEFI = \frac{F_E}{\overline{F_A}}$$

Where:

F_A = Number of actual failures (faults) which (will) occur over operating time T.

F_E = Number of actual failures (faults) which (will) occur over time T that are isolated to a nonfailed unit or group of units.

What Does 100% Fault Detection/Fault Isolation Mean?

In defining FFD as a contractual requirement for most programs, it is sometimes simpler to exclude those types of direct detection means (for example, detection through the use of technicians) which would, in general, be unsatisfactory to a given mission environment than to define those that are acceptable. The fact that an FFD requirement is imposed should not imply that 100% of all expected failures should not be detectable. The contractor should be tasked with the development of cost-effective, defined procedures to detect all expected failures. All of these, however, need not be direct means or belong to the type of direct means which are defined as satisfactory for general mission operational use, provided maintainability and other requirements can still be met. Detection can include direct or indirect indications to an operator, the use of maintenance technicians or other personnel performing in accordance with a series of defined routines, or some combination of these.

For FFI 100% coverage is required, which simply states that using a combination of all diagnostic resources, all faults can be isolated, given an adequate amount of time. Applying restrictions in time means that 100% of all expected faults will be isolatable, but a certain fraction (1-FFI) may have ambiguity levels greater than the value stated or be isolatable through means which are definable, but which do not belong to the class of diagnostic means cited as being acceptable for general use in the given mission or use environment. Consideration must be given as to how and where isolation to the faulty unit(s) must take place.

In summary, specifications should indicate a 100% fault detection/fault isolation coverage at each maintenance level (e.g., combinations of automatic and manual troubleshooting means should equal 100%). This does not mean that 100% of faults can be isolated to a given unit within a given time using specific diagnostic resources.

What is Diagnostic Growth?

Another aspect which is recommended to be introduced is that of diagnostic growth--similar in concept to the already established reliability growth. This growth requirement is especially important in the maturation of the system. Figure 2 is a conceptual version of this growth process. Demonstrations that these goals, or requirements, have been achieved at various phases of weapon system development must be tailored to the specific weapon system acquisition strategy. For instance, if the performance of an aircraft is to be evaluated at the conclusion of Dem/Val, then the entire diagnostic capability for the aircraft should reach the specified requirement at that point in time. On the other hand, if only specific units (usually high risk) of a weapon system are developed during Dem/Val, then the diagnostic capability for only those specific units may be demonstrated. The maturation of a diagnostic capability for the entire weapon system, in most cases, will extend into the Deployment Phase.

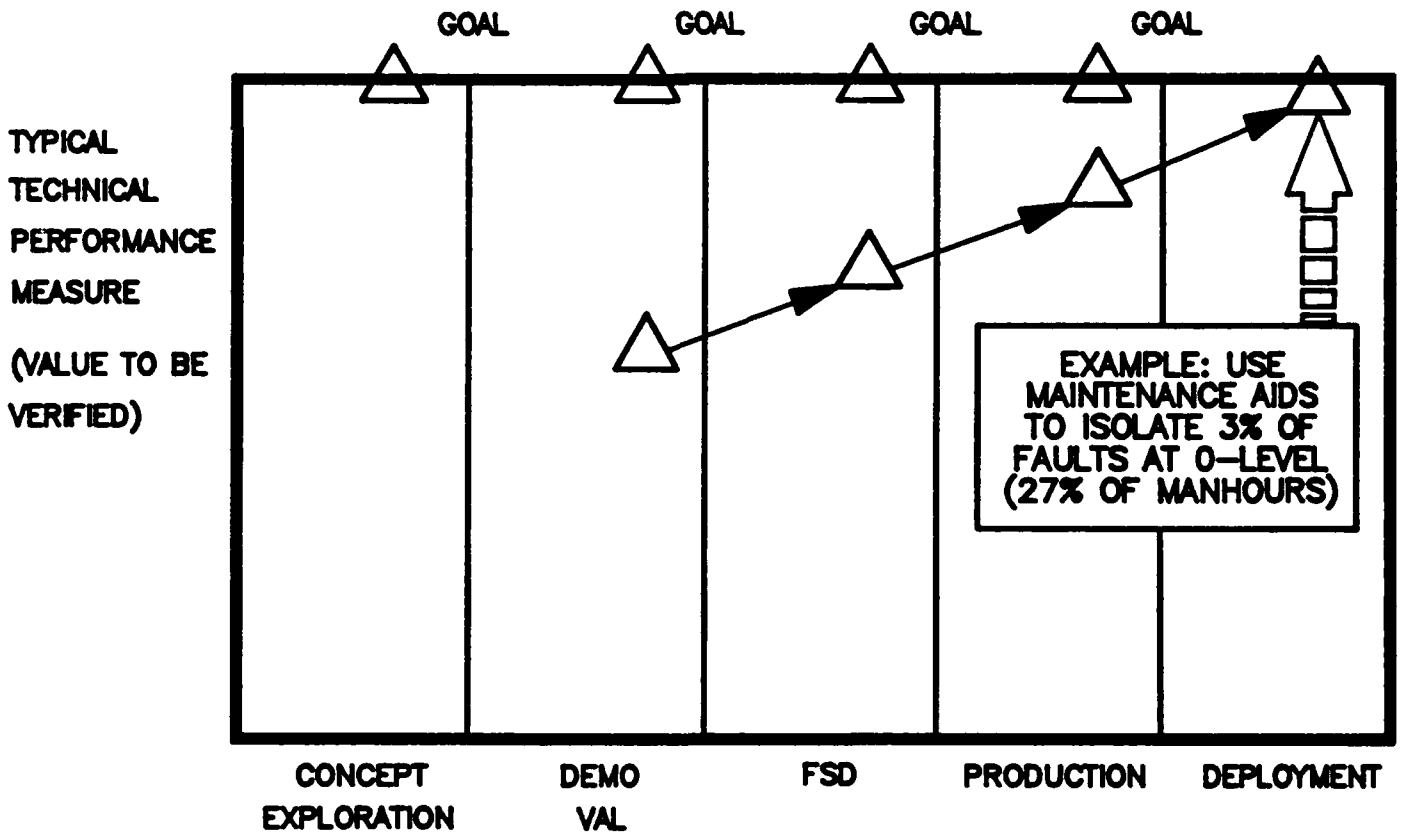


FIGURE 2. DIAGNOSTIC GROWTH CONCEPT

What Does a "Diagnostic Specification" Contain?

The diagnostic portions of the weapon system specification differ, depending on the stage of development. Normally, these specifications take the form of a Preliminary System Specification, resulting from Concept Exploration; a System Specification, derived from the Demonstration and Validation Phase; and a Configuration Item Development Specification, which allocates requirements down to subsystem and item levels. (A more complete definition of the various types of specifications is contained in MIL-STD-490, Specification Practices.) The following examples of diagnostic portions of specifications follow this form. The content must be tailored to fit a specific system requirement.

Preliminary System Specification

The Preliminary System Specification is a result of Concept Exploration Phase studies, prior to conducting the detailed diagnostic/testability requirements analysis during the Demonstration and Validation Phase.

Quantitative testability/diagnostic parameters are not specified in the Preliminary System Specification. Rather, qualitative system-level diagnostic/testability goals are included.

The model paragraphs below may be included in the Preliminary System Specification primarily to alert the performing activity that diagnostic/testability is considered to be an important aspect of the design and that quantitative requirements will be imposed in the final System Specification.

3.X.X Design for Testability

3.X.X.1 Partitioning. The system shall be partitioned based, in part, upon the ability to confidently isolate faults.

3.X.X.2 Test Points. Each unit within the system shall have sufficient test points for the measurement or stimulus of internal circuit nodes so as to achieve an inherently high level of fault detection and isolation.

3.X.X.3 Built-In Test. Mission critical functions shall be monitored by Built-In Test. BIT tolerances shall be set to optimize fault detection/false alarm characteristics. BIT indicators shall be designed for maximum utilization by intended personnel (operator/maintainer).

System Specification

Quantitative testability/diagnostic requirements are derived from the tradeoff analysis during the Demonstration and Validation Phase and are incorporated in the System Specification. Requirements may be expressed in terms of goals and thresholds rather than as a single number. Requirements for diagnostic/testability in a System Specification are provided in the following model.

3.2.4.X Diagnostic/Testability-The_____ system (insert name) shall be designed for testability and constructed to permit the status of the system and the unambiguous location of faults to be confidently determined and reported in a timely fashion.

3.2.4.X.1 Partitioning (Functional Modularity) - System/Subsystems will be partitioned into Line Replaceable Units (LRU) based on the function, minimum or optimum number of interconnections, the ability to fault isolate to the correct unit. LRUs will be subdivided into next level replaceable items (e.g., Shop Replaceable units, or SRU) based on function, minimum or optimum number of interconnections, and the ability of personnel with the aid of support equipment, training, and technical manuals to fault isolate.

3.2.4.X.2 Test Points and Contacts - Test points and contacts shall be conveniently located and have safe access to signal nodes and shall be provided for the measure or injection to significant parameters for the purpose of evaluating or troubleshooting the circuit mechanisms. the number and choice of accessible nodes shall be sufficient to obtain the equipment fault detection/isolation requirements listed herein.

3.2.4.X.3 Diagnostic Capability - For each level of maintenance: all diagnostic resources shall be integrated to provide a consistent and complete diagnostic capability. A complete diagnostic capability must identify the diagnostic resources that will be used to have full FD/FI coverage. The degree of diagnostic automation shall be consistent with the proposed personnel skill levels and maintenance repair times.

3.2.4.X.4 Built-In-Test - Built-In Test (BIT) provisions shall be designed into the _____ system to test system/equipment and to inform the operator of the ability of the equipment to perform a particular mission.

3.2.4.X.4.1 On-Line BIT Performance Monitoring - The on-line BIT performance monitoring features shall be operative and shall provide valid performance indications prior to and during operation. The performance monitoring operation shall be automatic and continuous and shall:

1. *Ensure subsystems are operational and are capable of satisfying their designated mission functions.*

2. *Detect any system failure or degradation which would adversely affect the system's ability to satisfy its mission objectives.*

All BIT implementations of this requirement shall be contained within the system or subsystem hardware and will not degrade mission performance at any time.

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3.2.4.X.4.1.1 NO-GO Condition Detection - The system on-line BIT performance monitoring features shall detect at least _____ percent of all NO-GO condition occurrences over the mission time. (As applied at the weapon system level or as applied independently at the subsystem level.)

3.2.4.X.4.1.2 False Alarms - The number of false alarms shall not exceed _____ percent of all indicated NO-GO condition occurrences or alternately no more than _____ indicated NO-GO condition occurrences in any 24-hour period of system operating time.

3.2.4.X.4.1.3 Performance Monitor and Self-Test Data - Performance monitor and self-test data shall be transmitted in a manner such that the transmitted data shall follow the actual condition of the system, that is, a malfunction which corrects itself shall change the fault data line accordingly.

3.2.4.X.4.2 Off-Line BIT - The _____ system BIT provision shall furnish the means for an operator to initiate BIT tests for purposes of determining and displaying the functional status of the systems/subsystems including a fault detection and isolation capability. The intended use of the off-line BIT tests is two-fold: as a System readiness test to permit operating crew to accumulate status and fault information on an opportunity basis prior to and during operations; and to verify a fault indicated during operation and to isolate the fault at the Organizational level of maintenance.

3.2.4.X.4.2.1 NO-GO Condition Detection - The system off-line BIT features shall detect at lease _____ percent of all NO-GO condition occurrences. (As applied at the weapon system level or as applied independently at the subsystem level.)

3.2.4.X.4.2.2 False Alarms - The number of false alarms shall not exceed _____ percent of all indicated NO-GO conditions occurrences or alternately no more than _____ indicated NO-GO condition occurrences in any 24-hour period of system operating time.

3.2.4.X.4.2.3 Off-Line BIT Fault Detection - The off-line BIT fault detection capability shall be designed to monitor, detect, and evaluated faults on all system or subsystem functions available at the system or subsystem interface. When a fault or system degradation is detected, the off-line BIT provision may determine the amount of degradation and automatically branch into the appropriate diagnostic fault isolation routine.

3.2.4.X.4.2.4 Off-Line BIT Fault Isolation - The off-line BIT fault isolation routines shall be provided at each fault detection point and shall be automatically entered when a NO-GO is detected. The off-line BIT shall provide fault isolation to one Line Replaceable Unit _____ percent of the time, fault isolation to _____ or fewer Line Replaceable Units _____ percent of the time. In no case shall the ambiguity group be greater than _____ LRU.

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3.2.4.X.2.5 Off-Line BIT Fault Isolation Time - The off-line BIT Fault Isolation time shall be consistent with the requirements of the Organizational level Mean Time To Repair (MTTR) requirements.

3.2.4.X.4.3 BIT Self Test - BIT self test provisions shall be incorporated into the _____ system. The time for the BIT self test shall be less than _____ (and/or the duty cycle of the BIT self test shall be _____). [The BIT failure rate shall be less than _____ percent of the prime system BIT failure indication rate.]

3.2.4.X.4.4 Fail Safe Provisions - The circuits and devices which provide BIT and fault isolation functions shall be designated in such a manner that failure of these circuits and/or devices will not cause a critical failure or unsafe action of the system.

3.2.4.X.4.5 Skill Levels - A personnel skill level of _____ is required to permit the accomplishment of all actions associated with the fault isolation and removal/replacement of LRUs at the operational/Organizational level. BIT provisions and, where required, Organizational level test equipment and maintenance procedures will be used to provide fault isolation within the MTTR specification.

3.2.4.X.5 Test Equipment Interface - Signals shall be included at the module interface which maximizes the similarity of built-in testing by the equipment and external testing by manual test equipment and/or on ATE systems. The system shall be designed for compatibility for test with the selected or targeted ATE (or _____ (insert test equipment name/designator)). Maximum use shall be made of operational pins to provide test control and access to satisfy the fault detection/fault isolation requirements of external test.

3.2.4.X.6 Test Tolerances - Appropriate tolerances and signal limits shall be established in diagnostic routines at each level which the system/equipments are subject to testing such that false alarms and Retest Okay rates are minimized.

3.2.4.X.7 Technical Information Access Time - Average time required for the maintenance technician to access maintenance technical information shall be less than _____ minutes at the Organizational level of maintenance.

Configuration Item Development Specification

A model testability specification suitable for inclusion in the CI development specification is provided as follows:

3.2.4.X Testability/Diagnostic - The _____ subsystem/item (insert name) shall be designed for testability and constructed to permit the status of the subsystem/item and the unambiguous location of faults to be confidently determined and reported in a timely fashion.

3.2.4.X.1 Partitioning (Functional Modularity) - Subsystems/items will be partitioned into Shop Replaceable Units (SRU) based on the function, minimum or optimum number of interconnections, the ability to fault isolate the correct unit and the ability of personnel with the aid of support equipment, training, and technical manuals to fault isolate to the correct unit.

3.2.4.X.2 Test Points and Contacts - Test points and contacts shall be conveniently located and have safe access to signal nodes on the unit under test, and shall be provided for the measure or injection of significant parameters for the purpose of evaluating or troubleshooting the circuit mechanisms. The number and choice of accessible nodes shall be sufficient to obtain the equipment fault detection/isolation requirements listed herein.

3.2.4.X.3 Diagnostic Capability - For each level of maintenance: all diagnostic resources shall be integrated to provide a consistent and complete diagnostic capability. A complete diagnostic capability must identify the diagnostic resources that will be used to have full FD/FI coverage. The degree of diagnostic automation shall be consistent with the proposed personnel skill levels and maintenance repair items.

3.2.4.X.4 Built-In Test - Built-In Test (BIT) provisions shall be added to the _____ subsystem/item to satisfy system level performance monitoring and off-line BIT requirements.

3.2.4.X.4.1 On-Line BIT Performance Monitoring - The on-line BIT performance monitoring features shall be operative and shall provide valid performance indications prior to and during operation. The performance monitoring operation shall be automatic and continuous shall be automatic and continuous and will monitor self-contained signal generating circuitry. All BIT implementations of this requirement shall be contained within the system or subsystem hardware and will not degrade mission performance at any time.

3.2.4.X.1.2 NO-GO Condition Detection - The system on-line BIT performance monitoring features shall detect at least _____ percent of all NO-GO condition occurrences. (As applied independently at the subsystem level.)

3.2.4.X.4.1.3 False Alarms - the number of false alarms shall not exceed _____ percent of all indicated NO-GO condition occurrences or alternately no more than _____ indicated NO-GO condition occurrences in any 24-hour period of system operating time.

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3.2.4.X.4.1.4 Performance Monitor and Self-Test Data - Performance monitor and self-test data shall be transmitted in a manner such that the transmitted data flow shall be transmitted in a manner such that the transmitted data shall follow the actual condition of the system, that is, a malfunction which corrects itself shall change the fault data line accordingly.

3.2.4.X.4.2 Off-Line BIT - The _____ subsystem BIT provision shall furnish the means for an operator to initiate BIT tests at the system level for purpose of determining and displaying the functional status of the system/subsystems including a fault detection and isolation capability. The intended use of the off-line BIT test is two-fold: as a System readiness test to permit operating crew to accumulate status and fault information an opportunity basis prior to and during operations; and to verify a fault indicated during operation and to isolate the fault at the O-Level of maintenance.

3.2.4.X.4.2.1 NO-GO Condition Detection - The system off-line BIT features shall detect at least _____percent of all NO-GO condition occurrences. (As applied independently at the subsystem level.)

3.2.4.X.4.2.2 False Alarms - The number of false alarms shall not exceed _____ percent of all indicated NO-GO condition occurrences or alternately no more than _____ indicated NO-GO condition occurrences in any 24-hour period of system operating time.

3.2.4.X.4.2.3 Off-Line BIT Fault Detection - The off-line BIT fault detection capability shall be designed to monitor, detect, and evaluate faults on all system or subsystem functions available at the system or subsystem interface. When a fault or system function degradation is detected, the off-line BIT provisions shall determine the amount of degradation and automatically branch into the appropriate diagnostic fault isolation routine.

3.2.4.X.4.2.4 Off-Line BIT Fault Isolation - The off-line BIT fault isolation routines shall be provided at each fault detection decision point and shall be automatically entered when a NO-GO is detected. The off-line BIT shall provide fault isolation to one Shop Replaceable Unit _____ % of the time, fault isolation to ___ or fewer Shop replaceable Units _____ % of the time.

3.2.4.X.4.2.5 Off-Line BIT Fault Isolation Time - The off-line BIT fault isolation time shall be consistent with the requirements of Mean Time To Repair (MTTR) requirements.

3.2.4.X.4.3 BIT Self Test - BIT self test provisions shall be incorporated into the _____ subsystem/item. The time for the BIT self test shall be less than _____ (and/or the duty cycle of the BIT self test shall be _____). The BIT failure rate shall be less than _____ % of the prime system BIT failure indication rate.

3.2.4.X.4.4 Fail Safe Provisions - The circuits and devices which provide BIT and fault isolation functions shall be designed in such a manner that failure of these circuits and/or devices will not cause a critical failure or unsafe action of the subsystem/item.

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3.2.4.X.6 Skill Levels - A personnel skill level of _____ is required to permit the accomplishment of all actions associated with the fault isolation and removal/replacement of SRUs at the intermediate maintenance level. BIT provisions, test equipment and maintenance procedures will be used to provide fault isolation within the MTTR specification.

3.2.4.X.7 Test Equipment Interface - Signals shall be included at the module interfaces which maximize the similarity of built-in testing by the equipment and off-board testing by manual test equipment and/or on ATE systems. The system shall be designed for compatibility for test with target off-line automatic test equipment. Maximum use shall be made of operational pins to provide test control and access to satisfy the fault detection/fault isolation requirements of off-board test.

3.2.4.X.8 LRU Fault Detection/Isolation Requirements - The following requirements apply to fault detection/isolation capability at the intermediate level of maintenance using automatic test resources (ATE/TPS and BIT).

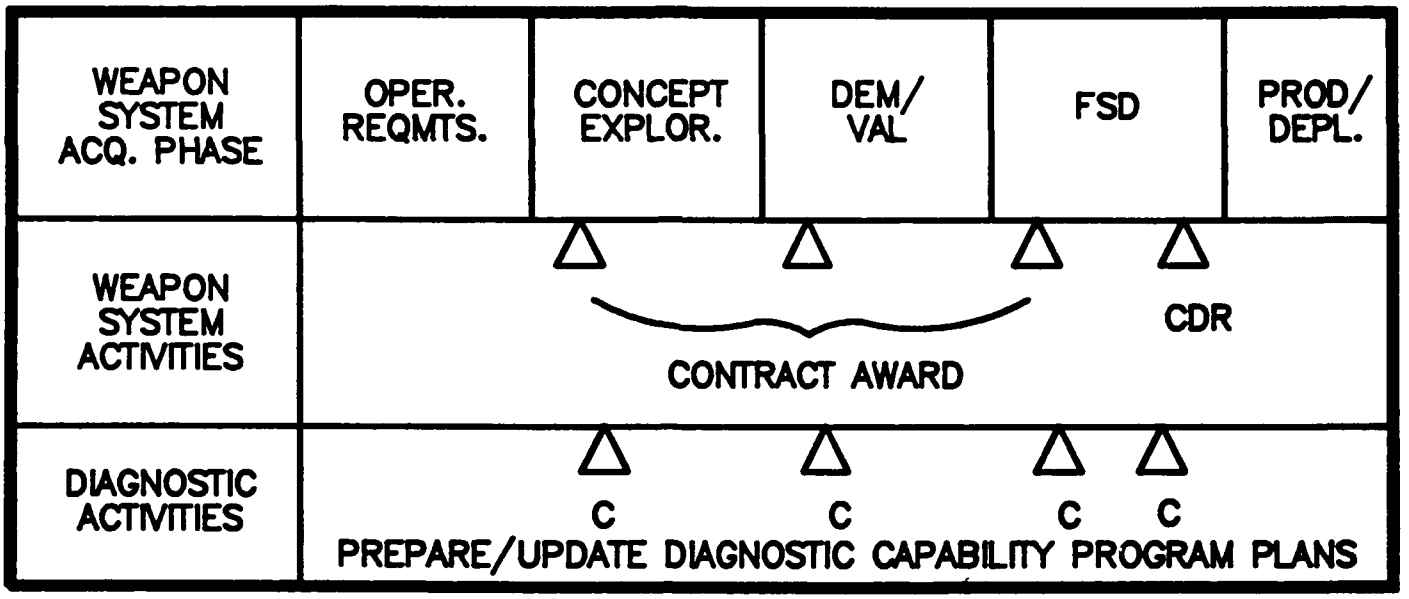
- *Fault isolation shall be _____ percent of all organizational detected failures.*
- *Average (or maximum) test time for GO/NO-GO end-to-end tests shall be less than _____ (minutes/hours).*
- *Maximum rate of false NO-GO indications resulting in Cannot Duplicates and Retest Okays shall be _____ percent of all Organizational level detected failures.*
- *Fault isolation capability shall provide fault isolation to one SRU _____ percent of the time, fault isolation to _____ or fewer SRUs _____percent of the time. In no case shall the ambiguity group size be greater than _____ SRU.*
- *Average (or maximum) diagnostic fault isolation time shall be less than _____ (minutes/hours).*

3.2.4.X.9 SRU Fault Detection/Isolation Requirements - The following requirements apply to fault detection/isolation capability at the Depot level of maintenance using automatic test resources (ATE/TPS and BIT).

- *Fault isolation shall be _____ percent of all detected failures.*
- *Average (or maximum) test time for GO/NO-GO end-to-end tests shall be less than _____ (minutes/hours).*
- *Maximum rate of false NO-GO indications resulting in Retest Okays shall be _____ percent of all detected failures.*
- *Fault isolation capability shall provide fault isolation to one component _____ percent of the time, fault isolation to _____ or fewer components _____ percent of the time. In no case shall the ambiguity group size be greater than _____ components.*
- *Average (maximum) diagnostic fault isolation test time shall be less than _____ (minutes/hours).*

CHECKLIST

- ☑ Has the Contractor Program Manager worked closely with the Government Program Manager, prior to the issuance of the RFP, to assure the diagnostic requirements are feasible, cost–effective and promote innovation?
- ☑ Does the proposal address all the diagnostic requirements? Does it promote integration? Does it promote innovation?
- ☑ Does the specification address necessary FD/FI requirements for each level of maintenance?
- ☑ Has the concept of "diagnostic growth" been invoked in the diagnostic specification?



C– CONTRACTOR PREPARED

DIAGNOSTIC ACTIVITY

Program planning is required to ensure that the development and support of the diagnostic capability is properly managed throughout the acquisition of a weapon system. This planning, which is prepared by the Contractor Program Manager, must address how this development will be conducted to achieve this goal.

PROCEDURE

Program planning for the development of the diagnostic capability is required throughout the acquisition of the weapon system. It begins soon after the award of the first developmental contract and is expanded and updated as the development proceeds.

The program planning can take the form of a single Diagnostic Capability Program Plan or can be incorporated in a series of program plans which are described in a number of programmatic-type military standards. The requirements of these planning documents will be defined in the contract's Statement of Work. To avoid unnecessary duplication of programs plans, the inclusion of this planning information in existing documents is preferred. Therefore, the guidance which follows addresses diagnostic inputs to these existing plans, but can be easily be tailored to respond to the requirements in the contract.

The SEMP is the logical key plan, because it reinforces the principle that integrated diagnostics is a systems engineering function. Thus, when a SEMP is required, the Government Program Manager will likely rely on this plan as the critical diagnostic planning document. If required, the Testability Program Plan usually would be included as

an integral part of the SEMP for testability is a design consideration and is the foundation of the diagnostic capability.

GUIDANCE

Each of the management-type plans is required during specific phases of the weapon system acquisition. The following (Table 2) is a listing of these plans and phases where these plans are generally required. Normally, the initial version of the SEMP is prepared during Concept Exploration. An alternative is for the government to require the preparation of the SEMP as part of the contractor's response to the Request for Proposal (RFP).

TABLE 2 – APPLICATION MATRIX

PLAN TITLE	GUIDANCE DOCUMENT	PROGRAM PHASE			
		CE	DEM/VAL	FSD	PROD
SYSTEM ENGINEERING MANAGEMENT PLAN (SEMP)	MIL-STD-499	X	X	X	X
LOGISTIC SUPPORT ANALYSIS PLAN (LSAP)	MIL-STD-1388-1	X	X	X	
TESTABILITY PROGRAM PLAN	MIL-STD-2165		X	X	
RELIABILITY PROGRAM PLAN	MIL-STD-785		X	X	
MAINTAINABILITY PROGRAM PLAN	MIL-STD-470		X	X	
INTEGRATED SUPPORT PLAN (ISP)	EITHER DOD-D-5000.39 OR MIL-STD-1388	X	X	X	X
SYSTEM SAFETY PLAN	MIL-STD-882		X	X	
HUMAN ENGINEERING PROGRAM PLAN	MIL-H-46855		X	X	
TEST AND EVALUATION MASTER PLAN (TEMP)	DOD-D-5000.3		X	X	X

SYSTEM ENGINEERING MANAGEMENT PLAN (SEMP)

The requirement for a SEMP, which is composed of three (3) parts, is governed by MIL-STD-499. Specific guidance relating to preparation of this plan follows:

PART I - Technical Program Planning and Control

This part of the plan should describe the contractor(s) organization and internal interfaces required to integrate the design of the diagnostic capability as an integral part of the system engineering process. The extent to which integrated diagnostics has been institutionalized within the contractor's operating polices and procedures must be addressed. A single individual shall be identified which has the overall responsibility and authority for implementation of the integration process. The placement of this individual within the contractor's organization is an important issue. Since no two company organizations are identical and operate the same, there can be no specific guidance on this issue other than saying the individual:

- o Should have direct influence over both the design and supportability diagnostic functions.
- o Should have direct access to the Contractor Program Manager.

The review process is used to ensure that the integration of the task is accomplished across all involved functional disciplines and that an adequate feedback system exists to redirect efforts to meet diagnostic goals and requirements. Where subcontractors, or teaming arrangements with associate contractors, contribute to the integration of the diagnostic capability, describe these organizational interfaces and the planning and control functions to be implemented to assure a totally integrated effort. A schedule should be established for each of the data deliverables cited in the Statement of Work.

PART II - System Engineering Process

This part of the plan should contain a description of the process to be used in meeting the overall program objectives and requirements, the general maintenance concept to be used to support the system/equipment, and the contractor's methodology for arriving at the desired diagnostic approach. Analyses and trade studies should be identified and the proposed methodology for conducting these studies described. Reference to models approved by the procuring activity must satisfy the methodology requirement. If not, these models/methodologies should be described, along with their capabilities and limitations. The relationship and interface with the Logistic Support Analyses required by MIL-STD-1388-1 should be established. In addition, the plan should include:

1. An integrated approach to the maintenance diagnostics design that is an integral part of the weapon system/subsystem(s) design.
2. Discussion of how diagnostic requirements are to be met and integrated with each other in the overall weapon system design. This shall include

procedures for identifying deficiencies, needed actions, and corrective measures.

3. Discussion of how diagnostic elements are integrated with each other into the cost-effective achievement of primary maintenance goals (e. g., 100% unambiguous fault isolation capability).

PART III - Engineering Specialty Integration

This part should include a detailed description of the integrated diagnostics interrelationships involving human engineering, personnel, safety, reliability, training, logistics, product assurance, maintainability, etc., and their integration with the system engineering process. The plan should address the need for combined demonstration programs (e. g., reliability, maintainability).

LOGISTIC SUPPORT ANALYSIS PLAN

The Logistic Support Analysis Plan (see MIL-STD-1388-1) should define the interface between the analysis being conducted to define the specification for the diagnostic capability and the LSA.

RELIABILITY PROGRAM PLAN

Specifically, the Reliability Program Plan should address the conduct of the Failure Modes, Effects, and Critically Analysis (FMECA), as the basis for initial diagnostic design. In addition, the reliability modeling task, Task 201, MIL-STD-785, should take into count fault-tolerant design and its relationship meeting diagnostic goals utilizing redundancy.

MAINTAINABILITY PROGRAM PLAN

The Maintainability Program Plan is the basic planning document for assuring that diagnostic requirements are met. Each of the MIL-STD-470 200-series tasks has a direct interface with the design of the diagnostic capability. In addition, Task 301, Maintainability Demonstration, is the basic demonstration task for both testability and diagnostics.

INTEGRATED SUPPORT PLAN

This is the formal planning document for logistic support. It must reflect how all of the diagnostic elements will be provided and supported.

SYSTEM SAFETY PLAN

The System Safety Plan (MIL-STD-882) should provide diagnostic inputs that impact the determination and identification of diagnostic requirements for detecting potential safety problems. This performance monitoring analysis should be closely tied to the FMECA.

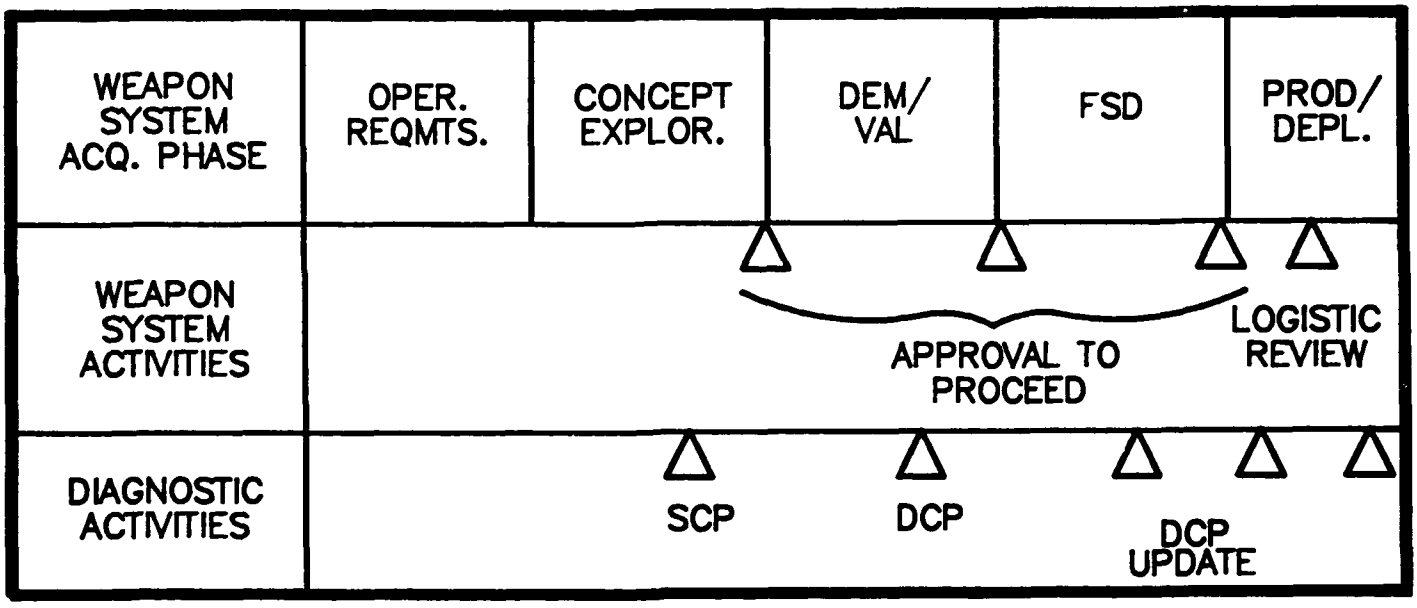
HUMAN ENGINEERING PROGRAM PLAN

The Human Engineering Program Plan needs to address the technician's role/interface with the entire weapon system diagnostic capability, including the time required to access technical information from whatever media is used. Careful attention must be paid in planning to have technicians evaluate the entire diagnostic capability (at all maintenance levels) during test and evaluation.

CHECKLIST

- ☑ Does the SEMP address design of the diagnostic capabilities as an integral part of the system engineering process (i.e., emphasis on Parts I and II of the SEMP, as opposed to Part III)?
- ☑ Does Part III of the SEMP require combined "ility" and logistic demonstrations?
- ☑ Are the diagnostic implications included in the various "ility" and logistic plans?
- ☑ Do the various plans place major emphasis on design for testability?
- ☑ Is there a single individual assigned full diagnostic responsibility? With "sign off" authority?

PREPARATION OF SCPs/DCPs	REQUIREMENT #1.4



DIAGNOSTIC ACTIVITY

Prior to Milestones I through V (DoD Instruction 5000.2), the preparation of a paper by the Government Program Manager is required to summarize the results of the acquisition and deployment of a major weapon system. Prior to Dem/Val, a System Concept Paper (SCP) is required. Prior to FSD, preparation of a Decision Coordinating Paper (DCP) is required. An update of the DCP is required prior to Milestones III, IV, and V. The SCP and the DCPs for Milestones II and III are required to secure approval to proceed to the next acquisition phase. Milestone IV is a logistic readiness and support review, which is conducted one or two years after deployment to assure that operational readiness and support objectives are achieved. Milestone V is a major upgrade or system replacement decision, which also requires an updating of the DCP. Diagnostic Issues should be addressed in these documents.

PROCEDURE

DoD Instruction 5000.2 delineates the need and the format for both an SCP and a DCP. It is likely that this documentation will address diagnostic issues. Although this type of documentation is required only for major weapon systems, similar documentation may be required by the individual services at significant milestones. Thus the following guidance can apply to all weapon systems and equipment. It is also important to note that Milestone IV, being a logistic readiness and support review, coincides with the projected maturation schedule for the diagnostic capability. Thus the Maturation Program Plan will probably relate to this milestone.

These documents are almost always prepared by the Government Program Manager. The following guidance is included in this document to promote understanding by the Contractor Program Manager of what is required to successfully justify a weapon system development.

GUIDANCE

The format for the SCP and the DCP is identical. However, the SCP is primarily concerned with: (1) program alternative tradeoffs; (2) performance/cost and schedule tradeoffs, including the need for a new development program vs. buying or adapting existing U. S. or Allied military or commercial systems; (3) appropriateness of the acquisition strategy; (4) prototyping of the system or selected system components; (5) affordability and life cycle costs; (6) potential common-use solutions; and (7) cooperative development opportunities. Thus diagnostic inputs to the SCP will most likely address these factors.

On the other hand, the DCP requirements for Milestone II, Full-Scale Development Decision, will normally address: (1) affordability, in terms of program cost vs. the military value of the new or improved system and its operational suitability and effectiveness; (2) program risk vs. benefit of added military capability; (3) planning for the transition from development to production, which will include independent producibility assessments (hardware/software/data bases); (4) realistic industry surge and mobilization capacity; (5) factors that impact program stability; (6) potential common-use solutions; (7) results from prototyping and demonstration/validation; (8) milestone authorization; (9) manpower, personnel, training, and safety assessments; (10) procurement strategy appropriate to program cost and risk assessments; (11) plans for integrated logistics support (DoD Directive 5000.39); (12) affordability and life cycle costs; and (13) associated command, control, communications, and intelligence requirements, including communications security.

The DCP requirements for Milestone III, Full Rate Production Decision will normally address: (1) results of completed operational test and evaluation; (2) threat validation; (3) production or construction cost verification; (4) affordability and life cycle costs; (5) the production and deployment schedule; (6) reliability, maintainability, and plans for integrated logistics support (DoD Directive 5000.39); (7) producibility, as verified by an independent assessment (DoD Directive 5000.38); (8) realistic industry surge and mobilization capacity; (9) multiyear procurement or milestone authorization; (10) manpower, personnel, training, and safety requirements; (11) cost effectiveness or plans for competition or dual sourcing; and (12) associated command, control, communications, and intelligence requirements, including communications security.

Primary considerations for Milestone IV, Logistic Readiness and Support Review, are: (1) logistic readiness and sustainability (peacetime and wartime); (2) weapon support objectives; (3) the implementation of integrated logistics support plans, per DoD Directive 5000.39; (4) the capability of logistics activities (i. e., supply, transportation, etc),

facilities, training, and manpower to provide support efficiently and cost effectively; (5) disposition of displaced equipment; and (6) affordability and life cycle costs. This should coincide with the completion of the diagnostic capability's maturation period.

Milestone V, Major Upgrade or System Replacement Decision, is concerned with: (1) capability of the system or facility to continue to meet its original or evolved mission requirements; (2) the potential necessity of modifications and upgrades to ensure that mission requirements are met and that the useful life is extended; (3) changes in threat that require increased capability or utility; (4) changes in technology that present the opportunity for a significant breakthrough in system worth; and (5) disposition of displaced equipment. A significant question to be decided at this point is whether deficiencies are critical enough to warrant major modification, retirement, and/or new start considerations. Feedback on the performance of the diagnostic capability is an important factor in this decision.

The above guidance relates to all of the information required in preparing SCPs and DCPs. Each of these items will normally be addressed by the Government Program Manager in relation to the diagnostic capability, as appropriate. Much of the data required to provide this information will be an output from the various studies conducted by the contractor as discussed in this guide under Requirement #2.

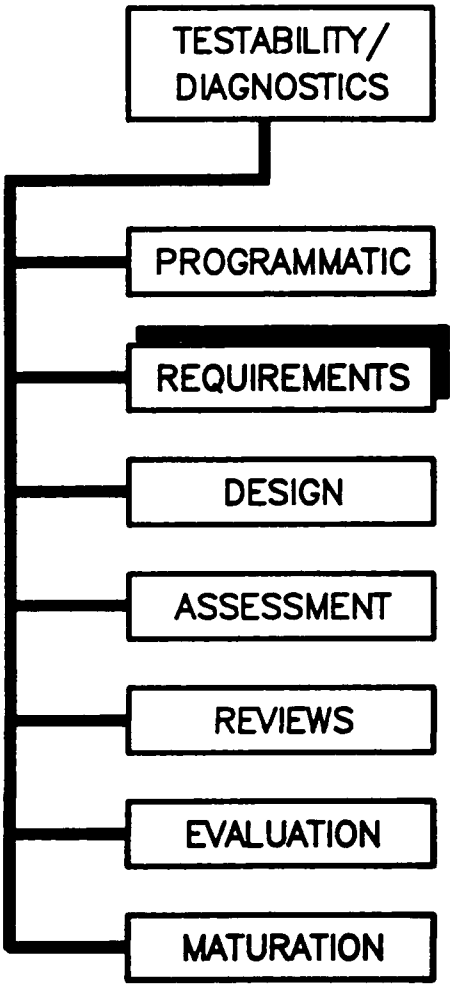
CHECKLIST

☑ Am I furnishing the Government Program Manager with the proper information for him to adequately justify his program?

ESTABLISHING AND ALLOCATING DIAGNOSTIC REQUIREMENTS

OVERVIEW

Good diagnostics and testability are based on the ability to properly establish diagnostic requirements, which are in turn based on weapon system mission, the system's sustainability, operational, and support requirements and the allocation of these requirements at system, subsystem, and unit levels. Lack of appropriate attention to this process results in diagnostic designs with questionable basis and justification. Unfortunately, this process has not been transformed from an art to a rigorous methodology. An integrated series of proven tools does not exist and thus the quality of the process depends on the expertise of the persons performing this function. The system is further complicated by the advanced weapon system architecture which is now being applied. This architecture involves complex redundancy, reconfigurable elements, and configurations which allow graceful degradation. A proper allocation methodology is an integral part of logistic support, reliability, and maintainability analyses and is based on the weapon system's mission scenario and performance requirements. The analyses are an iterative process, which extend over the acquisition phases and often into deployment of the weapon system. Implementation of these analyses are normally the responsibility of the Contractor Program Manager, with the results reviewed by the Government Program Manager.



IMPORTANT CONSIDERATIONS TO BE ADDRESSED

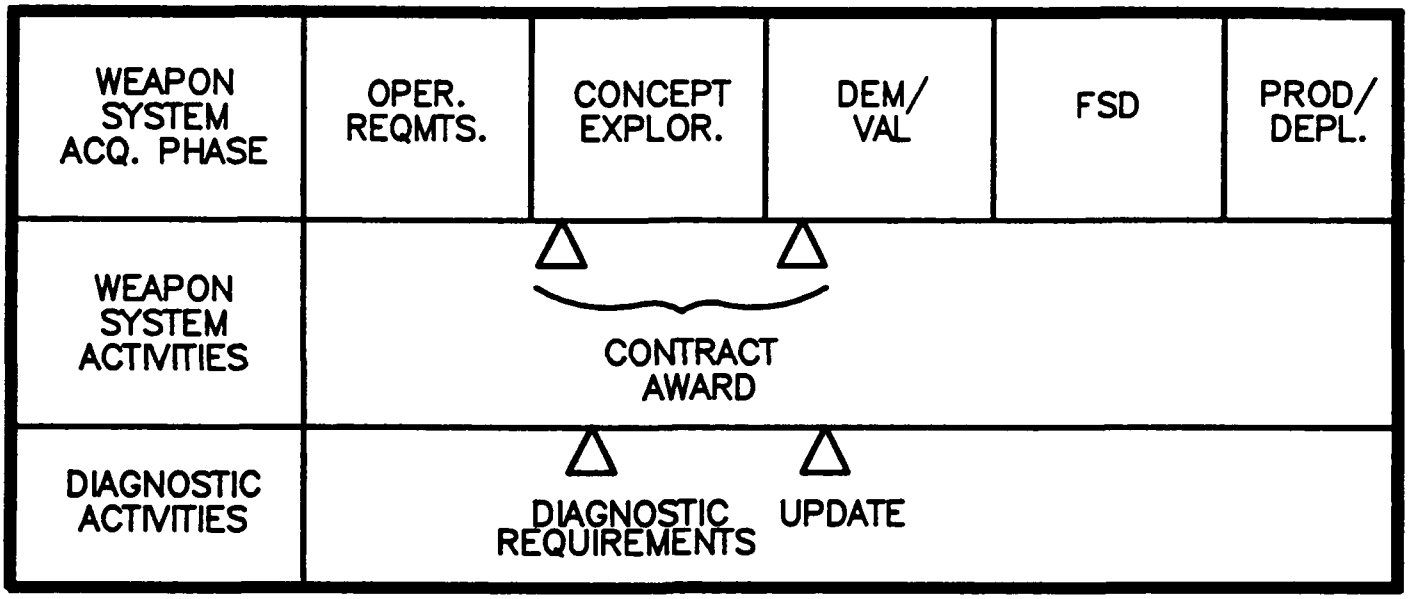
Reqmt.

2.1 Translate mission and performance requirements into diagnostic requirements.

2.2 Allocate diagnostic requirements to system, subsystem and unit elements.

2.3 Optimize the mix of diagnostic elements.

2.4 Assess the risk of each diagnostic alternative.



DIAGNOSTIC ACTIVITY

Diagnostic requirements are identified in the Concept Exploration Phase from an analysis of the prime system mission and operational requirements.

PROCEDURE

The generation of weapon system operational requirements is usually performed by the government from mission studies and analyses based on the Statement of Need for a weapon system. The translation of those requirements and weapon system performance characteristics into diagnostic requirements which are included in the system specification produced as a result of Concept Exploration. The tasks involved in translating these requirements may be performed by the contractors or the government depending upon the acquisition process selected during Concept Exploration. For "in-house" programs, this task is performed by government engineers. Frequently, however, the translation of mission and performance characteristics into diagnostic requirements, the selection and integration of the diagnostic elements to meet these requirements, the allocation of these requirements to subsystem and unit level, and the assessment of risk is performed by the weapon system contractors.

The proper implementation of this task is that it be performed in conjunction with the system engineering and logistic support analysis process and include synthesis and analysis of the various mixes of resources which make up a total diagnostic subsystem. The diagnostic requirements analysis process involves the development of a strategy for a comprehensive diagnostic capability including a mix of resources to be defined for roviding FD/FI capability at each level which the system is subject to maintenance.

TRANSLATING MISSION REQUIREMENTS	REQUIREMENT #2.1

In order to translate mission and operational requirements to diagnostic capability, it is important to postulate a "diagnostic subsystem." Characteristics defining the capability of the "diagnostic subsystem" represent the results of the translation. In other words, one must change mission requirements into diagnostic capability requirements in order to successfully complete this task.

The diagnostic elements constituting the diagnostic subsystem include embedded diagnostics, support equipment at all levels of maintenance, technical data in all its forms, and personnel numbers and required skill levels.

In order to be responsive to weapon system mission and performance requirements, it is essential that the translations start by reviewing all the requirements documentation and studies. The key document is the Statement of Need which contains the weapon system mission and operational requirements. Also important is the prime system architecture concept which is an essential element in the translation since many architectural concepts contain an inherent diagnostic capability that must be identified and addressed early in the analysis process.

There are two key factors which will influence the translation of weapon system mission and operational requirements into diagnostic requirements. They are:

- *Specific requirements* as spelled out in the Statement of Need
- Available technology.

Analysis of these specific requirements will translate requirements for the diagnostic capability as well as constraints on the diagnostic subsystem dictated by the operational parameters. The technology will impact the inherent diagnostic capability of the prime system architecture as well as impact the assessment of risk of the final diagnostic subsystem implementation.

Based upon the above analyses, translation of mission and operational requirements to a diagnostic capability will result in a preliminary set of diagnostic requirements for the entire diagnostic subsystem. The optimum mix of diagnostic elements which constitute the diagnostic capability will follow the requirements allocation to the weapon system, subsystem and unit levels.

During the Demonstration/Validation Phase and Full-Scale Development Phase the detailed trade studies will formally optimize the diagnostic element mix and provide implementation specifications for the diagnostic subsystem to be produced. This process is obviously iterative but most dependent upon a thorough job of mission and performance requirements analysis and initial translation into diagnostic requirements.

For example, the Dem/Val Phase may result in a System Specification only, with the allocation of the system requirements to be performed and redefined in the FSD

Phase. For some less-than-major systems, Dem/Val Phase may be bypassed altogether. In both of these cases, both the system-level specifications may be developed during FSD Phase. The analyses described within this section should be performed at appropriate points based upon, and commensurate with, the level of detail achieved in the definition of the system and the definition of the support and maintenance concepts for the system.

GUIDANCE

Currently there is no formal DoD model for translating mission and operational requirements into a diagnostic capability. However, using system engineering approaches defined in MIL-STD-499, the contractor can, indeed, develop an initial set of diagnostic subsystem requirements which are traceable to weapon system requirements, weapon system priorities, and available technology.

Success in translating mission and operational requirements into diagnostic requirements is embodied in the ability to develop higher order measures for defining weapon system characteristics that relate to fault detection and fault isolation parameters.

Typical weapon system characteristics which must be evaluated include the following:

- Probability of Mission Success
- Availability
- Utilization Rate
- Population
- Turnaround Time
- Threat
- Mobility
- Safety
- Alert
- Deployment
- Basing
- Weight
- Repair Concept
- Personnel
- Training
- Cost
- Etc.

The following weapon system priorities are of major concern:

- War fighting capability
- Survivability
- Mobility
- Manpower
- Life Cycle Cost.

During the Concept Exploration Phase, mission-oriented measures are overriding for diagnostic requirements generation. Resource criteria (manpower, cost, facilities, etc.) become significant during synthesis of specific diagnostic element mixes.

The mission data to be collected and considered for generating the diagnostic requirements is as follows:

- o Mission scenarios definition (prioritized in order of criticality)
- o Mission rate/length
- o Mission operation (continuous vs. intermittent)
- o Mission phases
- o Time demands and operational constraints per mission phase
- o Subsystem/function utilization per mission phase (survivability or safety critical)
- o Functions/failures impacting personnel safety
- o Functions/failures impacting system/equipment safety (sustainability or mission critical)
- o Functions/failures impacting mission success (per mission phase).

A key diagnostic parameter to be determined through the analysis of mission requirements is the maximum failure latency per operating function for each mission phase. This parameter will drive the fault detection requirements which, in turn, serve as the basis for BIT design. Failure latency is the elapsed time between fault occurrence and failure indication. Maximum failure latency is the maximum allowable time between the occurrence of a fault and the reporting or "handling" of the failure. As a simplistic example, if a fire control system fault occurs, and the fire control system function is highly critical to mission success, then the maximum failure latency will be very small -- perhaps expressed in microseconds or nanoseconds. The fault detection (FD) time requirement will reflect the failure latency factor -- thereby driving the BIT technique to provide concurrent performance monitoring. Fault tolerance through redundancy may be required or considered. This simplistic example is made more complex by factoring in the time demands per mission phase of the fire control system. It is made still more complex by factoring in operating anomalies and intermittents into the FD requirements.

In the definition of diagnostic requirements, it is important to note that the diagnostic capability is made up of the inherent diagnostic capability of the prime system, as well as added diagnostic elements. It is therefore important that diagnostic analysis be integral to the prime weapon system engineering process, since performance and support parameters can no longer be isolated from design.

The prime configuration represents a performance capability. The mission requirements can be related directly to the configuration by analysis of the behavior of the utilized configuration items over the time demands imposed by mission. A representation of performance over time can be easily presented to management for setting

requirements. This measure is referred to as P (Performance time dependency), which is described in MIL-HDBK-338. P can be calculated and plotted using equations for mission reliability in MIL-STD-756.

Operational constraints also must be addressed. The checklist below presents the operational data to be collected and considered in diagnostic requirements analysis.

- o Environmental conditions (temperature, rain, dirt, salt spray, etc.). Applies to both the prime system and support equipment
- o Operating locations (dispersed vs. centralized) (remote/accessible/inaccessible)
- o Space limitations (for personnel and/or test equipment)
- o Mobile or fixed maintenance facilities
- o Independent operation or part of a battle group
- o Manpower constraints (number and skill levels).

The constraints under which a weapon system will operate must be identified and evaluated in terms of the impact on testability requirements. System design and supportability factors must take into account these constraints. Operating constraints will often drive the diagnostic strategy to use of embedded versus external test resources.

Prime System Architecture/Configuration

Data must be collected on the architecture and configuration alternatives of the prime system to be developed with respect to partitioning, interconnections and flow as input to the testability requirements analysis. The architectures under consideration will have inherent characteristics which may support or impede diagnostics. The performance capability of alternative prime system architectures must be evaluated against the mission requirements, time phases and equipment utilization/demands.

It is useful for this evaluation to plot curves of capability vs. time demands imposed by the mission. The resulting P (Performance over Time) curve can include resource constraints (spares, personnel) and operational constraints (maximum allowable repair time).

The following prime system configuration data should be collected for input to this step:

- o Work Breakdown Structure (MIL-STD-881)

- o List of government furnished equipment/ off-the-shelf equipment/ non-developmental items (for above, item or candidate item)
- o Prime system architecture alternatives
- o Initial failure rate projections and characterization
- o Fault-tolerant or redundant functions
- o Technologies to be used (if known)
- o Level of integration vs. autonomy.

Based upon analysis of architectures under consideration, high-level diagnostic opportunities should be identified. This includes incorporation of a test and maintenance bus, fault-tolerant design coordination, system-level diagnostic resources - such as data acquisition/collection subsystems or embedded adaptive diagnostic subsystem and use of standard diagnostic connections and interfaces.

Diagnostic inputs must be made within the system engineering process prior to the final selection of the prime system architecture.

Evaluate Technology Opportunities

Advanced diagnostic technology opportunity or implications must be identified based on the following areas:

- o Baseline comparison system major drivers, supportability problem areas, targets of improvement
- o Incorporation of LSI, VLSI, VHSIC, expert system or other advanced design technology in system
- o Need to improve requisite operational capability having no prior design solution.

Examples of advanced diagnostic technology opportunities which may be exploitable on the new system include:

- o Expert system based maintenance aids
- o Test and Maintenance bus concepts
- o "Smart" BIT techniques
- o Adaptive diagnostic subsystems
- o Prognostics concepts

- o Automated technical information authoring
- o Advanced packaging techniques
- o Advanced instrumentation (stimulus and measurement) technologies
- o Automatic capture of CAD data for diagnostics generation.

Upon determination of advanced technology applications, inputs must be made to the design engineering effort regarding design constraints related to the above concepts.

Diagnostic Element Constraints

In order to define specific diagnostic characteristics and requirements of the system or to further "close in" the envelope within which tradeoffs are conducted, diagnostic-related constraints are established. This includes constraints placed on built-in test design attributes and functions, testability constraints and test equipment constraints. This may also include broader diagnostic-related constraints, such as page count of technical information or maintenance technician skill-levels. These constraints are driven by mission requirements, design, operation and support characteristics, or standardization policies imposed.

Sample diagnostic-related constraints are provided below.

Driving System Requirement	**Resulting Diagnostic Constraint/Requirement**
<u>Mission Requirement</u>	
Mobility	Test Equipment Size/Weight
Continuous Operation	BIT Interface Planned Maintenance Duty Cycle
Sustainability	Redundancy
Reconfigurability	Fault-Tolerant Design
<u>Standardization Imposed</u>	
Standard Test Equipment	Standard Diagnostic Connectors Controllability, Observability Interface to UUT
Standard Bus	Interface Design/Protocol
GFE	Bit Design/Capabilities

Design Characteristics

Power Availability	BIT Power Consumption
System Weight	BIT and Test Connector weight
System Size	Volume of BIT Circuitry and Test Connectors (Real estate available for BIT circuitry) Volume required for increased modularity
Memory Limitation	Memory allocatable to BIT functions
Operating System Char.	Software BIT function constraints
Cost	Cost of additional hardware required for BIT and testability

Establish Diagnostic Objectives

Analysis of weapon system data ascertained must be performed to identify diagnostic objectives based on system requirements. Diagnostic objectives to be considered include:

- o BIT FD/FI requirements to support preliminary maintenance concept
  - Repair Times
  - Reconfigurability
  - *Deferred Maintenance*
  - Fault Tolerance
- o BIT requirements to support system confidence checks
- o Requirement to deal with intermittent faults or operational anomalies
- o Prime system architecture testability opportunities
- o GFE testability factors/constraints
- o Requirements for vertical testability.

Examples of typical objectives to be established at this point are provided below.

DRIVING SYSTEM FACTOR	SAMPLE DIAGNOSTIC OBJECTIVE
Maximum Acceptable Failure Latency----⇒	Fault Detection Time
Mission/Safety Critical Function------⇒	Performance Monitoring
MTTR, Spares----------⇒	Fault-Isolation Level
Manpower and Skill Levels----------⇒	BIT Fault-Isolation Level
GFE Constraints----------⇒	System-Level BIT Requirements
Fault-Tolerant Design Coordination----⇒	Performance Monitoring
2 Level Maintenance----------⇒	Ambiguity Group Size/ATE Size & Weight
Life Cycle Cost Priorities----------⇒	Reliance on Embedded Diagnostics
Minimize RTOK Rate Between----------⇒ Maintenance Levels	Utilize Compatible Test Equipment, Techniques, Tolerances

Initial diagnostic requirements result from analysis of weapon system characteristics, prioritized as needed, on diagnostic elements. It is convenient to partition the diagnostic elements as embedded and external.

Some of the tradeoffs to be made for generating embedded and external diagnostic requirements include:

- Functions and level of built-in test vs. external diagnostics
- Functional vs. parametric testing
- Built-in test fault detection
  - Concurrent performance monitoring
  - Periodic BIT routines
  - Operator initiated BIT routines
- Level of diagnostic capability at each level of maintenance (e.g., detect 95% of faults; isolate to 3 LRUs; within 30 minutes)
- Diagnostic elements to be used at each level of maintenance (e.g., test equipment, technical information and maintenance aids, training and skill levels).

Once the level of built-in test is established, a maintenance workload generated by operational and failure rate data can be projected. At this point, detailed tradeoffs can be performed regarding the optimization of testability, including level of diagnostic capability at each level of maintenance, and the effectiveness and efficiency of the mix of diagnostic elements to be used at each level of maintenance. A baseline comparison system is used to project failure data. The requirements that need to be established are outlined below:

Embedded Diagnostic Requirements

- System Integrated Test (SIT) requirement for monitoring of mission-critical functions and functions affecting personnel safety (derived from maximum allowable failure latency)
- BIT/SIT requirements to support operational constraints
- Requirement to deal with/handle intermittents/anomalies
- BIT/SIT requirements to support system confidence checks
- Prime system architecture, testability opportunities, and GFE testability factors/constraints

- o BIT requirements to support preliminary maintenance concept, based on:

  - Level-of-repair analysis
  - Manpower available
  - Skill levels available/required
  - Deferred maintenance goals
  - Repair times (driving fault isolation time)
  - Sparing concepts (driving fault isolation levels)
  - Standardization requirements/goals (test equipment, personnel qualifications)

- o Requirement to provide handshake to external diagnostic resources (vertical testability, vertical diagnostics).

External Diagnostic Requirements (Support Equipment, Technical Data, and Personnel)

OPERATIONAL/ORGANIZATIONAL MAINTENANCE LEVEL:

- o Requirement for elements to optimize interface/utilization of embedded diagnostic elements

- o Define FD/FI functions to satisfy O-Level maintenance operations (driven by inputs from operational constraints and preliminary maintenance concept), based on:

  - Minimization of unnecessary removals
  - Mobility requirements/space available
  - Level-of-repair analysis
  - Sustainability
  - Manpower available
  - Skill levels available/required
  - Repair times
  - Sparing concepts
  - Standardization requirements/goals

- o O-Level technical information (including maintenance aids)

- o O-Level test equipment

  - Manual test equipment
  - Automatic test equipment and test programs
  - Portable maintenance aids

- o O-Level training requirements to support skills required

- On-the-job training
- Formal school training

o O-Level data acquisition/collection system (and data management)

o Requirements to provide O-Level handshake to I-Level diagnostic elements (vertical testability, vertical diagnostics)

INTERMEDIATE MAINTENANCE LEVEL:

o Define FD/FI functions to satisfy I-Level maintenance operations based on:

- Minimization of unnecessary removals
- Mobility requirements/space available
- Level-of-repair analysis
- Sustainability of spares pipeline
- Manpower available
- Skill levels available/required
- Repair times
- Sparing concepts
- Standardization requirements/goals

o I-Level technical information requirements (including maintenance aids)

o I-Level test equipment requirements

- Manual test equipment
- Automatic test equipment and test program sets

o I-Level training requirements to support skills required

- On-the-job training
- Formal school training

o I-Level data acquisition, collection, management, analysis, processing system requirements

o Requirement to provide I-Level handshake to Depot-Level diagnostic elements (vertical testability)

DEPOT MAINTENANCE LEVEL:

o Define FD/FI functions to satisfy Depot-Level maintenance operations, based on:

- Level-of-repair analysis
- Sustainability of spares pipeline
- Manpower availability
- Skill levels available/required
- Repair times
- Sparing concepts
- Standardization requirements/goals

o D-Level technical information requirements (including maintenance aids)

o D-Level test equipment requirements

- Manual test equipment
- Automatic test equipment and test program sets

o D-Level training requirements to support skills required

- On-the-job training
- Formal school training

o D-Level maintenance data acquisition, collection, analysis, processing

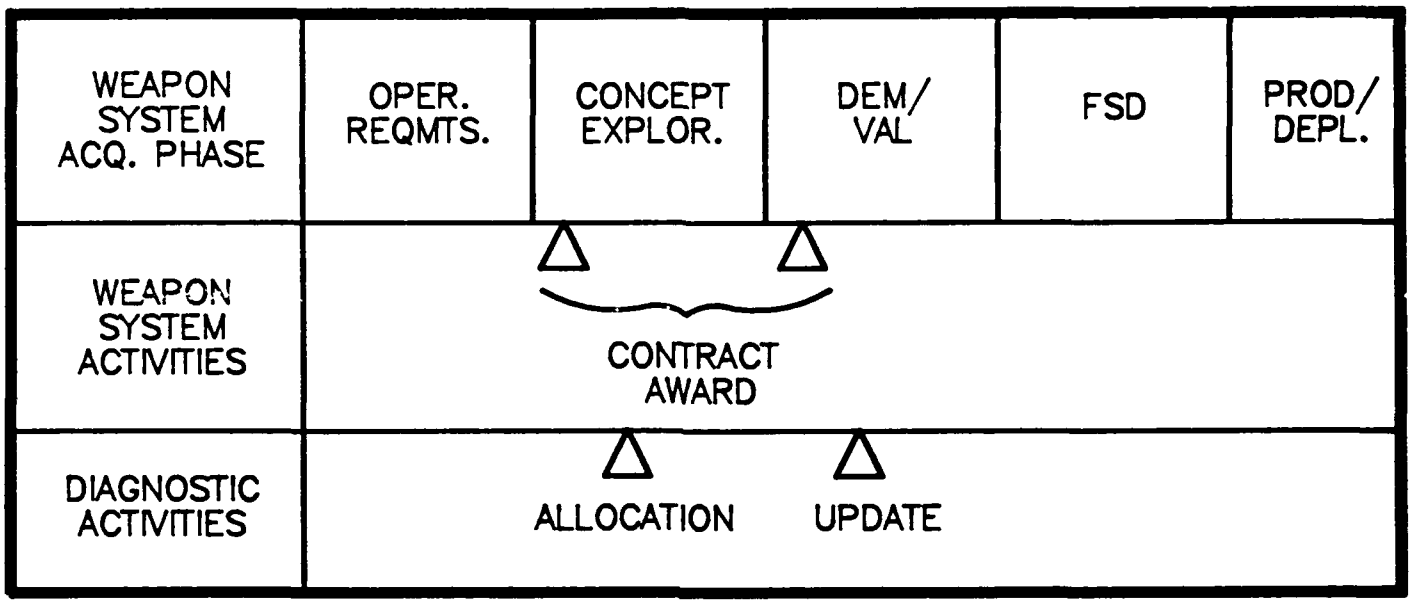
o Requirement to capture and utilize factory test resources and results and/or data for Depot use (vertical testability, vertical diagnostics).

Since the overall diagnostic capability must be defined, quantified, designed, evaluated, etc., it is best defined as a "diagnostic subsystem." This subsystem can be broken down into its component parts and defined in a type of format. This format will facilitate the hierarchical allocation and diagnostic mix optimization process because function and cost parameters can be quantitatively assigned to each element. Alternative diagnostic subsystems may then be easily synthesized and evaluated.

CHECKLIST

- ☑ Has the inherent diagnostic capability of the prime system architecture been included in the analysis?
- ☑ Have the requirements been generated for both embedded and external diagnostics?
- ☑ Have the mission and operational data been utilized in the diagnostic requirements generation?

ALLOCATION OF DIAGNOSTIC REQUIREMENTS	REQUIREMENT #2.2



DIAGNOSTIC ACTIVITY

Allocation of diagnostic requirements from the system level to the subsystem, and unit level is required in order to assign specification values to each configuration item which forms part of the weapon system. The allocation process, which is normally done by the contractor, shall assure that the weapon system diagnostic requirements and the constraints on the diagnostic subsystem are not violated during the "flow down" process.

PROCEDURE

Initial allocation of diagnostic requirements to lower system levels must be based upon the time demands placed upon the system configuration by the mission requirements.

After the initial set of diagnostic requirements has been defined, a diagnostic mix is postulated from the synthesized diagnostic subsystem alternatives in order to implement the initial set of diagnostic requirements.

Whereas the initial diagnostic requirements are driven by mission time demands, the optimization of the diagnostic element mix is driven by resource constraints. Simply stated, the requirements generation process indicates what is needed and the diagnostic mix generation process indicates the most affordable solutions. A risk analysis performed during the subsequent phases of system development confirm the solutions as feasible. It is, therefore, important to note that the allocation procedure is a partial step in the development of a diagnostic system. During the diagnostic element optimization and design process, it may be cost effective to reallocate the diagnostic requirements in order to achieve better implementations with respect to resource constraints. Many of these

tradeoffs are driven by both technology and the acquisition business decisions that are made for each weapon system program. For example, allocation of a testability strategy to each subsystem may not be feasible due to the existence of many government-furnished equipments within a particular weapon system. In those cases, a centralized system-level test approach may be more desirable. A shift in allocation from subsystem to system level will prove effective in the implementation of that particular weapon system diagnostics.

To achieve this flexibility, the allocation process must be tied to the system-level reliability and maintainablity models. This model will contain the allocated parameters with traceability back to system-level parameters. In this way, as the program proceeds from Concept through Dem/Val into Full- Scale Development, each of the values can be traded off as the diagnostic subsystem is configured and optimized as a result of knowledge gained from trade studies.

GUIDANCE

A preliminary diagnostic allocation should be prepared. The allocation should include all diagnostic elements and consideration of all maintenance levels. The allocation of diagnostic goals/values should be accomplished through the application of structured processes, based on task description and guidance provided within applicable military standards. The tasks and guidance paragraphs that define the allocation process to be employed are:

MIL-STD-499	Task 10.2.3	Allocation
MIL-STD-785	Task 202	Reliability Allocation
MIL-STD-470	Task 202	Maintainability Allocation
MIL-STD-2165	Task 201	Testability Requirements.

MIL-STD-499 addresses the entire allocation process for all performance and design requirements. Time requirements, which are prerequisites for a function, or set of functions, affecting mission success, safety, and availability are derived. It is essential that the diagnostic requirements be derived in conjunction with the entire weapon system allocation process. Reliability and maintainability allocations are derived as part of the overall weapon system allocations. Thus, they have a direct affect on the diagnostic allocations. Failure rates and repair rates are the drivers in establishing diagnostic allocations. However, other considerations dealing with safety monitoring, readiness monitoring, and logistic functions all play a part in this process. The allocation of diagnostic requirements is usually performed as part of the overall LSA process. Closely tied to the LSA process is the establishment of testability requirements, including performance monitoring, BIT, test equipment, diagnostic test points, etc.

It is important that this allocation process includes:

- o FD/FI coverage for all (100%) faults known or expected to occur at each maintenance level, and
- o Quantification of all diagnostic elements.

Figure 3 is a Notional Diagnostic Allocation Specification, which exemplifies these concepts. This allocation process is also closely tied to the optimization process (Requirement #2.3). It is important that this allocation process includes quantification of all diagnostic elements. For instance, the time to access technical information can determine whether paper or electronic delivery of technical information is required. Formal training time may influence the need for on-the-job training aids.

This system-level allocation forms the basis for the System Specification discussed under Requirement #1.2. It also is followed by allocation down to subsystem and item levels.

LEVEL OF MAINTE-NANCE[1]	DIAGNOSTIC CAPABILITY[1]	FAULT DETECTION COVERAGE[2]	FAULT ISOLATION COVERAGE[2]	MEAN TIME TO DIAGNOSE	TECH INFO ACCESS TIME	OTHER REQUIREMENTS[1]
ORGANI-ZATIONAL	STATUS MONITOR/BIT	_____%		_____		____% OF FAULT COVERAGE BY STATUS MONITOR FOR MISSION-CRITICAL FUNCTION
	BIT		_____%	_____	_____	
	MANUAL DIAGNOSIS	_____%	_____%	_____	_____	
	VISUAL	_____%	_____%	_____		BIT MEMORY ALLOCATION NOT TO EXCEED X WORDS
	TOTAL:	100 %	100 %			
INTER-MEDIATE	EXTERNAL ATE/ EXPERT SYSTEM	_____%	_____%	_____	_____	ATE LIMITED TO X LB. Y CUBIC FT.
	MANUAL TEST	_____%	_____%	_____	_____	
	TOTAL:	100 %	100 %			
DEPOT	EXTERNAL ATE	_____%	_____%	_____	_____	
	MANUAL TEST	_____%	_____%	_____	_____	
	TOTAL:	100 %	100 %			

1/ Listed by way of example.

2/ Unambiguous percentage of fault coverage for each capability shown. Total at each level of maintenance should add to 100% of the identified replaceable items for that level.

Figure 3. Notional Diagnostic Allocation Specification

Allocate Requirements to Item Development Specification

System-level diagnostic requirements are allocated down to subsystem and item levels for the purpose of the development of those items. Diagnostic requirements for Configuration Items (CI) support two distinct requirements: system test (primarily BIT) and shop test (ATE and GPETE).

Quantitative testability requirements for each Configuration Item are allocated from system diagnostic requirements based upon FMEA data, relative failure rates of CIs, mission criticality of the CIs, what is achievable for each CI or other specified criteria. The failure detection level of the CI is weighted by the items' failure rate to ensure that system-level fault detection capability is achieved. Table 3 is an example of an allocation of a system- level BIT fault detection requirement which is allocated to five configuration items. The table shows three alternative FD allocations which meet the system- level BIT FD requirement of 95%.

TABLE 3. SAMPLE ALLOCATION OF 95% BIT FD REQUIREMENT

CONFIGURATION ITEM	λ X 10^{-3}	FD ALLOCATION #1	FD ALLOCATION #2	FD ALLOCATION #3
A	100	.95	.98	.95
B	10	.95	.80	1.00
C	50	.95	.70	.98
D	200	.95	.99	.90
E	100	.95	.98	.99
SYSTEM	460	.95	.95	.95

The BIT performance capability and testability characteristics of GFE portions of the system should be considered in the allocation. For example, assume a GFE item has only 70% BIT fault-detection capability. In order to accomplish the 95% system-level capability required in the above example, the allocation distribution must take into account the capability of each of the items which make up, or contribute to, the system level. The capability of the GFE then serves as a constraint in the allocation. In the above example, given that Item C is GFE with 70% BIT fault-detection capability, the FD allocation scheme #2 is a real world alternative and the others, #1 and #3 are not.

Shop test requirements are determined by how the CI is further partitioned, if at all, into Units Under Test (UUT). Diagnostic requirements for each UUT should be

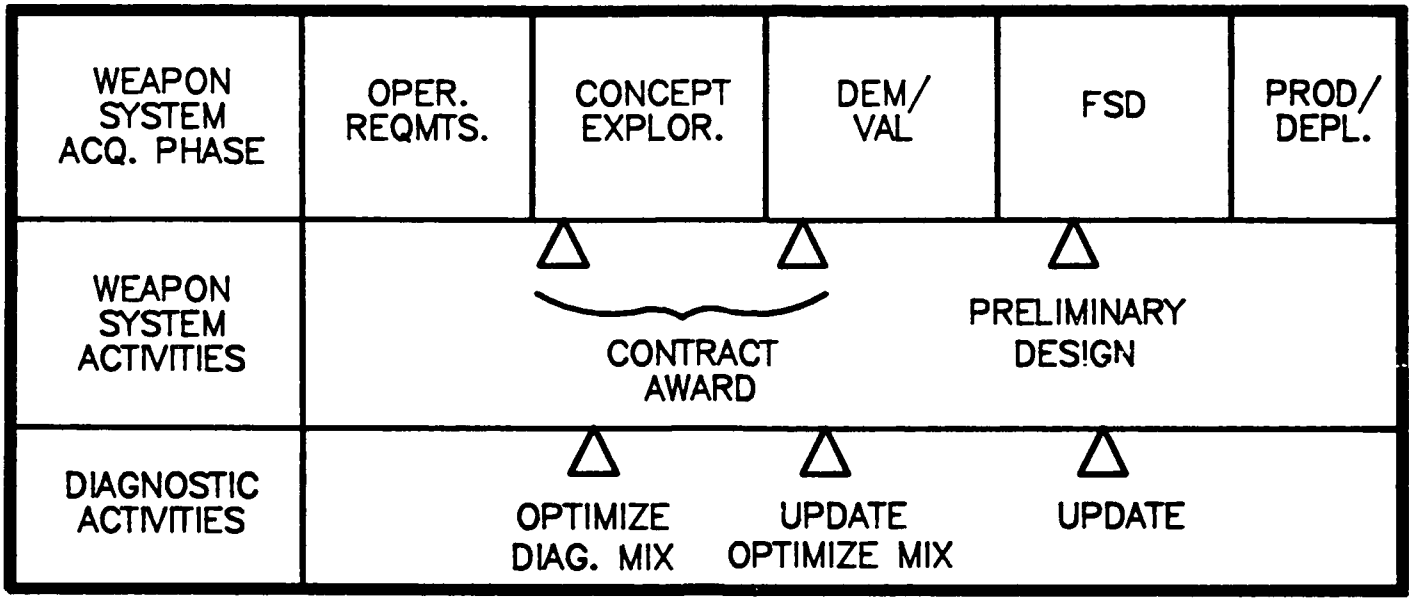
included in the appropriate CI Development Specification. These parameters are not allocated from the system-level requirements, but rather are driven by the diagnostic concept of off-line test requirements of the Configuration Items.

In many digital systems, built-in test is implemented in whole or in part through software. Here, diagnostic requirements will appear in a Computer Program Configuration Item (CPCI) development specification. The CPCI may be dedicated to the built-in test function (i.e., a maintenance program) or may be a mission program which contains test functions.

CHECKLIST

- ☑ Were the system reliability and maintainability models used in the diagnostic allocation process?
- ☑ Are the allocated values traceable to Weapon System Requirements?
- ☑ Were constraints allocated to all diagnostic elements?
- ☑ Were constraints assigned to all maintenance echelons?

OPTIMIZATION OF THE DIAGNOSTIC ELEMENT MIX	REQUIREMENT #2.3



DIAGNOSTIC ACTIVITY

Given the allocation of diagnostic requirements to the subsystem and unit level, the "diagnostic subsystem" must be defined by the contractor as part of the overall weapon system specification. The resulting diagnostic subsystem includes both embedded and external support. External support must be defined at all levels of maintenance and includes technical information, support equipment, and personnel numbers and skill levels.

PROCEDURE

The starting point for developing the diagnostic subsystem is the generation of a diagnostic subsystem profile from the weapon system characteristics and priorities. Each of the diagnostic elements will have a differing impact on the weapon system characteristics. For example, a high priority constraint on logistic support would favor a high degree of embedded diagnostics. On the other hand, constraints on personnel may favor technical information systems with a high degree of artificial intelligence. Operational constraints, which are common across the military services, are:

- Environmental conditions (temperature, rain, dirt, salt spray, etc.)
- Operating locations (dispersed vs. centralized) (remote/accessible/inaccessible)
- Space limitations (for personnel and/or test equipment)

- o Mobile or fixed maintenance facilities
- o Independent operation or part of a battle group
- o Manpower constraints (number and skill levels).

Analysis of the weapon system characteristics in terms of their impact on the support elements will generate various support element diagnostic profiles.

The diagnostic profiles will portray various mixes of diagnostic elements for different weapon system characteristics and constraints. Each of the diagnostic element profiles infers a diagnostic subsystem which can be built and delivered with the weapon system. The optimization issue is the selection of a diagnostic subsystem which can be implemented at low risk and which meets the requirements allocated to system, subsystem, and unit level.

The key to optimization, therefore, is the development or synthesis of various alternative diagnostic subsystems based upon the weighted diagnostic element profiles. This is an engineering task and represents an important aspect in the overall development of a diagnostic capability for the weapon system. By generation of a diagnostic subsystem, early in Concept Exploration, the overall design integration of support and prime design elements will be achieved. During the Dem/Val and Full-Scale Development Phases, the diagnostic subsystem is refined based upon trade studies.

The key is to identify the sensitivity of the various diagnostic element function contributions to the overall life cycle costs, and to ensure that all diagnostic functional requirements are considered and included as part of the total diagnostic subsystem synthesis.

Each diagnostic subsystem alternative synthesized is evaluated with respect to:

- o Impact on Mission Performance Over Time
- o Impact on Resource Requirements
  - Acquisition Cost
  - Life Cycle Cost
  - Manpower Requirements
- o Responsiveness to operational constraints.

The evaluation is performed by assigning values related to the evaluation factors listed above to the diagnostic subsystem or to the elements of the diagnostic subsystem.

To evaluate the mission responsiveness of the diagnostic subsystem, time demands on the specific weapon system configuration must be characterized. performance (interval reliability) for each mission duration is calculated.

To evaluate the responsiveness of the diagnostic subsystem to operational constraints, the operational constraints must be assigned qualitative or quantitative values. The impact of the diagnostic subsystem characteristics on those values (time demands) must then be determined. This analysis includes availability parameters as well as mission reliability calculations based upon the stated time demands and subsystem utilization. The system reliability model is a very effective and available tool for this analysis.

To evaluate the impact of the diagnostic subsystem on resources, cost factors must be assigned to each element of the diagnostic subsystem. Non-recurring (development) and recurring (production and support) costs must be considered. The manpower requirements associated with the alternative diagnostic subsystems must be evaluated. Existing LCC models should be used in this analysis. Data items should be standardized wherever possible.

The cost deltas associated with each alternative must be evaluated with respect to the off-line maintenance workload costs and efficiencies generated by the alternative embedded diagnostic subsystems. A key diagnostic element workload driver is ambiguity group size and RTOK rates.

Based upon the evaluations performed, the optimum diagnostic subsystem alternative is selected and the weapon system diagnostic concept is established and documented. The diagnostic concept includes prime system architecture considerations, BIT requirements at the system and subsystem levels, test equipment, technical information and personnel and training requirements for each level of maintenance. The diagnostic function of each element must be clearly and quantitatively defined as a diagnostic requirement.

Utilizing the above procedure, the result of the optimization process is the development of a diagnostic subsystem early in Concept Exploration. This parallels the development effort for radar subsystems, fire control subsystems, etc. The diagnostic subsystem becomes a weapon system attribute early in Concept Exploration and continues to evolve during subsequent program phases.

GUIDANCE

As of the publication date of this document, there is no formal guidance available for the synthesis and optimization of a diagnostic subsystem. Methodology for performing diagnostic optimization will be a product of the RADC Automated Testability Decision Tools Program which will be completed and published in mid-1990. A generic hierarchical view of a diagnostic subsystem which includes engineering and program

management disciplines as well as embedded and external support elements is included below to serve as guidance for the contractors. This indentured diagnostic subsystem breakdown will allow costing by the contractor for various alternatives proposed to satisfy the diagnostic requirements which have been allocated at all system levels. As experience data is accumulated on diagnostic subsystem effectiveness and cost, it will be possible to predict many of these values early in Concept Exploration using the diagnostic profile.

DIAGNOSTIC SUBSYSTEM HIERARCHY

I. PROGRAM MANAGEMENT/ENGINEERING

A. Requirements Analysis
B. Diagnostic Design & Analysis/Assessment
C. System Integration & Test
D. Maturation Program

II. EMBEDDED DIAGNOSTIC ELEMENTS

A. System-Level Diagnostic Elements
    1. System-Level Diagnostic Hardware
        a. Test and Maintenance Bus
        b. Sensors/Monitors
        c. Diagnostic Panel/Display
        d. Embedded ATE

    2. System-Level Diagnostic Software
        a. Status Monitoring
        b. Self Test/Expert Systems
        c. Prognostics
        d. Reconfigurability

    3. Diagnostics Data Collection System

B. Subsystem Diagnostics

    1. Subsystem "A" BIT
        a. BIT Hardware
            1. On Chip
            2. On Printed Circuit Board
        b. BIT Software & Firmware
        c. Interface to T&M Bus

    2. Subsystem "B" BIT (Radar) etc.

III. EXTERNAL DIAGNOSTIC ELEMENTS

A. O-Level Diagnostics

1. Technical Information
    a. Maintenance Aids
    b. Paper-Based Manuals
    c. Diagnostic Data Base

2. Test Equipment
    a. Manual Test Equipment
    b. Automatic Test Equipment
        1. ATE Hardware
        2. Diagnostic Software
            a. Expert Systems
            b. Test Program Sets (TPS)
        3. ATE/ILS

3. Trained Personnel
    a. Manpower
    b. Skills
        1. Formal Training
        2. On-The-Job Training

4. Diagnostic Data Collection/Analysis System

B. I-Level Diagnostics

1. Technical Information
    a. Maintenance Aids
    b. Paper-Based Manuals
    c. Diagnostic Data Base

2. Test Equipment
    a. Manual Test Equipment
    b. Automatic Test Equipment
        1. ATE Hardware
        2. TPS
        3. ATE/ILS

3. Trained Personnel
    a. Manpower
    b. Skills
        1. Formal Training
        2. On-The-Job Training

4. Diagnostic Data Collection/Analysis System

C. D-Level Diagnostics

1. Technical Information
    a. Maintenance Aids
    b. Paper-Based Manuals
    c. Diagnostic Data Base

2. Test Equipment
    a. Manual Test Equipment
    b. Automatic Test Equipment
        1. ATE Hardware
        2. TPS
        3. ATE/ILS

3. Trained Personnel
    a. Manpower
    b. Skills
        1. Formal Training
        2. On-The-Job Training

4. Diagnostic Data Collection/Analysis System

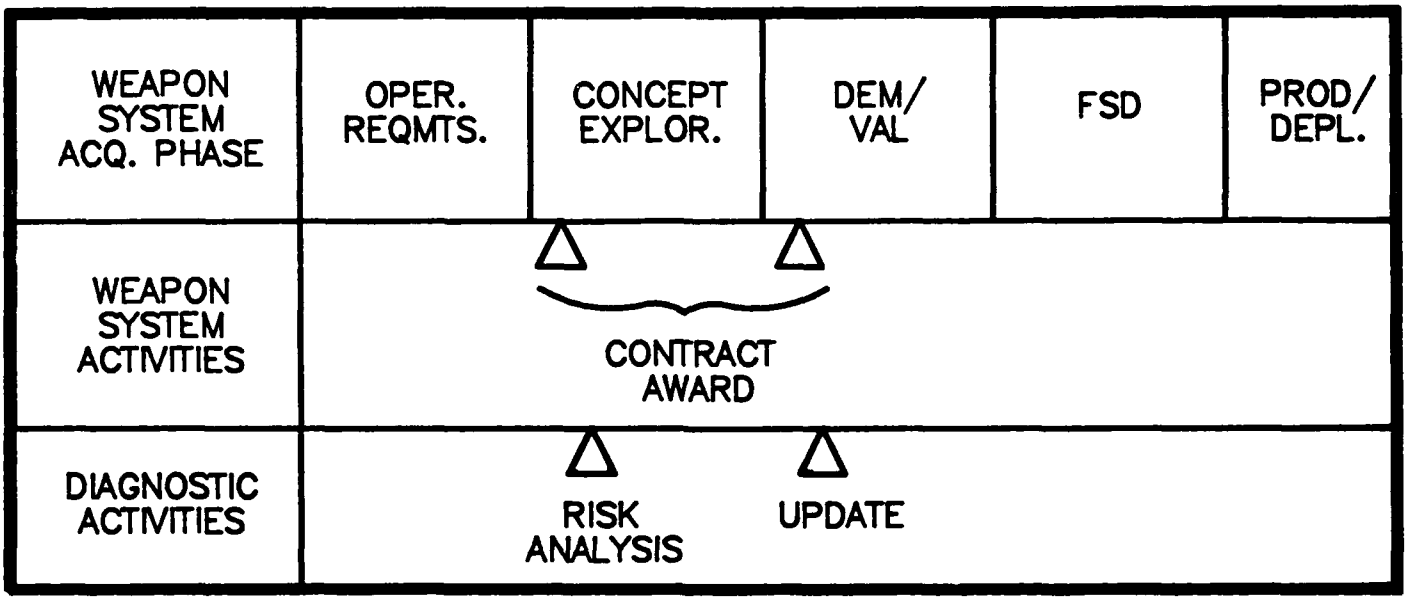
OPTIMIZATION OF THE
DIAGNOSTIC ELEMENT MIX

REQUIREMENT #2.3

CHECKLIST

- ☑ Have alternative "diagnostic subsystems" been generated for optimization purposes?
- ☑ Does the "diagnostic subsystem" include all maintenance levels as well as program management and engineering?
- ☑ Was a life cycle cost model used that was sensitive to diagnostic parameters?

RISK ASSESSMENT	REQUIREMENT #2.4



DIAGNOSTIC ACTIVITY

The initial diagnostic subsystem, generated to implement the allocated diagnostic requirements, must go through a thorough risk analysis during the Dem/Val Phase. During subsequent Full-Scale Development, the diagnostic subsystem is optimized utilizing results of trade studies. The initial diagnostic element mix postulated during Concept Exploration is analyzed by the contractor for risk during that phase by technology assessments. However, risk assessment can take into account threat, technology, resources, schedule, and cost.

PROCEDURE

The procedure for performing risk analysis on the diagnostic subsystem will follow the same type of assessments conducted for risk analysis for other weapon system elements. For example, the risk assessment for a radar during Dem/Val will include prototyping of its new development components, assessment of schedule, cost risks, and assessment of the overall technologies involved in the development and integration of a total system to meet the performance requirements. Since the diagnostic subsystem will be treated as a major element of a weapon system, the same procedures should apply for it. Heretofore, diagnostic subsystems were not treated as an entity and risk analysis was limited only to the physical diagnostic hardware, such as automatic test equipment and built-in test.

Risk assessment shall include the isolation within the diagnostic subsystem of all development and non-development items. For development items, weighting factors in

terms of criticality of that item shall be assigned and the items shall be categorized with respect to risk. For items considered high development risk, workarounds shall be developed and trigger points for decisions on their implementation shall be listed. The risk analysis documentation shall be utilized to impact the Statement of Work for the Dem/Val Phase. During Dem/Val high-risk items shall be prototyped and demonstrated to the satisfaction of the Government Program Manager.

GUIDANCE

The Defense Systems Management College has generated guidance on risk management, which includes risk assessment, risk analysis, risk handling techniques, and risk control. This guidance covers risk management for the entire weapon system, but is equally relevant to the weapon system's diagnostic capability. Both risk assessment and risk analysis need to be addressed early in the development of the weapon system. Risk assessment is the process of examining a situation and identifying areas of potential risk. Risk analysis is examining the change of consequences with the modification of risk input variables. At the time this Contractor Program Managers Guide was issued, the Defense Systems Management College is publishing a risk management guide, which further defines the methodology for doing risk assessment and analysis.

MIL-STD-1388-1 (Logistics Support Analysis) contains in Tasks 203, 205, and 303 guidance on comparative analysis, supportability related design factors, and evaluation of alternatives for trade-off analysis, all of which are directly related to the weapon system's diagnostic capability.

Lessons learned have pointed to some overriding areas of risk which must be considered during the initial risk assessment and analysis. These high-risk areas are listed in the following paragraphs:

1. The logistic support analysis process will usually generate requirements for each of the logistic elements comprising the overall logistic system. These requirements are based upon inputs regarding the level of embedded support to be designed into the weapon system. The Logistic Element Manager, given these inputs, proceeds to develop sparing requirements, support equipment requirements, training requirements, etc. A large program risk area occurs when the promised embedded support area does not materialize. It is imperative, therefore, to close the loop between assessment during Dem/Val of the diagnostic element capability and that impact on all logistic elements.

2. A second major risk area occurs when a prime weapon system, which has been developed for a specific maintenance strategy and concept, is utilized in a completely different mission environment. For example, a major weapon system deployed in a three-level maintenance environment may be required to operate for extended periods of time in a dispersed operating location with less than full support. The sustainability and mobility requirements imposed upon that weapon system may not have been included with sufficient priority in the initial analysis to develop capability for that operational

environment. It is, therefore, imperative that as part of the risk analysis, the assessment of weapon system characteristics and the application of weapon system priorities be reviewed prior to commitment of system development resources.

3. A third high risk area worthy of special consideration is the analysis of the very large scale integrated circuits and very high speed integrated circuits (VLSI/VHSIC). Despite the intensive use of on-chip testing for these devices, it is imperative that a standard systems approach be generated by the contractor. Testability techniques including signature analysis and boundary scan designs must be evaluated at the system and subsystem level prior to commitment of development resources. Standardization by the contractor of the embedded support architecture will eliminate many high-risk problems caused by multiple vendors supplying different types of on-chip testing.

4. A fourth high risk area occurs when weapon system managers fail to comprehend and implement the existing fielded maintenance standards that are used to support the deployed system. For example, the military has for many years been formalizing the use of IEEE-STD 716 C/ATLAS language for Depot maintenance. The CASS, IFTE and MATE programs have institutionalized this approach. Despite this level of standardization, many programs completely ignore this fact during the Dem/Val and FSD Phases of a program. Since the targeted Depot ATE has been standardized, it is possible to develop test programs starting with Factory-level testing through integration and test of the products that are compatible and easily translatable to the fielded environment. This concept, called vertical commonality, will mature the test programs so that during deployment the logistic system will have a major capability and remove many of the risks associated with transition from interim contractor support to full government support. Utilizing expert system knowledge during these same phases will allow the test program to contain levels of artificial intelligence to extract and utilize experience data on prior failures during the Deployment Phase.

5. The fifth high risk area is the incorporation of government furnished equipment (GFE) in weapon systems. Care must be taken to ensure that the diagnostic requirements and capability are known and verified. The Government Program Manager must be informed if the required weapon system diagnostic capability is compromised by deficiencies in the GFE.

6. The sixth and final large risk area is the integration and test of the weapon system prior to delivery. Since weapon systems have become extremely software dependent and since many weapon systems are multi-mission in nature utilizing shared resources, it is imperative that the integration and test function in a program be utilized to remove as much risk as possible from the weapon system. Integration of the diagnostic elements into the weapon system will provide a major "handle" for the contractor in terms of enhancing the integration and test functions. If no attention is paid early in the game to this high potential risk, the integration and test functions will be extremely time consuming, may not come together on schedule, and may cause program hardships. If properly achieved, integration and test can be streamlined to recover much of the upfront monies

spent on enhanced testability features. It is therefore imperative that this area be given serious attention by risk assessment studies early in Concept Exploration and again in Dem/Val and Full- Scale Development.

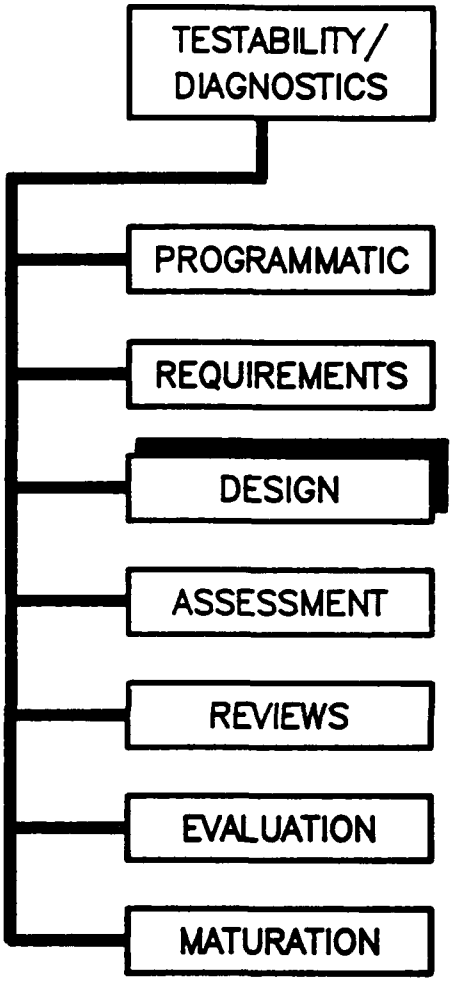
CHECKLIST

- ☑ Was risk analysis performed for the entire "diagnostic subsystem"?
- ☑ During DEM/VAL were testing/prototyping efforts undertaken to determine feasibility of achieving diagnostic performance requirements?
- ☑ Were adjustments planned for in those cases where one of the diagnostic elements fails to meet expectations?
- ☑ Were the weapon system priorities taken seriously?
- ☑ Have the integration and test risks been defined?

DESIGNING THE DIAGNOSTIC CAPABILITY

OVERVIEW

The design of the diagnostic capability is fractionated among a number of system engineering and supportability functions. Reliability, maintainability, integrated logistic support, testability, human engineering, and safety considerations all play significant roles in determining the requirements of the diagnostic capability and the design of this capability. The design process is further fractionated by the relegation of this capability to the various levels of maintenance. The diagnostic design process is controlled by a large number of military standards which deal with the design process and criteria. All of these "pieces" of the design process must not only work together, but the diagnostic data produced must be available at specific times. A break in one of the links can compromise the design. A cohesive, integrated design process is required. It is the Program Manager's job to assure that this integration is realized and the designer's job to produce this effective diagnostic capability in an efficient manner.

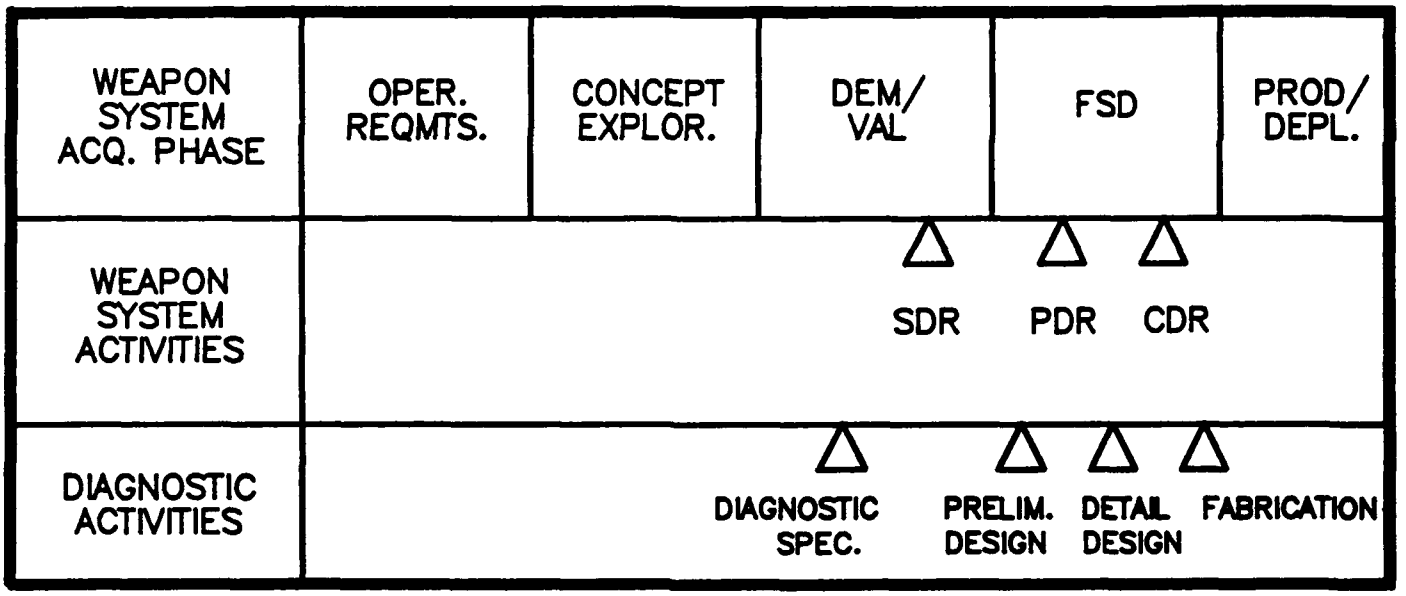


IMPORTANT CONSIDERATIONS TO BE ADDRESSED

Reqmt.

3.1 Assure cohesiveness and efficiency in the design of the diagnostic capability.

3.2 Establish diagnostic design criteria which can be effectively utilized.



DIAGNOSTIC ACTIVITY

The Contractor Program Management function is to ensure that an effective and efficient diagnostic design process is instituted and implemented.

PROCEDURE

The cohesiveness of the diagnostic design process is dependent upon the cohesiveness of the design information flow. Many factors impact the effectiveness and efficiency of this information flow. The first is timing - What is done and in what sequence is it done? The second factor relates to the various disciplines involved in the design of the diagnostic capability. These disciplines are controlled by a sizeable number of military standards, which relate to reliability, maintainability, testability, safety, human engineering, software, and training. These standards tend to fractionalize the design of the diagnostic capability, inasmuch as each plays a significant role in the process. The third factor deals with the automation of the design process. Computer-aided tools can promote the cohesiveness and the efficiency of the process. Thus, the Contractor Program Manager must understand the interfaces among these various engineering and logistic functions to assure that the necessary cohesiveness is achieved. In addition, the automation of the diagnostic design process should be supported and encouraged to provide a more efficient process and a more effective diagnostic capability.

GUIDANCE

The guidance provided in this section is designed to permit maximum visibility into the diagnostic design process. The Contractor Program Manager must understand the design process flow, timing, and data requirements which must be satisfied. In addition, it is important to recognize that current data item procurement practices may not always be supportive of the design activity in-process data needs. Very often, the CDRL and associated DID do not adequately reflect these in-process needs. The high data item generation/revision costs generally experienced are strong motivators for delaying data item preparation to a point where the design has stabilized. Such motivation is in direct conflict with the utilization of the data to make design decisions. A complete, detailed data submittal indicating that the design is flawed is of little use after the design has been completed. The guidance that follows has been designed to provide the necessary insight into the design process, which will assist the Program Manager in the progress assessment and decision-making process.

Design Environment

The diagnostic design environment is an essential component of the overall diagnostic design activity, which has been established by the contractor in response to the RFP requirements. This environment encompasses both the implementation methodology and the specialty coordination associated with the diagnostic design process. Evidence of these should be apparent in the interim products of the design effort, which are made available to the government program management function (at both informal in-process reviews and formal system-level design reviews).

Diagnostic design is characterized by its iterative nature and a high degree of interdependence with the supportability engineering specialties (i. e., reliability, maintainability, integrated logistic support, testability, human engineering, and safety). The allocation of diagnostic resources must be based on inputs from these disciplines. Therefore, the timing and quality of data interchanges must be in accordance with the program plans. A breakdown in data availability and exchange can be responsible for program delays and shortfalls in the fielded diagnostic capability.

The data flow required to develop the composite diagnostic capability must be responsive to the diagnostic mix established for the specific system under consideration. Embedded diagnostic features, such as built-in test (BIT), built-in test equipment (BITE), system integrated test (SIT), performance monitoring, status monitoring, embedded training, embedded maintenance aiding, adaptive AI-based diagnostic systems, etc., are an integral part of the prime equipment design. Therefore, the diagnostic data flow associated with these features must be incremental and continue until the detail prime system Configuration Item designs are complete. For the external diagnostic elements, such as automatic test equipment and the associated test program sets, manual test equipment, portable maintenance aids, technical information (hard copy or electronic delivery), training, etc., the diagnostic data flows into the LSA process up to the point

where the firm requirements for these diagnostic elements can be established. Once firm requirements exist, the diagnostic design environment must facilitate a smooth transfer of data, which is sufficient in terms of detail and format to permit fabrication of the required external diagnostic capability.

Program management must develop an understanding for the complexity of the data flow requirements associated with the program under consideration. Given the required understanding, maintaining cognizance over the content and timeliness of data availability cannot be overemphasized.

Table 4 is a listing of the major military standards which influence the design of the diagnostic capability. Some of these military standards are programmatic in nature, in that they establish a specific program and described the tasks which can be undertaken. The remainder of the standards are process or product-oriented. As can be seen, these various standards influence various aspects in the design of the diagnostic capability, starting from establishing diagnostic requirements, through the design and assessment of the diagnostic capability. There is a sequence of tasks and procedures cited in these standards which can be applied to the diagnostic capability. The interfaces and relationships between these various activities are complex and cannot be easily diagrammed to promote understanding. Establishing diagnostic requirements is described in Requirement #2, and the assessment is described under Requirement #4. Thus the following guidance will address the design of the embedded and external diagnostic capability.

TABLE 4. MILITARY STANDARDS APPLICABLE TO THE DESIGN OF THE DIAGNOSTIC CAPABILITY

		REQUIREMENT				DESIGN							ASSESS	
		ESTABLISH	ALLOCATE	OPTIMIZE	RISK ASSESS.	FAULT TOLERANT	INHERENT TSTAB	BIT/SIT	ATE/TPS	MANUAL TEST EQ	TECH. INFO.	PERS. & TRNG.	ANALYSIS	DEMONSTRATION
PROGRAMMATIC	MIL-STD-1388-1 Logistic Support Analysis	X	X	X	X								X	X
	MIL-STD-785 Reliability	X	X	X	X	X		X						
	MIL-STD-470 Maintainability	X	X	X	X			X	X	X	X	X	X	X
	MIL-STD-2165 Testability	X	X	X	X	X	X	X	X	X			X	X
	MIL-STD-882 Safety	X				X		X						
	MIL-STD-2167 Software Development	X	X	X	X	X		X	X				X	X
	MIL-H-46855 Human Engineering	X	X	X							X	X		
PRODUCT/PROCESS	MIL-STD-1591 Analysis		X	X										
	MIL-STD-415 Test Provisions						X	X	X					
	MIL-STD-1519 Preparation of -1345 Test Rqt. Doc.								X	X				
	MIL-STD-1629 Procedures for FMECA					X		X						
	MIL-STD-2077 Requirements for TPS								X					
	MIL-STD-471 Maintainability Demonstration													X
	MIL-STD-756 Reliability Modeling & Pred.		X											
	MIL-STD-1379 Contract Training Prog.											X		X

Design Integration

Figure 4 is a simplified diagram of the information flow in the design of the diagnostic capability. The design process begins with a maintenance concept and design data, such as specifications, block diagrams and schematics. Establishing the system's architecture is the next step. System's architecture has a major impact on the design of the fielded diagnostic capability. The concept of fault tolerance supports the maintenance concept by promoting graceful degradation of the system's performance, thereby allowing the maintenance to be performed at the user's convenience rather than dictated by when faults occur. Design for testability concepts play an important part at this time. Partitioning especially is closely tied to fault tolerance, because the performance monitoring capability must be able to detect failed items in order that the capability of the system is known, that necessary switching to alternate means is facilitated, and that maintenance actions can be identified.

The Failure Modes and Effects Criticality Analysis (FMECA) utilizes the system's architecture and design data to determine the modes, causes and effects of item failures. This data drives the maintenance and safety requirements which in turn help to establish the diagnostic logic, test point selection, and test requirements. From this information, the diagnostic capability is designed and fabricated, including the testing, (built-in and external), technical information, training, and personnel capability. Obviously this entire process is iterative in nature - a factor not indicated in Figure 4.

The concept of vertical testability was introduced years ago. In essence, this concept addressed the compatibility of testing among all levels of maintenance, including factory testing. The core of this concept is twofold. The first is the establishment of a Cone of Tolerance among these levels, and the second deals with the compatibility of environments under which these tests are performed.

The Cone of Tolerance concept is depicted in Figure 5, in which the testing tolerances are widened as the unit is tested closer to its operational environment.

PROVIDING A COHESIVE DIAGNOSTIC DESIGN PROCESS REQUIREMENT #3.1

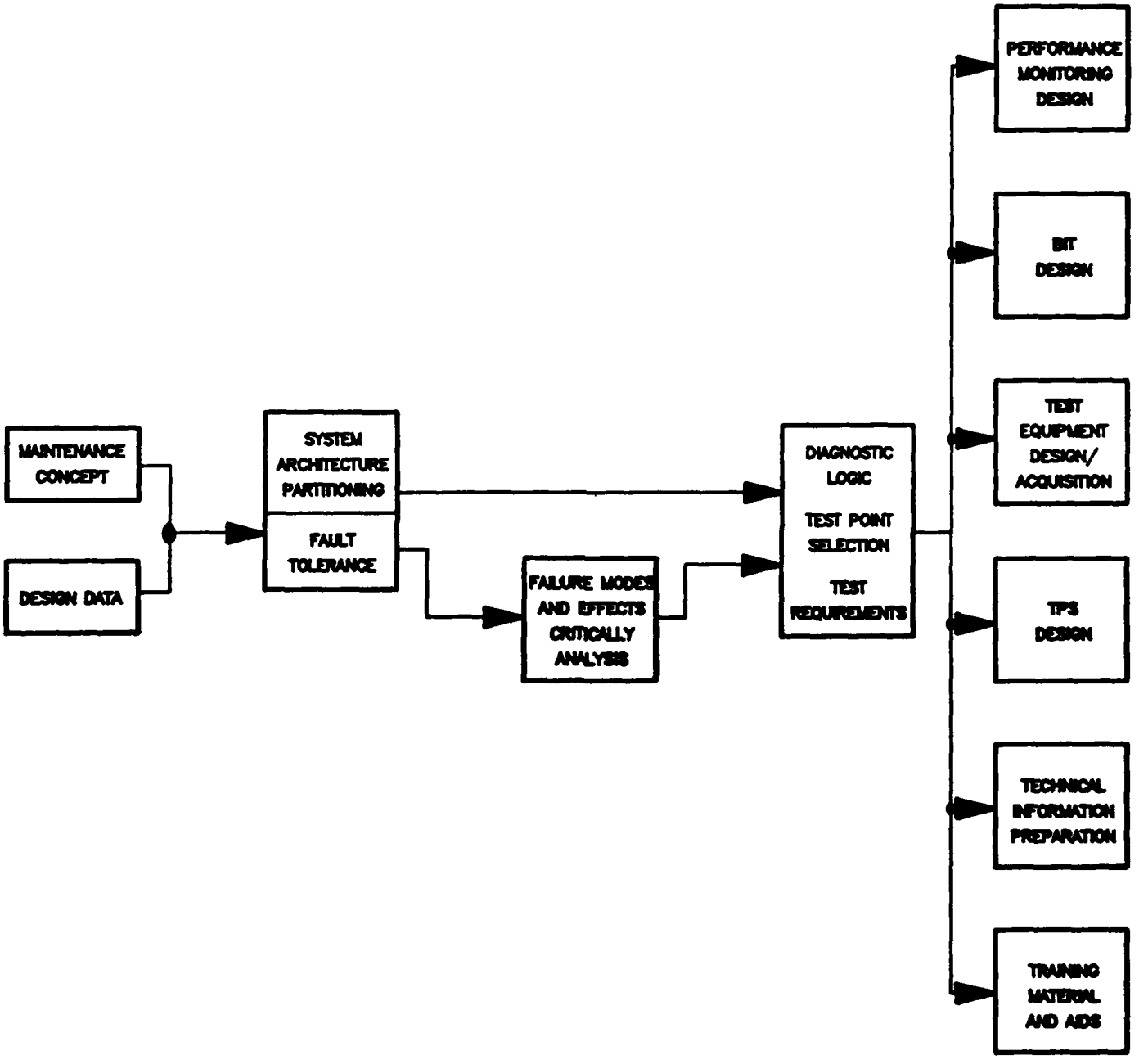


FIGURE 4. INFORMATION FLOW IN THE DESIGN OF THE DIAGNOSTIC CAPABILITY

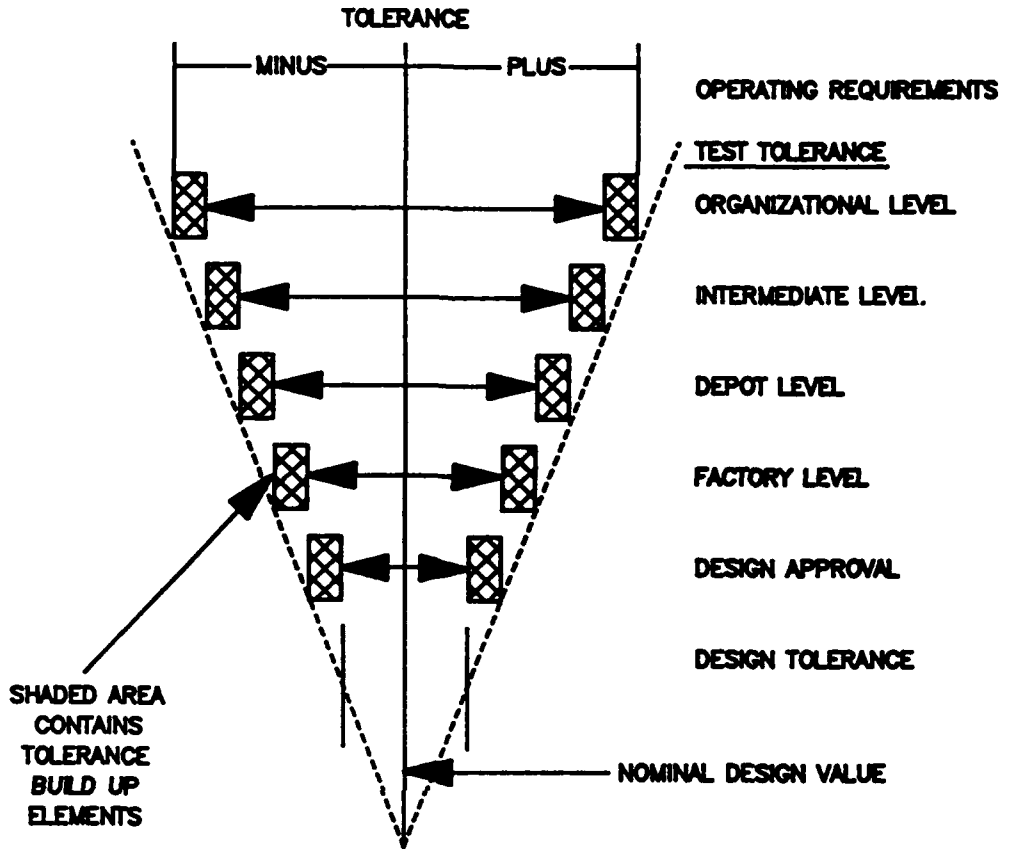


FIGURE 5. CONE OF TOLERANCE

The compatibility of testing environments can be implemented best through the use of common test equipment at Intermediate, Depot, and Factory Levels.

Extension of this vertical testability concept is recommended for the entire fielded diagnostic capability. Figure 6 depicts this concept, in which vertical testing is shown on the left and is joined by technical information and personnel and training compatibility requirements. Not only is this compatibility required vertically, but also horizontally. All elements that make up the diagnostic capability must be compatible at each maintenance level.

This concept of vertical and horizontal compatibility is key to the integration of diagnostic capability. The entire process is driven by the diagnostic logic which effects the requirements for all of the diagnostic elements. This diagnostic logic can be established

by a variety of means including the use of maintenance dependency charts, fault trees, etc. To implement this concept, a series of matrices similar in format to Figure 6 can be prepared at various system hierarchy levels (e.g., system, subsystem, LRU, SRU). These matrices should be tailored to the unique requirements of a specific weapon system and may be used in conjunction with other required data deliverables (e.g., test requirements document).

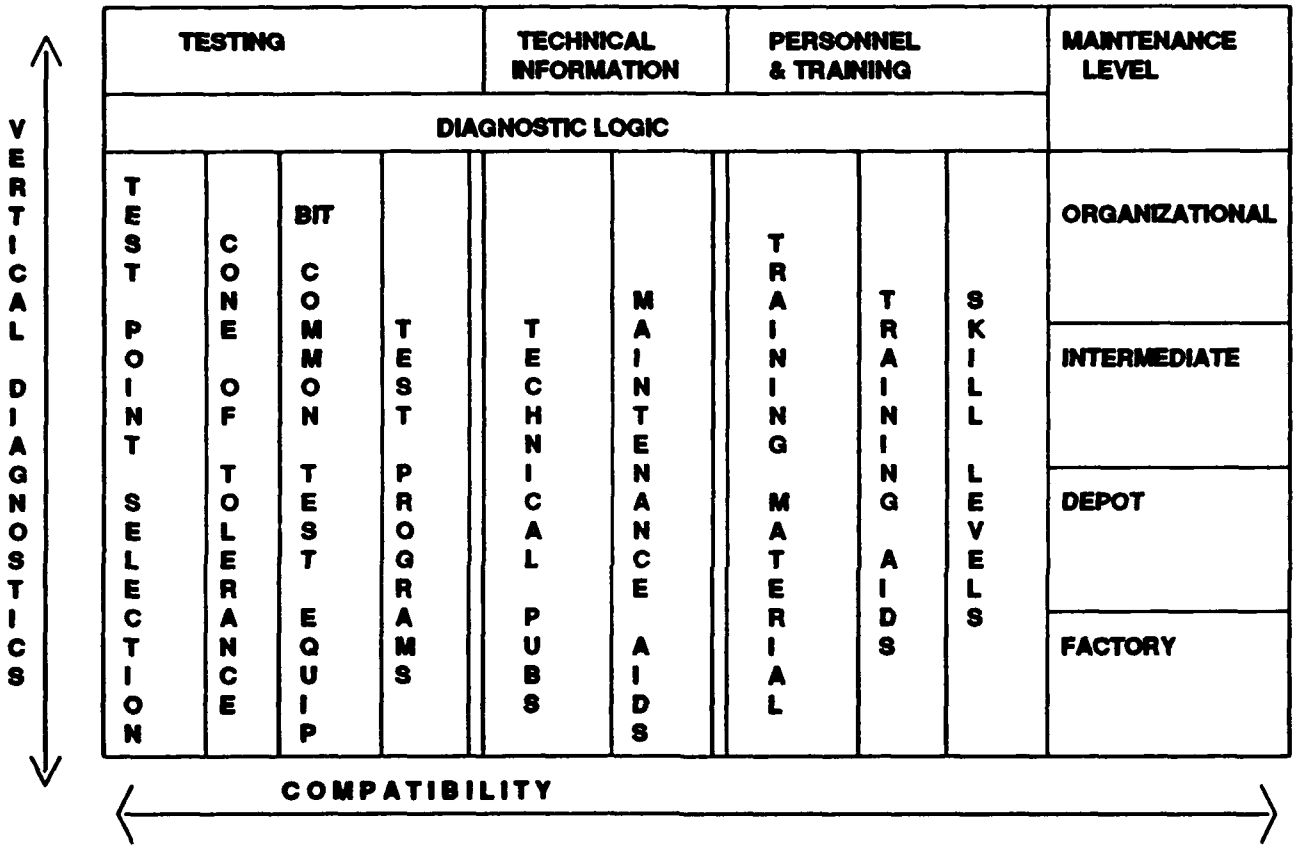


FIGURE 6. Design Integration of Diagnostic Capability

AUTOMATION OF THE DIAGNOSTIC DESIGN PROCESS

Automation of the diagnostic design process is encouraged to provide a more efficient and effective design process. The diagnostic design process should be an integral part of prime system computer-aided engineering and design.

The added efficiency and effectiveness in the use of automation is reflected in a number of ways. The effect of changes in either the diagnostic design or the prime system design can be readily ascertained as the design progresses. This iterative process then can give the Contractor Program Manager, as well as the designer, information on whether or not the diagnostic specification requirements will be met. In addition, automation permits the concurrent development and evaluation of the entire diagnostic capability along with the remainder of the prime system.

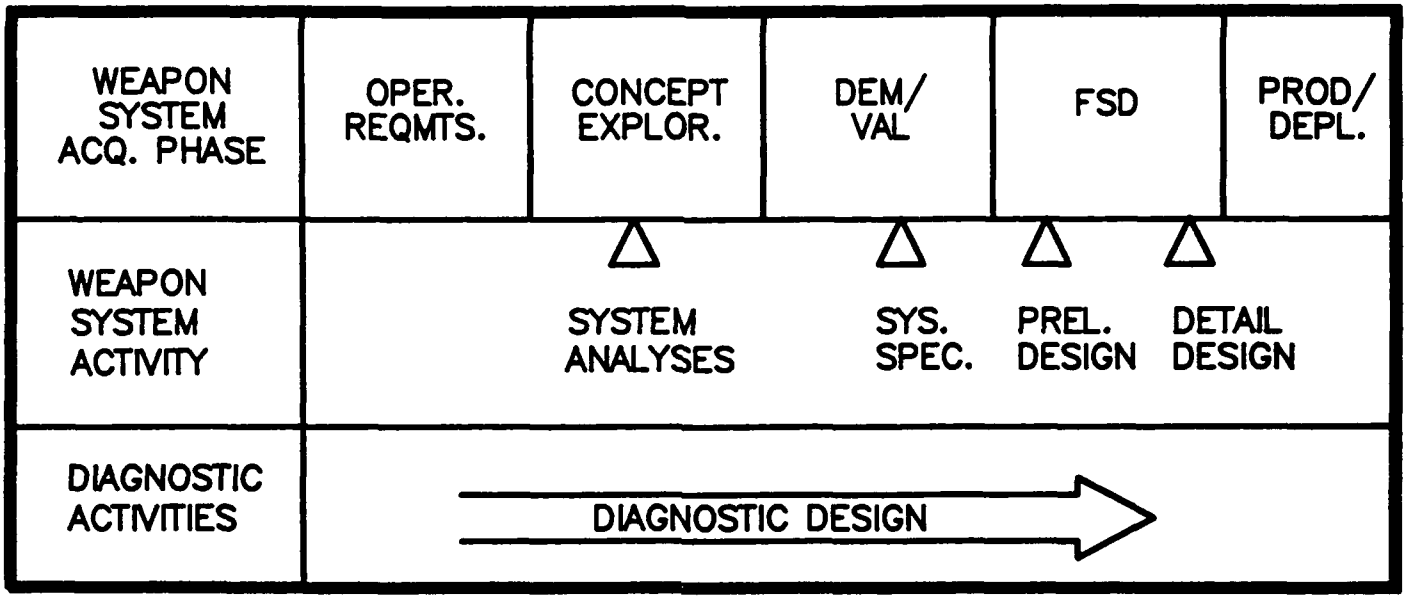
PROVIDING A COHESIVE DIAGNOSTIC DESIGN PROCESS REQUIREMENT #3.1

The diagnostic design and assessment tools enhance the effectiveness and efficiency of the process. A description of available tools and processes is available in the Design Encyclopedia Guide.

CHECKLIST

- ☑ Has a diagnostic design environment been adequately defined and imposed to ensure that diagnostic design requirements are considered as part of the mainstream design effort?
- ☑ Has a concerted effort been made to assure vertical and horizontal integration and compatibility of all elements which comprise the diagnostic capability? Has this been documented for review?
- ☑ Have steps been taken to utilize automation of the diagnostic design process to enhance design efficiency and to improve the effectiveness of the fielded diagnostic capability?
- ☑ What measures will be taken to ensure that vertical and horizontal diagnostic concepts are being implemented?
- ☑ How are the interfaces with training, technical information, and off-line test being managed to facilitate concurrent delivery of weapon system and support to the extent required for test and evaluation and maturation?

CRITERIA FOR DESIGNING DIAGNOSTIC CAPABILITY	REQUIREMENT #3.2



DIAGNOSTIC ACTIVITY

Design of the diagnostic capability and the elements that make up this capability are initiated early in weapon system development. It begins soon after initial analyses and allocation are completed and extends at least until the end of Full-Scale Development. Design criteria and guidance need to be available for use as the diagnostic capability design progresses. Obviously, the bulk of this design guidance is utilized by the designer of the prime system and its support capability. The Contractor Program Manager needs to be aware of the type of guidance that is available and if the contract specifies any design criteria.

PROCEDURE

Design criteria and guidance relating to the diagnostic capability and individual diagnostic elements are available from a number of sources, including standards, handbooks, and guides. Most often, this guidance is not a contractual requirement, except when a specific military standard is invoked. However, for the most part, the contractor should utilize this guidance material as he sees fit, as long as diagnostic requirements are met and interfaces are controlled.

Guidance to the Contractor Program Manager consists of identifying applicable guidance documents, and where published material is not readily available, limited guidance is furnished.

Of particular concern to the Contractor Program Manager is the implementation of inherent testability in his system. Design of a cost effective and efficient diagnostic capability must start with foundation of inherently testable circuits and assemblies. Inherent testability is based soley on basic design features such as physical and electrical partitioning, controllability, observability, and test point placement. The inherent testability of a unit will greatly reduce the cost, complexity, efficiency and development time of both the on-line and off-line diagnostics required. Good diagnostics design and design practices built on a foundation of circuit and unit designs, which are inherently testable, will close the loop and provide the most effective system diagnostics capability at minimum cost.

In the commercial sector, many major companies have made corporate decisions to design electronics products to be testable. The impetus for testability in the commercial sector is based upon the time and cost savings achieved in the factory test environment. Factory rework time and costs are decreased based upon confident, early detection and diagnosis of faults. Test coverage, test time, diagnostics time, fixturing and programming costs are all significantly impacted by the inherent testability characteristics of a product. Further benefits of testability are achieved in the field maintenance environment. The design for testability decision in the commercial sector is based upon a return on investment parameter where the beneficial impacts of testability are evaluated against the costs associated with testability implementation - recurring and nonrecurring.

In the military environment, the key driver for testability is the impact of test effectiveness on mission success and life cycle cost. The quantification of testability benefits in military applications has been difficult to assess. The impact of improved test effectiveness shown in the chart below (Figure 7) intuitively leads to significant benefits. However, quantification of these benefits can only be done on a case-by-case basis.

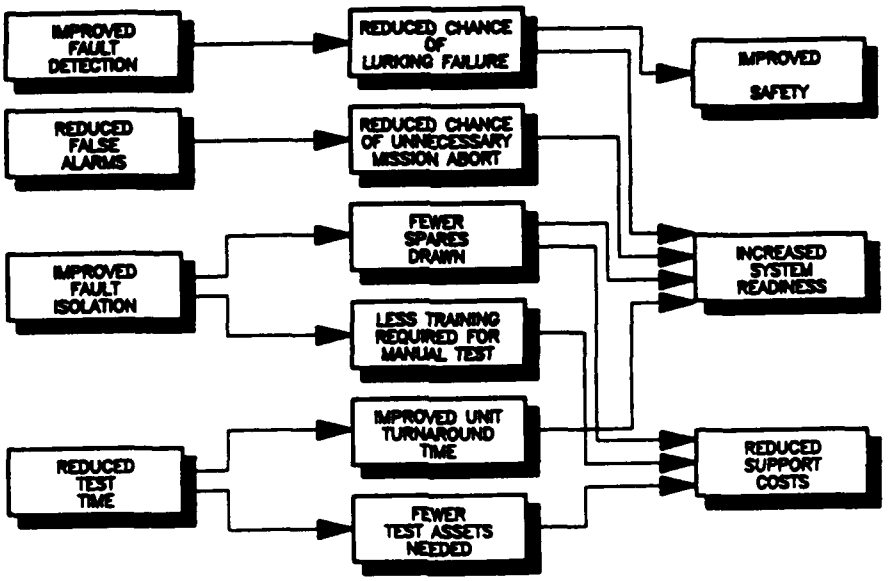


FIGURE 7. IMPACT OF IMPROVED TEST EFFECTIVENESS

GUIDANCE

Detailed design criteria and guidance in relation to the entire diagnostic capability, as well as for each diagnostic element, are addressed in detail in the Design Encyclopedia Guide. A substantial amount of information that is contained in that guide is not available in other existing guides. Guidance contained in this Contractor Program Managers Guide is limited to references to other available design criteria and guidance.

The following are references to existing design criteria and guidance.

General Guidance

1. MIL-STD-454, Standard General Requirements for Electronic Equipment

   This standard covers the common requirements to be used in military specifications for electronic equipment. Reliability, maintainability, and human engineering requirements are included in this standard. However, for these types of engineering disciplines, the guidance stresses that this standard does not establish requirements and must not be referenced in contractual documents. These three requirement examples offer direction on what should be considered in preparing contractual documents.

2. MIL-STD-415, Design Criteria for Test Provisions for Electronic Systems and Associated Equipment

   This standard establishes design criteria for test provisions that permit the functional and static parameters of electronic systems and associated equipment to be monitored, evaluated, or isolated. The standard, in its present form, (Revision D) addresses older technologies and thus, if referenced in contractual documents, must be tailored to address only certain provisions in this standard.

3. The RADC Reliability Engineers Tool Kit

   The Tool Kit is intended for use by a practicing reliability and maintainability (R&M) engineer. Emphasis is placed on his role in the various R&M activities of an electronic systems development program. The Tool Kit is a compendium of useful R&M reference information to be used in everyday practice.

System Architecture

There are a number of guides, which address the architecture of the system design, that promote improvements in the system's diagnostic capability. Included are:

1. Architecture Specification for PAVE PILLAR Avionics, January 1987, SPA90099001A

   This specification addresses the advanced avionics architecture which is specifically targeted for advanced tactical fighters and, in general, for all military aircraft applications. This architecture promotes a much-improved approach, which will foster an improved diagnostic capability. An example of this approach is contained in the Design Encyclopedia Guide.

2. Reliability, Testability Design Considerations for Fault Tolerant Systems (RADC-TR-84-57)

   Furnished reliability and testability evaluation and application guidance for fault-tolerant designs.

Testability

There are a number of guidance documents which address testability issues. Some of these are listed below. These deal with the design techniques of controllability, observability, and partitioning. Controllability is a design attribute which describes the extent to which signals of interest may be controlled by the test process. It relates to difficulty of test generation, length of test sequence, and diagnostic resolution. Observability is another design attribute which describes the extent to which signals of interest may be observed by the test process. The emphasis is upon selection of the most appropriate test points. Partitioning deals with both the physical hardware and the functional partitioning of the circuitry. Test times and test generation costs escalate rapidly as partitioning size increases.

1. RADC Testability Notebook, Final Technical Report, June 1982

   This notebook presents a consolidation of information relating to testability design techniques, procedures, cost trade-off tools, and the relationship of testability to other design disciplines and requirements. Specific examples of good testability design are contained in this document.

2. Avionics Testability Design Guide -- MATE Guide 3, Part Three, Testability Design Handbook

   This portion of the MATE Guides discusses testability design techniques.

3. MIL-STD-2165, Testability Program for Electronic Systems and Equipments

   Appendix B of MIL-STD-2165 cites a series of factors which affect the inherent testability of a weapon system. This information can be used either

as design guidance or, if weighted and scored, can actually provide a Figure of Merit for a specific system/unit.

4. Testability Analysis Handbook (Draft)

   At the time of printing the Contractor Program Managers Guide, the Testability Analysis Handbook was in draft form. Publishing is scheduled during FY89. The Preparing Activity is the Naval Sea Systems Command, CEL-DST. This handbook provides a systematic methodology for implementing testability analysis and design requirements, which are prescribed in MIL-STD-2165, Tasks 201, 202, and 203.

Built-In Test

1. Built-In Test Design Guide--Joint AMC/CNO/AFLC/AFSC Commanders, April 1987

   This Joint Service BIT Design Guide provides detailed guidelines on the implementation of BIT, including BIT design techniques at all levels within the weapon system.

2. *Smart* BIT (RADC-TR-85-148)

   Application of Artificial Intelligence techniques in the design of BIT, to minimize false alarms, retest OKs and non-required maintenance.

3. Sensor Handbook for Test, Monitoring, Diagnostic, and Control System Applications to Military Vehicles and Machinery, National Bureau of Standards

   This handbook is intended as a guide for those who design, specify, use, and test weapon systems containing monitoring sensors. The handbook addresses measures and principles of measurement, data acquisition, sensor calibration and testing, environmental considerations, stability, durability, reliability, and error assessment for various types of sensors.

Automatic Test Equipment (ATE)

1. Modular Automatic Test Equipment (MATE) Guides

   Although Air Force-oriented, these guides describe procedures and techniques for acquiring automatic test equipment. Of particular interest is Guide 5, which addresses the acquisition of test program sets.

2. MIL-STD-2077, General Requirements, Test Program Sets

This standard covers the acquisition of test program sets for use with ATE. Design criteria is included, which addresses many detail requirements for TPSs.

Human Engineering

1. MIL-STD-1472, Human Engineering Design Criteria for Military Systems, Equipment, and Facilities

   This standard covers general human engineering design criteria which can be applied to any weapon system.

Technical Information

There are a variety of standards which address the preparation of technical publications. Most of these documents are directed at a specific military service. All address the delivery of paper-type documentation. There is no firm guidance relating to other, perhaps more innovative means for generating and delivering technical information. In the past, many technical publications have been cited to have deficiencies. These deficiencies can best be described in the DoD Audit Report No. 87-115, April 3, 1987, "Summary Report on the Defense-Wide Audit on Acquisition of Technical Manuals and Related Data From Contractors."

Means should be sought for generating and delivering this technical information in a less costly manner, without compromising its quality. There are a number of tools available, or under development, which can assist the designer of this technical information in authoring the text, when electronic delivery of technical information is contemplated. Some guidelines and standards for automatic generation of technical information and its delivery electronically can be obtained from the Human Resources Laboratory at Wright-Patterson Air Force Base. This guidance information has been developed under the Integrated Maintenance Information System (IMIS) Program.

Innovative ideas for displaying this technical information are encouraged, as stipulated in Task 303, MIL-STD-1388-1. Care should be taken to provide for quick access to the required data. For electronic delivery of this data, formats may vary substantially from paper-based technical manuals. Previously specified access times and information modification times should influence the type of generation and delivery methods. DoD-Instruction 4151.9 requires the services to plan and schedule the acquisition of technical manuals (technical information) to ensure their availability in final form before, or concurrently with, delivery of the system to the field. During design, final plans should be developed, along with the support equipment which is furnished.

Maintenance Aids

There is a need to present technical information and troubleshooting advice to the technician on location and readily available for his use. The maintenance aid, sometimes called a job performance aid, presents information generated by experts to assist the less-experienced technician.

The maintenance aid is a device, publication, or guide used on the job to facilitate performance of maintenance. It delivers:

- Historical information on what fault was found when similar symptoms were experienced
- Troubleshooting logic to assist in finding the fault
- Procedural information which assists the technician in finding and correcting a failure.

Normally, a maintenance aid is used in conjunction with a testing capability. Maintenance aids could be paper-based or employ electronic delivery systems.

Electronic delivery of this type of information opens the door to solving some of the problems associated with paper maintenance aids. Two attributes of electronic delivery systems are:

- Information can be available to the technician in a matter of seconds by carefully constructed menus, in lieu of the technician having to page through a paper document.
- The collection of historical data and the subsequent modification to the software programs which deliver this technical information can be updated in a matter of seconds, instead of a matter of months.

This latter attribute lends itself to the introduction of expert systems, which often employ artificial intelligence technology. The expert system has the capability of combining various pieces of information to lead the technician to a logical decision on what is faulty and how it can be repaired.

Another important aspect of the maintenance aid is its ability to train technicians on the job. Training programs must be closely associated with the design and development of a maintenance aid.

Over the past 20 years, many maintenance aids have been designed, developed, and tested. These tests, for the most part, have proven successful. However, the transition of these maintenance aids into the field has not been accomplished to any

great extent. One of the reasons is that specifications, standards, and guidance information on how to invoke this requirement are lacking.

A few important facts should be remembered when applying maintenance aids and expert systems.

- The design of the maintenance aids must be done with the user in mind. Once a working model of the equipment is available, there should be a dynamic interchange of information between the maintenance technician and the design engineer, to ensure an effective and efficient man-machine interface is attained.

- User acceptance and adoption of maintenance aids will be facilitated in cases where potential users are given a trial period in which to become familiar with these devices prior to their formal implementation.

- A system must be devised to assure timely updating of information to correct errors and to add newly acquired information. Without such a system, the maintenance aid will quite rapidly become obsolete.

Manpower and Training

After personnel and training requirements/allocations have been made, the training curriculum needs to be established concurrently with the system detail design. This includes the formal schooling curriculum, as well as on-the-job training. One of the alternatives available, if electronic delivery of technical information is employed, is combining training aids with the delivered technical information. These two types of information (aiding and training) are somewhat similar in nature and, at times, indistinguishable. The training curriculum should be aimed at the user(s) and accessed in a manner which can be utilized by a variety of users.

These training devices can be freestanding or embedded in the prime system. Separate and distinct training devices (maintenance trainers) may be required to be developed for the formal schooling.

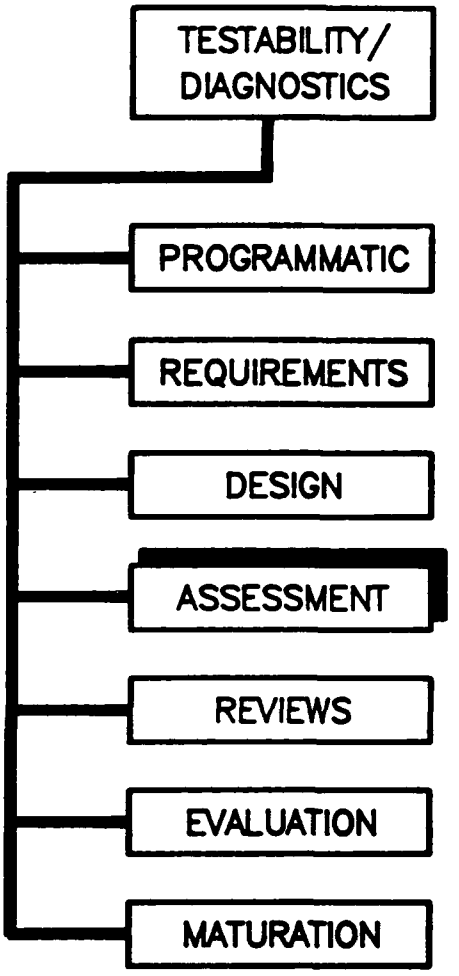
Integration of Diagnostic Elements

There are a variety of ways in which diagnostic elements can be integrated to produce a more effective and efficient diagnostic capability. Expert system technology can be incorporated in either ATE or BIT to supplement the basic testing capability. Fault-tolerant design and testability design can be introduced into prime system architecture to promote ease of testing, along with graceful degradation. Maintenance aiding and maintenance training can be combined to provide on-the-job maintenance and training information, utilizing a single portable device or embedded into the prime system. Several comprehensive examples of this integration appear in the Design Encyclopedia Guide.

CHECKLIST

- ☑ Is the contractor utilizing available design guidance?
- ☑ Is the contractor attempting to integrate the various diagnostic elements to provide a more effective and efficient diagnostic capability?

ANALYSIS AND ASSESSMENT OF THE PERFORMANCE OF THE DIAGNOSTIC CAPABILITY



OVERVIEW

Throughout the design of the weapon system's diagnostic capability, it is essential to analyze, assess and demonstrate its performance. Such assessments are an integral part of logistics, reliability, maintainability, testability, human engineering, software and safety programs. The ability to properly conduct these analyses, assessments, and demonstrations is hampered by the lack of available techniques and tools to help, and the incompatibility of the available tools and techniques to function together. Thus both the program manager and the designer must have sufficient knowledge to understand the processes utilized and integrate these processes and tools to do the best possible job.

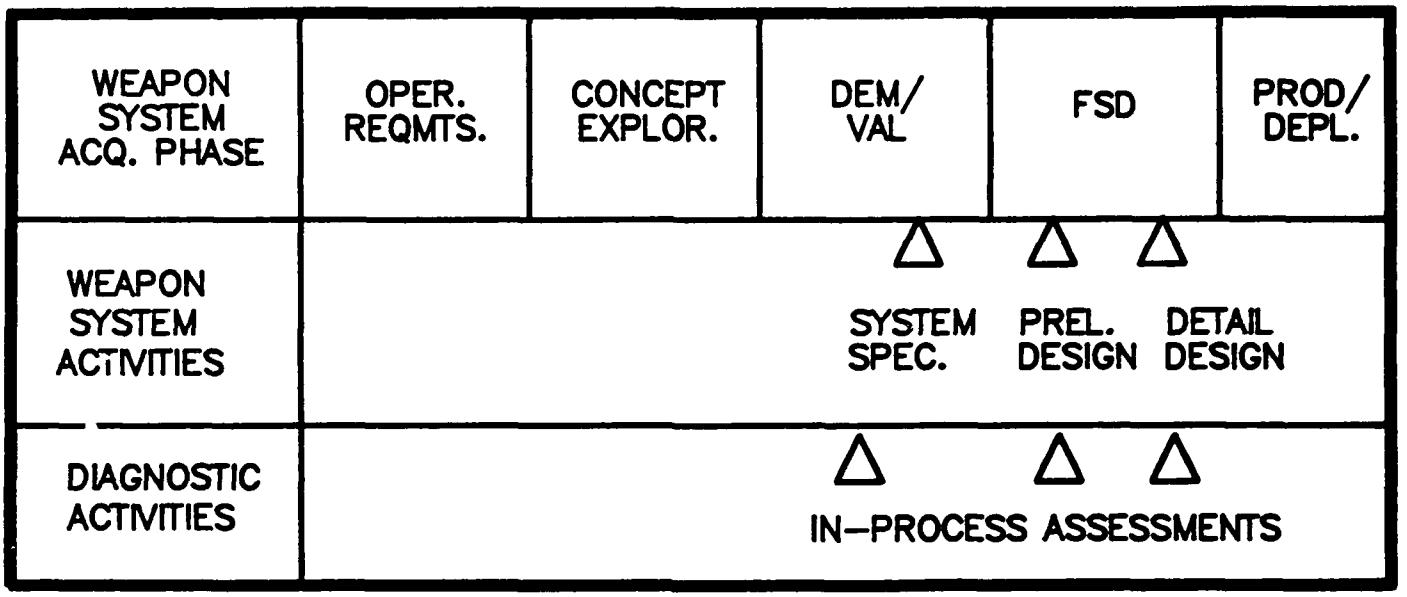
IMPORTANT CONSIDERATIONS TO BE ADDRESSED

Reqmt.

4.1 Analysis and assessment of the diagnostic capability should be performed for the entire diagnostic capability, as well as for each diagnostic element.

4.2 Maintainability demonstrations should be designed to verify that diagnostic requirements have been met.

IN–PROCESS TESTABILITY/DIAGNOSTIC ANALYSIS	REQUIREMENT #4.1



DIAGNOSTIC ACTIVITY

During Dem/Val and FSD, it is important to assess whether the testability/diagnostic requirements are being achieved. This activity encompasses all preliminary and full-scale engineering activities pertaining to both the embedded and external diagnostic capability.

PROCEDURE

In-process testability/diagnostic analyses can be conducted at most any time within Dem/Val and FSD. These in-process analyses are typically reviewed by the government at preliminary design reviews and critical design reviews. These analyses are, for the most part, implemented per MIL-STD-2165 (Task 202, Preliminary Design, and Task 203, Detail Design). Normally, these analyses will be the responsibility of the design or test engineer. However, it remains the job of the Government and Contractor Program Managers to understand the processes utilized and to interpret the results of these analyses.

GUIDANCE

Basically, there are two types of in-process analyses. The first deals with the inherent testability of the hardware design and is independent of test stimuli and response data. The second type deals with the effectiveness of the diagnostic capability which deals with measures that include consideration of hardware design, embedded diagnostics, and external diagnostics. Diagnostic effectiveness measures include, but are not limited to, fault coverage, fault resolution, fault detection time, fault isolation time, and false alarm rate.

There are a number of techniques and tools available, both automatic and manual, which can be used to assist in these analyses. Two documents describe in detail these techniques and the application of these tools. The first is the Testability Analysis Handbook which is described under Requirement #3.2. The second is the Diagnostic Design Encyclopedia (a companion document to this Contractor Program Managers Guide) which describes testability and diagnostic tools and their utilization. However, the Contractor Program Manager must understand the techniques and tools available to conduct these in-process analyses.

INHERENT TESTABILITY

The first analysis deals with inherent testability. Inherent testability assessment is an evaluation of how well a design supports the testing process, whether built-in test or off-line test. The evaluation is performed on the preliminary design and is performed before any test design is performed. It is, therefore, based solely upon the hardware design features, such as physical and electrical partitioning, controllability, observability, and test point placement, etc. The key to performing an inherent testability assessment is the identification of features which support or inhibit the diagnostic process early, at a point in time when the design can be changed relatively easily. The concept and the implementation of an inherent testability assessment can have great impact on overall system supportability.

In general, three generic groups of inherent testability predictive techniques are available, each with its unique advantages and disadvantages. Checklists are low cost, manual, and somewhat simplistic. Logic models utilize the actual circuit topology but often regard everything as a block, with inputs and outputs., The more detailed algorithmic approaches, such as Sandia Controllability/Observability Analysis Program (SCOAP), require libraries of the devices that most nearly simulate actual circuit devices.

Checklist approaches to inherent testability assessment have some very good characteristics, yet also have some major drawbacks. Checklists are manual approaches to testability assessment, yet are easily automated into an interactive format for the designer to input answers to the stated design criteria, with an automated grading being done. However, quite extensive engineering analysis is still required. Two of these, the RADC PCB checklist and the MIL-STD-2165 Appendix B checklist, are examples. The

RADC PCB checklist is limited to digital board applications, whereas MIL-STD-2165 Appendix B covers analog, digital, and hybrid applications from module to system level. The RADC checklist has fixed items of weighting, whereas MIL-STD-2165 Appendix B allows subjective treating of items and weighting values. Both items can be utilized well in selective applications, but the RADC checklist cannot accommodate more complex digital UUTs and the subjectivity of MIL-STD-2165 Appendix B has seen some criticism due to its variable weighting scheme.

Logic models have considerable success and validity other than in support of the testability discipline, including logistics, fault isolation, integrated diagnostics, and maintainability. The logic model algorithms are of varying sophistication and validity, although the methodology for defining dependencies are similar.

Logic models systems for testability are applicable to analog, digital, and hybrid applications. They can be modeled at the component, board, or module subsystem and system level. One limitation of this broad approach is that every item is identified as a box with inputs and outputs. Thus, box complexity might range from an OR gate to a complete microprocessor. The same variation applies to the lines between boxes. Critical signals, such as a clock or a tri-state bus are not more important than any other line. Two of the more well-known models are Logic Modeling (LOGMOD) and System Testability Analysis Maintenance Program (STAMP). Both are mature in nature, but each is tied to a specific vendor at the present time.

Algorithmic approaches are perhaps the most sophisticated approach. SCOAP seems to usually perform well, but has had some library limitations in the important area of CMOS primitives. Some CAE workstation vendors are including modified versions of SCOAP for up-front testability analyses. Daisy workstations include the Daisy Testability Analyzer (DTA) package, and GE/CALMA workstations include the Controllability-Observability-Predictability-Testability Report (COPTR) package. Both have improved on the basic SCOAP, via top-down modeling and large device model libraries of the more common IC types. GenRad also has a package called HITAP, which is based on the Computer-Aided Measure for Logistic Testability (CAMELOT) algorithm.

Another major issue surrounding inherent testability assessment is that many of the automated tools which exist are proprietary. This proprietary nature of the tools creates implementation problems from both a cost and a contractual point of view. Often, the best approach is to utilize a nonproprietary automated tool for inherent testability assessment.

Prior to the FSD phase, the design or test engineer should develop a total strategy for conducting inherent testability assessment on all systems, subsystems, etc. Based upon the availability and applicability of current inherent testability assessment approaches, it is anticipated that a combination of tools and techniques will be required to form a totally comprehensive measurement capability. In areas where an automated

capability is not available, use the baseline of existing models to make modifications to provide the total capability required.

An evaluation criteria for inherent testability assessment tools and techniques should be developed based upon specific system and subsystem specific needs. The following list of evaluation criteria is recommended:

- o Automation; degree of automation
- o Proprietary nature
- o User friendliness
- o Automated link to design data base
- o Acceptability of output to the government
- o Cost of use
- o Availability (currently available or under development)
- o Quality
- o Sensitivity to key testability features
- o Feedback provided (does it recommend design fixes?)
- o Comprehensiveness (digital, analog, RF, VHSIC, mechanical, etc.)
- o General techniques; principles used
- o Link to test effectiveness prediction technique
- o Output reports
- o Scoring methodology
- o Applicability to chip, board, subsystem.

TEST EFFECTIVENESS

The second type of analysis deals with test effectiveness. Traditional approaches to determining test effectiveness call for the generation of test sequences at the completion of the design phase and a measure or measures made of their effectiveness. The analysis need not wait on the completion of BIT and/or off-line TPS

software. Modeling is encouraged, since this approach can analyze test effectiveness on a large number of postulated faults prior to incorporating the test stimulus in either an embedded or off-line program. The results of the analysis can feed forward, so as to influence BIT or TPS software design, and feed backward to influence possible redesign of the prime system to improve its testability. Test effectiveness measures have traditionally included:

- o Fault coverage
- o Fault resolution
- o Fault detection time
- o Fault isolation time.

Computer programs are used to input (via software) a large number of faults into the software model of the hardware item (UUT). The response of the simulated item to the test sequence is then evaluated, given the presence of the simulated faults. Fault detection, resolution, etc., are automatically ascertained. Most modern Automatic Test Program Generation (ATPG) and simulation systems have very efficient fault simulation capabilities. The HITS system, for example, runs a concurrent fault simulation to greatly speed the process. The usefulness of this approach in measuring test effectiveness depends on the adequacy of the models (hardware item model and fault model) to accurately reflect the real-world situation. Modeling must be achieved at a level of detail that allows all known and statistically significant failure modes to be included.

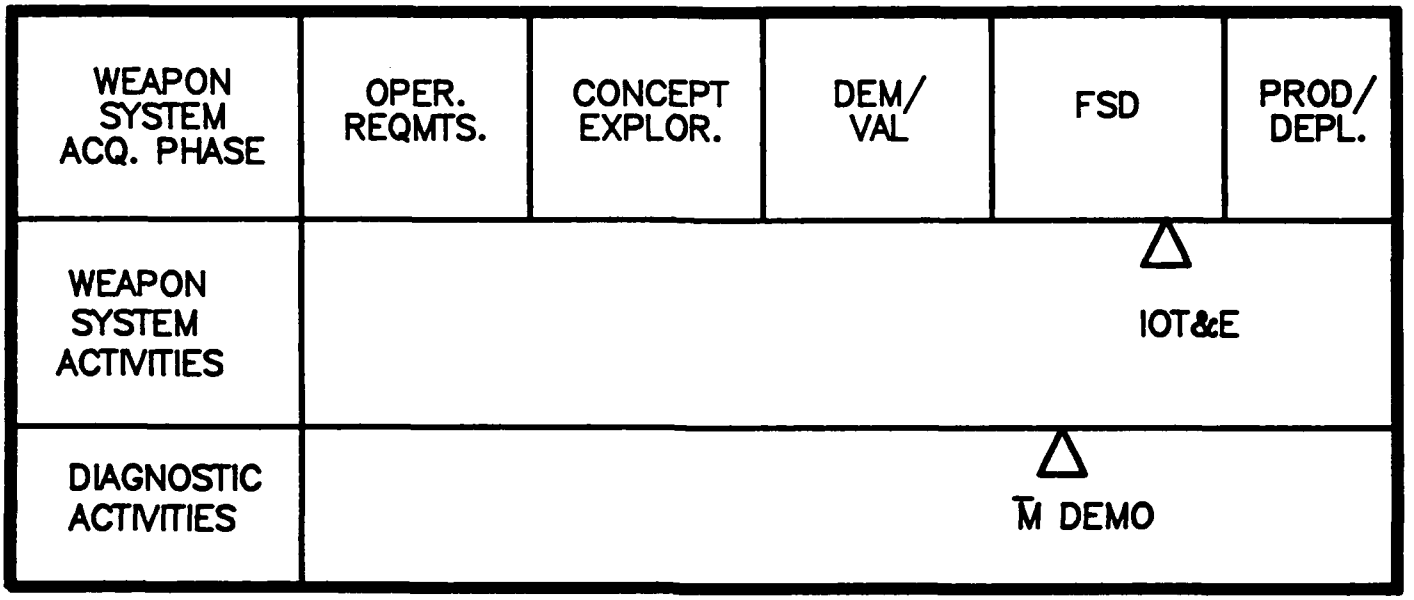
Although commonly accepted, the application of these measures is in various stages of maturity, based upon the equipment composition (i.e., digital, analog, radio frequency and/or mechanical). At this time, the application experience has been concentrated in the area of digital implementations. However, even in this area, significant additional effort will be required in order to relate these measures to operational performance. The degree of application of test effectiveness measurement techniques to the remainder of the listed equipment types has been quite limited to date. IDSS, the Navy's Integration Diagnostics Program, has recognized this need and has an active diagnostic tool development program underway. One of these tools, the Weapon System Testability Analyzer, is structured to address test effectiveness measurement, as well as inherent testability assessment.

Effective and realistic fault modeling is a key element in the development of the simulation capability needed to support the development of either an ATPG or an automated test effectiveness measurement tool. However, it is anticipated that no single fault model and/or simulator will be applicable to the broad range of equipments to be employed within a complex system; therefore, a combination of models will be required to meet the requirement for automated determination of fault detection and isolation levels.

CHECKLIST

- ☑ Does the analysis of testability/diagnostic requirements address all major support disciplines?
  - Off–line ATE
  - Embedded diagnostics
  - Manpower required to support analysis outputs
  - Training requirements
  - Information requirements.
- ☑ Are all analyses complete and unambiguous? Do they meet specification requirements?
- ☑ Is the analysis integrated and cohesive? Are any requirements in conflict?
- ☑ Are the training, information, and manpower requirements adequately scoped and specified to support the technical complexity of the subject end item in its operational environment?
- ☑ What design automation tools (e.g. simulators, analyzers) has the contractor proposed/used to verify the predicted diagnostic performance?

MAINTAINABILITY DEMONSTRATIONS	REQUIREMENT #4.2



DIAGNOSTIC ACTIVITY

Maintainability Demonstrations are performed in accordance with the appropriate demonstration method contained in MIL-STD-471A. Notice 2 of MIL-STD-471A (USAF) contains requirements for demonstration and evaluation of system BIT/external test/fault isolation/testability attributes. This method will demonstrate the integration of the diagnostic capability for the system (e.g., integration of embedded test software and hardware techniques, automatic and manual test, BIT/SIT, training levels, human interfaces). The Maintainability Demonstrations evaluate the diagnostic performance of the system with respect to the diagnostic performance criteria and objectives established in accordance with MIL-STD-470 (Maintainability Program) and MIL-STD-2165 (Testability Program) and the requirements for an "integrated" diagnostics capability demonstration contained in the FSD SOW.

PROCEDURE

The integrated diagnostics process increases the scope of maintainability demonstrations. It is the Contractor Program Manager's responsibility to ensure that this increased scope is understood and implemented.

The scope of Maintainability Demonstrations includes:

1. Demonstration of Testability Parameters
   - BIT Fault Detection
   - BIT Isolation Time
   - BIT Fault Isolation Level (Ambiguity Group)

2. Demonstration of Test Effectiveness (ATE) (MIL-STD-2077)
   - ATE Fault Detection
   - ATE Fault Isolation Time
   - ATE Fault Isolation Level (Ambiguity Group)
   - UUT/ATE Compatibility

3. Demonstration of Technical Information
   - Technical Information Access Time
   - Technical Information Relative Access Ease
   - Technical Information Format
   - Technical Information Usability

4. Demonstration of Training/Skills
   - Relationship between maintenance procedures and skills
   - Relationship between formal training and actual maintenance job flow.

5. Demonstration of Vertical and Horizontal Integration
   - Compatibility and Consistency of diagnostic demonstration results between maintenance levels and among their respective diagnostic elements.

GUIDANCE

Unfortunately, the ability to carry out a single demonstration, or even a series of demonstrations, to prove/evaluate this level of diagnostic capability is dependent upon having all of the diagnostic elements available for the maintainability demonstration. While this should always be the goal, it may not be feasible for all of the above due to development schedules, UUT design instability, data availability and other overall program constraints. (Note that this is a primary reason for a Diagnostics Maturation Program.)

Typically, the contractor prepares a Maintainability Demonstration Plan early in the FSD Phase and that plan is subject to government review and approval. The Contractor Program Manager should take advantage of this opportunity to maximize the scope and effectiveness of the Maintainability Demonstrations to include the factors cited above. This can have a significant cost-savings impact on the Diagnostics Maturation Program requirements. Maintainability Demonstrations represent the first major opportunity to evaluate the level of diagnostic capability achieved. Also, Maintainability Demonstrations can be conducted early enough to implement corrective action cost-effectively. Demonstrations are conducted while the system is still considered to be in the Development Phase. After the demonstrations are completed, the relative cost of identifying deficiencies and implementing corrective action is significantly increased. A significant milestone of 'Government Acceptance' occurs upon satisfactory completion of Maintainability

Demonstrations. After this milestone, costs for identification and resolution of diagnostic deficiencies may be subject to contract interpretation and/or negotiation. The total strategy for the test and evaluation of the diagnostic capability is placed on the TEMP, and detailed in the Integrated Test Plan.

Based upon the selected scope of the Maintainability Demonstration, procedures from MIL-STD-471 are utilized and adapted for the scope. These procedures are documented in the Maintainability Demonstration Plan. The results of the Maintainability Demonstration are documented in a technical report - Maintainability Demonstration Results.

Concurrent Demonstrations

The overall diagnostic capability is the sum of a variety of diagnostic elements. Therefore, a requirement should be established for early demonstration of the entire diagnostic capability produced by the integration of all of these diagnostic elements. This is referred to as concurrent demonstrations, where the timing of various diagnostic element demonstrations are planned and scheduled for concurrency so that the integrated capability can be assessed.

The Contractor Program Manager must evaluate schedules to determine the level of concurrency feasible. Critical and/or risk areas must be identified and evaluated.

Each element of the diagnostic capability must be demonstrated, as well as the result of the combining or integration of the elements. For example, a demonstration of subsystem BIT may prove fault detection and isolation levels. A demonstration of ATE may prove external fault detection and isolation levels. A concurrent demonstration of these two diagnostic elements will prove the ability of the ATE to use BIT circuitry, to use BIT results, and the consistency of test results between BIT and ATE. By concurrent demonstration, the whole is greater than the sum of the parts. A significant set of factors related to the result of the integration of the diagnostic elements must be evaluated early.

CHECKLIST

- ☑ Does the demonstration plan provide a 100% fault coverage capability across all levels of maintenance?
  - Organizational Level
  - Intermediate Level
  - Depot Level

- ☑ Are the failure modes to be demonstrated and criteria to be utilized adequately specified for each maintenance level?

- ☑ Does conducting the actual demonstration require a level of manpower, training, and/or technical information above and beyond that which will be provisioned? If so, why?

- ☑ Is the demonstation structured to provide an evaluation of the diagnostic capabilities as an integrated system?

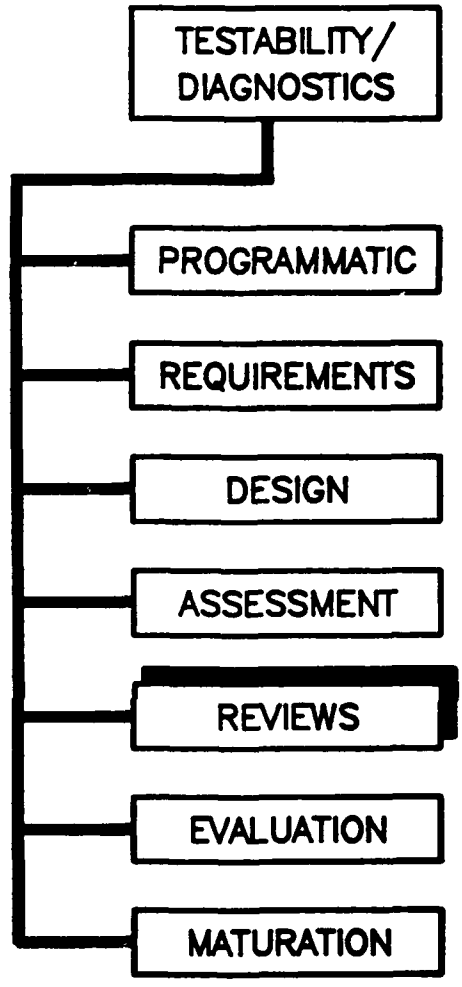
- ☑ Do the subject plans demonstrate an integrated, cohesive maintenance flow in terms of demonstrating how a fault would be detected? For example, at the Organizational Level and the subject repair effected at the Depot Level? Is a systems approach to the maintenance process taken in the overall approach to demonstration planning?

CONDUCTING DESIGN REVIEWS

OVERVIEW

During the acquisition of a weapon system there are at least eight formal technical reviews and audits, which may be conducted by the contractor for the Government Program Manager. As in the diagnostic design process, there is a tendency to conduct separate reviews and audits based upon the function being addressed. This particularly refers to logistics, reliability, maintainability, testability, human engineering, and safety. Integration of these reviews and audits to address diagnostic issues is a must. MIL-STD-1521 is the prime document which defines the issues to be addressed at each of these formal reviews. At present, these checklists are inadequate in terms of both testability and diagnostics and, thus, these reviews and audits may not serve their purpose. Additional guidance must be given to both the government and the contractor in order to alleviate this problem.

Informal reviews are often required. Guidance for these informal reviews can be drawn from formal review guidance.

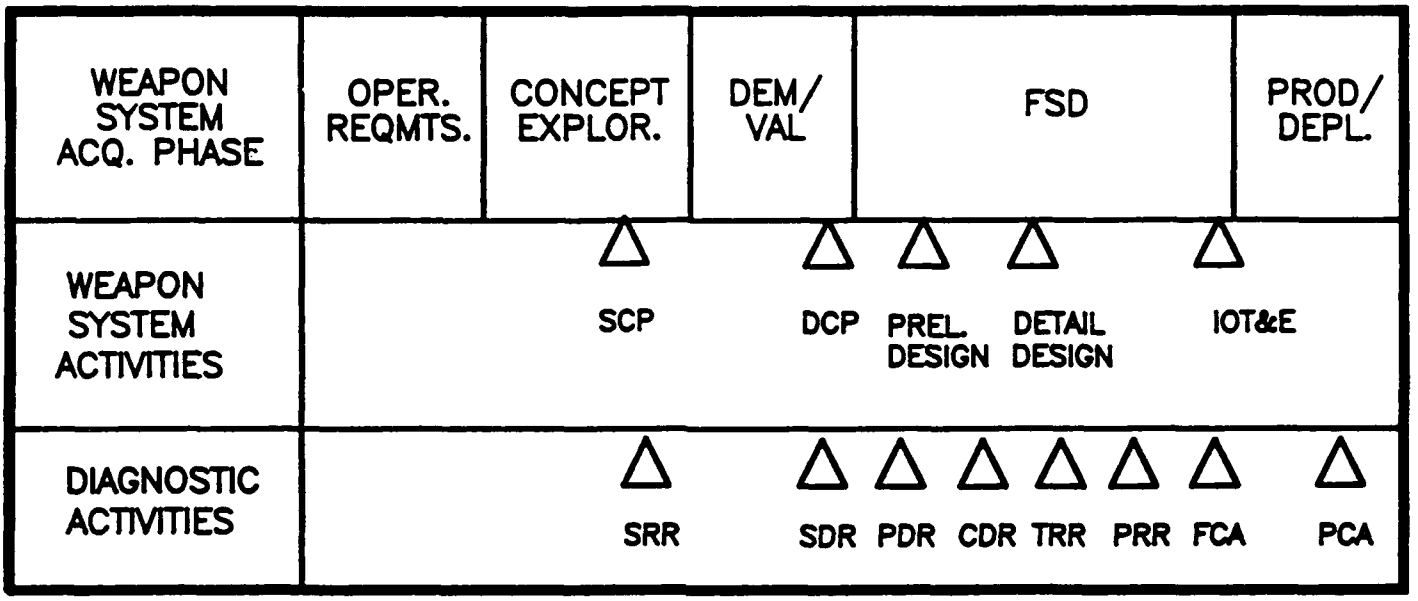


IMPORTANT CONSIDERATIONS TO BE ADDRESSED

Reqmt.

5.1 Technical reviews and audits must address all facets which affect the performance of the diagnostic capability.

Conduct the review and audit of testability and diagnostic functions as an integral part of system engineering and maintainability reviews.



DIAGNOSTIC ACTIVITY

Technical reviews and audits are an important factor in assuring that the government is furnished with a weapon system which meets its requirements.

PROCEDURE

MIL-STD-1521 lists 10 formal technical reviews and audits. Of these 10, eight are considered critical in the achievement of a satisfactory diagnostic capability. The following guidance supplements and expands the guidance contained in MIL-STD-1521, Technical Reviews and Audits for Systems, Equipments, and Computer Software.

Although design reviews are recognized as being important to verify design before production, the lack of depth in these reviews is alarming. The cause of these inadequate reviews must be shared by both the contractors and the government. Contractually, the government rarely requires the contractor to do a comprehensive technical review, and the contractor does not do so unless required, even though it may be cost effective from his point of view. Even when the right words are used, the end results depend largely on corporate policy to allocate sufficient resources to perform a detailed analysis of the design and associated processes.

GUIDANCE

Guidance relating to these various reviews is contained in the appendices to MIL-STD-1521. Because these appendices do not address all aspects of testability and diagnostics, some supplemental information is included in the following paragraphs.

System Requirements Review (SRR)

The objective of this review is to ascertain the adequacy of the contractor's efforts in defining system requirements. It will be conducted when a significant portion of the system functional requirements has been established.

The diagnostic capability review portion of the SRR will analyze the system items that are related to diagnostics. The following items will be reviewed, as appropriate:

- Mission and Requirements Analysis
- Functional Flow Analysis
- Preliminary Requirements Allocation
- System/Cost Effectiveness Analysis
- Trade Studies
- Synthesis
- Logistic Support Analysis
- Specialty Discipline Studies
- Generation of Specifications
- Program Risk Analysis
- Integrated Test Planning
- Technical Performance Measurement Planning
- Engineering Integration
- System Safety
- Human Factors Analysis
- Life Cycle Cost Analysis
- Manpower Requirements/Personnel Analysis
- Milestone Schedules.

The diagnostic capability review should address the impact of the results of the items listed above on the diagnostic pieces listed below.

- Designed-In Reliability, Prognostics, and Testability
- Self-Test, Built-In Test, System Integrated Test
- Support Equipment, Maintenance Aids
- Technical Data
- Personnel Skill Requirements
- Training and Training Devices.

System Design Review (SDR)

This review shall be conducted to evaluate the optimization, correlation, completeness, and risks associated with the allocated technical requirements. Also included is a summary review of the system engineering process which produced the allocated technical requirements and of the engineering planning for the next phase of effort. Basic manufacturing considerations will be reviewed, and planning for production engineering in subsequent phases will be addressed. This review will be conducted when the system definition effort has proceeded to the point where system characteristics are defined and the Configuration Items (CI) are identified.

Specific diagnostic considerations relate to:

- Optimizing the diagnostic capability (changes after Dem/Val usually are more costly and time consuming)
- Preparation of a Maturation Plan
- Preparation of a System Specification which provides a capability for addressing necessary FD/FI requirements at each level of maintenance
- *Allocation of diagnostic requirements for each diagnostic element*
- Review of the software requirements specification to assure that embedded diagnostic software considerations are included.

Preliminary Design Review (PDR)

This review shall be conducted for each Configuration Item or aggregate of Configuration Items to: (1) evaluate the progress, technical adequacy, and risk resolution (on a technical, cost, and schedule basis) of the selected design approach; (2) determine its compatibility with performance and engineering specialty requirements of the Hardware Configuration Item (HWCI) development specification; (3) evaluate the degree of definition and assess the technical risk associated with the selected manufacturing methods/processes; and, (4) establish the existence and compatibility of the physical and functional interfaces among the Configuration Item and other items of equipment, facilities, computer software, and personnel. For Computer System Configuration Items (CSCIs), this review will focus on: (1) the evaluation of the progress, consistency, and technical adequacy of the selected top-level design and test approach; (2) compatibility between software requirements and preliminary design; and, (3) on the preliminary version of the operation and support documents.

In addition, the following items in the diagnostic area should be presented at the appropriate depth for review.

- o Preliminary Failure Modes and Effects Analysis
- o Design data analyses for BIT/SIT integrated diagnostics, including requirements and preliminary design verification results
- o Maintenance concept for the portion of the system being reviewed and its traceability to the system maintenance concept
- o Operational maintenance functions
- o Results of the analysis of the inherent (intrinsic) testability of the preliminary design
- o Allocation of qualitative and quantitative requirements
- o Criteria for external diagnostic elements
- o Trade-off studies
- o Cost/System Effectiveness Modeling and Life Cycle Cost Analysis
- o Preliminary Logistic Support Analysis, including task analysis and related personnel and support equipment information
- o Impact of diagnostics on maintenance man-hours required
- o Evaluation of alternatives
- o Test and evaluation plans.

Critical Design Review (CDR)

This review shall be conducted for each Configuration Item when detail design is essentially complete. The purpose of this review will be to: (1) determine that the detail design of the Configuration Item under review satisfies the performance and engineering specialty requirements of the HWCI development specifications; (2) establish the detail design compatibility among the configuration and other items of equipment, facilities, computer software and personnel; (3) assess Configuration Item risk areas (on a technical, cost, and schedule basis); (4) assess the results of the producibility analyses conducted on system hardware; and, (5) review the preliminary hardware product specifications. For CSCIs, this review will focus on the determination of the acceptability of the detailed design, performance, and test characteristics of the design solution, and on the adequacy of the operation and support documents. The CDR shall be conducted on each Configuration Item prior to fabrication/production/coding release to ensure that the detail design solutions, as reflected in the Draft Hardware Product Specification, Software

Detail Design Document (SDDD), Data Base Design Document(s) (DBDD), Interface Design Document(s) (IDD), and engineering drawings, satisfy requirements established by the Hardware Development Specification and Software Top-Level Design Document (STLDD). The CDR shall be held after the Computer Software Operator's Manual (CSOM), Software User's Manual (SUM), Computer System Diagnostic Manual (CSDM), Software Programmer's Manual (SPM), and Firmware Support Manual (FSM) have been updated or newly released.

It is desired at each CDR to provide as much assurance as practicable that mission-critical FD/FI thresholds are realized and that all diagnostic requirements are satisfied: e. g., that 100% diagnostic capability will exist for each CI in the system. While it probably will not be practicable to certify that this will exist, the following data should be presented as an extension of the information presented at the PDR.

- Detailed fault detection/fault isolation analyses that identify the extent to which BIT/SIT detect and isolate faults and which identify those failures that will require support equipment and/or manual methods to detect and/or isolate.

- Diagnostic allocations in Part II CI specifications to the LRU and SRU level. Traceability of these requirements to the Part I CI System Specification should be demonstrated. Note: Flexibility to reallocate diagnostic allocations until product baseline is established at PCA should be provided within the envelope of system requirements.

- Definition of the maintenance plan/concept for the CI, together with supporting LSA documentation, including support requirement and level-of-repair analysis results. Logistic simulation results should be presented to substantiate the plan/concept.

- Presentation of testability analysis/assessment results for the CI design to substantiate the fault detection/ fault isolation analysis.

- Early program Failure Identification, Prevention, and Detection (FIPAD) analyses applicable to the CI should be presented to assist in verifying diagnostic capability.

- Review detailed Maintainability Demonstration Plan for inclusion of diagnostic capability test requirements

- Appropriate updates to the items reviewed during the PDR.

Test Readiness Review (TRR)

This review is conducted for each CSCI to determine whether the software test procedures are complete and to assure that the contractor is prepared for formal CSCI testing. Software test procedures are evaluated for compliance with software test plans and descriptions and for adequacy in accomplishing test requirements. At TRR the contracting agency also reviews the results of informal software testing and any updates to the operation and support documents. A successful TRR is predicated on the contracting agency's determination that the software test procedures and informal test results form a satisfactory basis for proceeding into formal CSCI testing.

The diagnostic segment of the system/CI TRR(s) shall be a formal review of the contractor's readiness to begin formal diagnostics-related CSCI testing. It is conducted after the software test procedures are available for diagnostics-related CSCI, such as CI BIT, System BIT, SIT, etc., and after computer system component (CSC) integration testing is complete.

The items to be reviewed include:

1. Requirement Changes --

   Any changes to BIT, SIT, or testability requirements contained in the system/CI Software Requirement Specification or Interface Requirements Specification that have not been approved and which impact CSCI testing.

2. Design Changes --

   Any changes made to the BIT, SIT, or testability design parameters contained in the Software Top-Level Design Document (STLDD), Software Detail Design Document (SDDD), Interface Design Document(s) (IDD) since the PDR and CDR which impact CSCI testing.

3. Software Test Plans and Descriptions --

   Any changes to the embedded diagnostic element portion of the approved Software Test Plans (STP) and Software Test Descriptions (STD).

4. Software Test Procedures --

   Test procedures to be used in conducting BIT and/or SIT test effectiveness validation as part of the CSCI testing, including retest procedures for test anomalies and corrections.

5. Integration Test Cases, Procedures, and Results --

Any embedded diagnostic element CSC (e. g., BIT components, SIT components) integration test cases, and procedures used in conducting informal diagnostic element CSC integration tests and the test results.

6. Software Test Resources --

   Status of any software test resources that are required specifically for embedded diagnostic element CSCI testing. Such resources may include diagnostic test personnel and supporting test software and materials, including software test tool qualification and review of the traceability between requirements and their associated tests.

7. Test Limitation --

   Identification of all software test limitations associated with embedded diagnostic element CSCI/CSC testing.

8. Software Problems --

   Summary of embedded diagnostic element software problem status, including all known discrepancies of the CSCI and test support software.

9. Schedules --

   Schedules for the remaining embedded diagnostic element software milestones.

Production Readiness Review (PRR)

This review is intended to determine the status of completion of the specific actions which must be satisfactorily accomplished prior to executing a production go-ahead decision. The review is accomplished in an incremental fashion during the Full-Scale Development Phase--usually two initial reviews and one final review, to assess the risk in exercising the production go-ahead decision. In its earlier stages, the PRR concerns itself with gross-level manufacturing concerns, such as the need for identifying high-risk/low-yield manufacturing processes or materials or the requirement for manufacturing development effort to satisfy design requirements. The reviews become more refined as the design matures, dealing with such concerns as production planning, facilities allocation, incorporation of producibility-oriented changes, identification and fabrication of tools/test equipment, long-lead item acquisition, etc. Timing of the incremental PRRs is a function of program posture and is not specifically locked into other reviews. The diagnostic consideration concerns the use of any of the external diagnostic elements (e.g., ATE) in the production testing environment.

Functional Configuration Audit (FCA)

This is a formal audit to validate that the development of a Configuration Item has been completed satisfactorily and that the Configuration Item has achieved the performance and functional characteristics specified in the functional or allocated configuration identification. In addition, the completed operation and support documents shall be reviewed.

The FCA is normally conducted on a prototype or preproduction item. The FCA validates that the item meets its specified performance requirements and is ready for production and acceptance into Air Force inventory. It is imperative that the diagnostic capability be validated against its specified performance requirements, so that any diagnostic capability deficiencies can be identified and corrected before the item proceeds into production and is then deployed.

Physical Configuration Audit (PCA)

This is a technical examination of a designated Configuration Item to verify that the Configuration Item "as built" conforms to the technical documentation which defines the Configuration Item.

After successful completion of the audit, all subsequent changes to the diagnostic elements are processed by an engineering change action. The PCA also determines that the diagnostic element acceptance testing prescribed by the documentation is adequate for acceptance of the production units by quality assurance activities. The procedures for conducting a PCA are contained in MIL-STD-1521, Appendix H. Sample PCA Certification Attachment Checklists are contained in MIL-STD-1521, Appendix I.

CHECKLIST

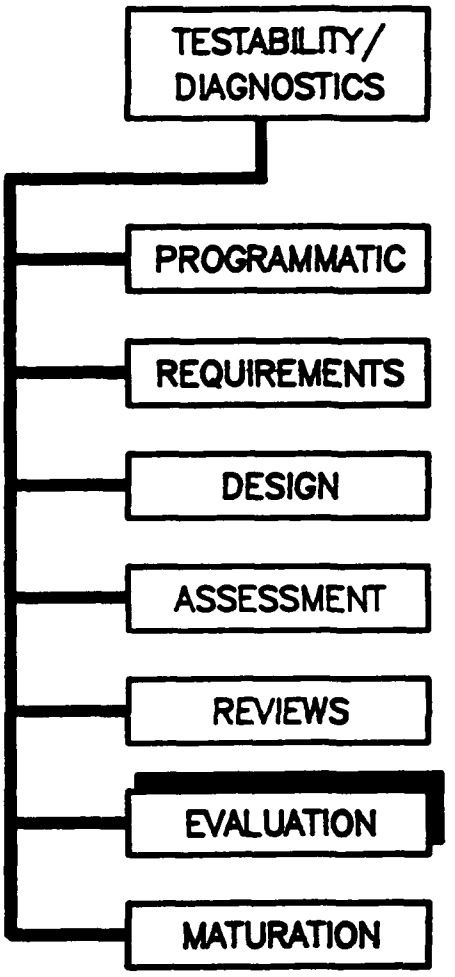
- ☑ Is emphasis being placed on technical interchange meetings between contractor and customer rather than large-scale reviews?
- ☑ Are qualified diagnostic technical experts, who can challenge the design and assess risks, included in these reviews?
- ☑ Are the diagnostic reviews held as an integral part of the prime system review, but in a timely manner that allows change (if necessary) in the diagnostic equipment or process?

CONDUCTING TEST AND EVALUATION

OVERVIEW

During the development of a weapon system, a number of tests and evaluations are conducted by subcontractors, the prime contractor, and the government. Many of these tests address the performance of the diagnostic capability. It is not uncommon that these tests are conducted separately and, thus, do not address the entire diagnostic capability. Oftentimes the entire diagnostic capability is not delivered in time to test and evaluate the diagnostic capability as a whole. During the major tests and evaluations (e.g., DT&E, OT&E) as much as possible of the entire diagnostic capability should be included. Integrated demonstration, test, and evaluation is required.

Coordination of all test and evaluations, including demonstrations, can be accomplished through the preparation of an Integrated Test Plan.



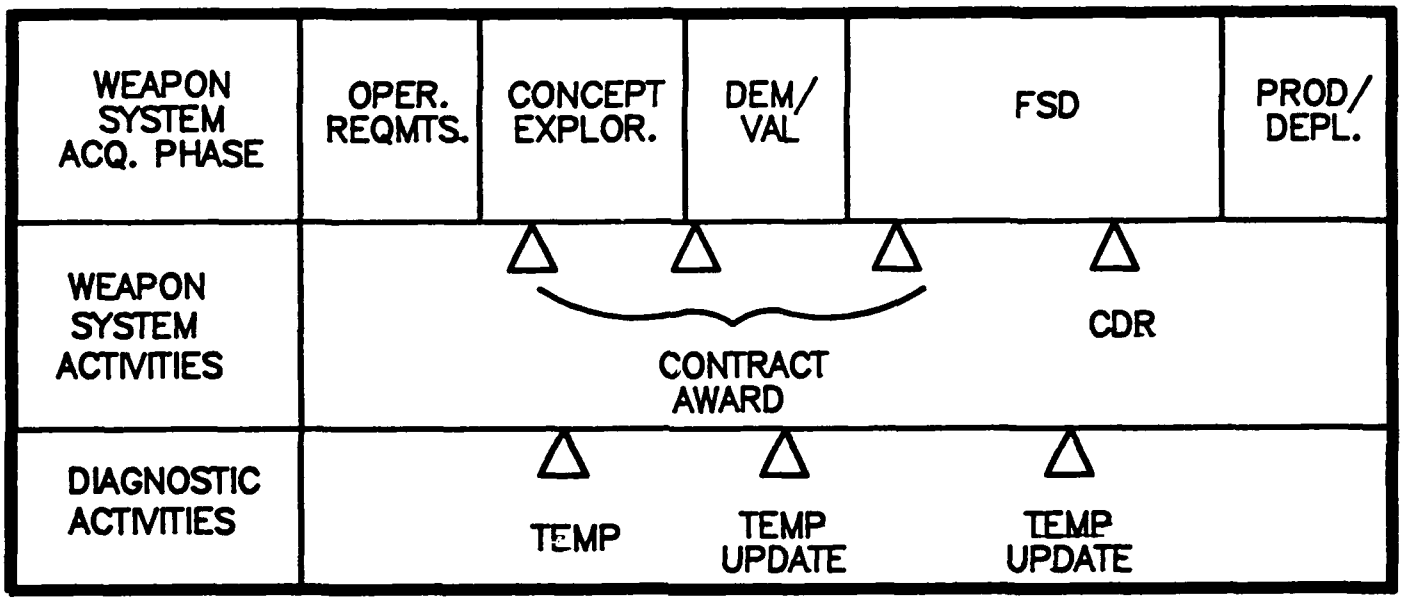
IMPORTANT CONSIDERATIONS BE ADDRESSED

Reqmt.

6.1 Prepare an Integrated Test Plan, which includes the requirements for a Test and Evaluation Master Plan.

6.2 Assure that formal test and evaluations address the entire diagnostic capability.

PREPARATION OF THE TEMP	REQUIREMENT #6.1



DIAGNOSTIC ACTIVITY

The requirements for diagnostics test and evaluation are identified, scheduled and integrated into the Test and Evaluation Master Plan (TEMP) by the contractor.

PROCEDURE

The Contractor Program Manager should ensure that adequate requirements are in place for diagnostics test and evaluation. The TEMP is a living document - its preparation goes through many iterations as the program proceeds through Concept Exploration Phase studies, Demonstration and Validation, Full-Scale Development, Production and Deployment. With each iteration, plans for diagnostic T&E should become firmer, better defined, and with target milestone dates attached.

Because test and evaluation is a major cost and schedule driver, adequate planning is essential long before its start. Test planning between subcontractors, the prime contractor, and the government should start with program initiation. To ensure a successful integrated test program, close coordination is required between the government, the prime contractor, and all subcontractors.

GUIDANCE

DoD Directive 5000.3 requires the preparation of a TEMP. The TEMP is a broad plan relating test objectives to required system characteristics and critical issues, and is a top-level document used at major milestone reviews to assess the adequacy of

planned test and evaluation. The TEMP normally covers only government-required tests, and does not provide a sufficient level of detail to identify contractor and subcontractor tests. In an attempt to control the test program at the contractor and subcontractor level, contracts may contain requirements for the submittal of individual test plans for government approval. If an Integrated Test Plan is not required, these individual test plans may not be reviewed for duplicate or missing test activities, resulting in an inefficient and costly test programs.

The prime contractor should be responsible for the preparation and updating of an Integrated Test Plan (ITP). To develop an efficient and well coordinated Integrated Test Plan, the prime contractor and all subcontractors should jointly participate in its preparation. The ITP should include all developmental tests to be performed by the prime contractor and all subcontractors at both the system and subsystem levels. The ITP should be a detailed working-level document which will aid in identifying risk, duplication or missing test activities, and provide for the most efficient use of test facilities and test resources. In developing the ITP, the purpose and time phasing of each individual test should be carefully examined. Unnecessary tests should be eliminated and test schedules should be adjusted to provide sufficient time for retest, should failures occur. The proper sequencing of tests is necessary to ensure completion of required lower-level subcontractor tests prior to the start of prime contractor tests. Detailed requirements for diagnostics T&E should be included in the Integrated Test Plan. These requirements should be phased T&E of all diagnostic elements and the integration of the elements. The ITP should also include close coordination between all T&E activities.

During Development Test and Evaluation (DT&E) the contractor and the government normally conduct separate, dedicated tests. In many instances these separate test periods result in redundant testing, testing which is not user-oriented, lack of continuity in the contractor's development program, and a lack of cooperation between contractor and government personnel. In order to increase the efficiency of DT&E effort, where possible, should be made to combine tests. This will help eliminate redundant testing, reduce the length of DT&E phases, provide more user-oriented test results, and result in a more mature system for Operational Test and Evaluation (OT&E).

Test schedules should be properly phased and based on development engineering considerations. The purpose or objective of each test should be considered as well as the interrelation of various tests with each other. As test programs progress, many tests will disclose a need for redesign and retest, such as redesign of System Integrated Test (SIT) or Built-In Test (BIT) hardware or software. In some instances only a minor correction and verification test will be required. In other cases the corrective actions may be extensive and require significant retest. If test schedules have not allowed sufficient time for redesign and retest, changes and retesting may be delayed until production equipment is available. If the changes prove incorrect and additional redesign is required, production units may have to be retrofitted and a large number of Engineering Change Proposals (ECPs) may be required during the early phases of the production

program. Also, due to the sequential nature of some tests, the performance of certain tests may be delayed until production, possibly resulting in additional ECPs.

Since the start of certain tests may be dependent upon the completion of others, critical tests should be identified and provisions made for schedule slippage due to needed redesign and retest. In certain cases critical test schedules can be accelerated by providing more test assets or additional test facilities. This strategy can provide significant leverage to reduce the overall development test schedule. Milestone reviews can then be planned on the basis of realistic test schedules. More engineering-oriented test results showing design strengths and weaknesses should be presented at design reviews. The review should discuss design weaknesses and how they have been or will be corrected. The overall success of a carefully integrated test program will result in a minimum of resources applied to testing and the elimination of a costly ECP or retrofit program during production.

In accordance with DoD Directive 5000.3, test and evaluation must begin as early as possible in the system acquisition process to reduce acquisition risks and to estimate the capability of the system under development to meet all technical and operational requirements. Critical test and evaluation issues (to include all effectiveness and suitability issues), objectives, methodologies and evaluation criteria are defined during *the initial establishment of an acquisition program. These criteria serve to define the* testing required for each phase of the acquisition process and provide the structure to guide the testing program. Diagnostics should be established as a critical suitability and logistic supportability issue in order to provide the proper degree of focus on diagnostics T & E. For example, if two-level maintenance is a system requirement, then diagnostics capability is very critical to achieving that requirement.

Testing must be planned and conducted to provide quantitative data and to minimize the need for subjective interpretation of system performance and suitability factors. This requires early planning to determine the number of test articles needed as well as other support resources. The developer and the test and evaluation agencies should share information and data during the acquisition process to establish a data base allowing progressive evaluation of the system.

The use of properly validated analysis, models and simulation is strongly encouraged, especially during development phases to assess the areas which cannot be observed through testing. Use of these methods can provide early projections and can reduce testing costs by supplementing actual test data.

Developmental Test and Evaluation (DT&E) is the T&E conducted throughout various phases of the acquisition process. This will ensure the acquisition and fielding of an effective and supportable system by assisting in the engineering design and development and verifying attainment of technical performance specifications, objectives and supportability.

Developmental Test and Evaluation also includes T&E of components, subsystems, preplanned product improvement (P^3I) changes, hardware-software integration and related software, as well as qualification and production acceptance testing. Test and evaluation of compatibility and interoperability with existing or planned equipment or systems is emphasized. This T&E encompasses the use of models, simulations and testbeds, as well as prototypes of Full-Scale Development models of the system. The diagnostic capability associated with component, assembly and subsystem DT&E should be included in these T&E activities.

Qualification Testing is that part of DT&E which verifies the design and the manufacturing process and provides a baseline for subsequent acceptance tests. This accomplishes two separate functions:

(1) Preproduction Qualification Tests are formal contractual tests that ensure design integrity over the specified operational and environmental range. These tests usually use prototype or preproduction hardware fabricated to the proposed production design specifications and drawings. Such tests include contractual reliability and maintainability demonstration tests required prior to production release. At a minimum, embedded diagnostics capabilities and the interfaces to external diagnostic elements should be tested and evaluated during preproduction qualification tests. As a goal, the capability of external diagnostic elements should also be tested and evaluated.

(2) Production Qualification Tests ensure the effectiveness of the manufacturing process, equipment and procedures. These tests are conducted on a sample lot taken at random from the first production lot, and are repeated as the process or design is changed significantly, and when a second or alternate source is brought on line. These tests are also conducted against contractual requirements. The utilization of diagnostic resources in the manufacturing process and the requirement for capture of diagnostic data from the manufacturing process should be evaluated during production qualification testing.

The completion of Preproduction Qualification Test and Evaluation before Milestone III decisions are made is essential and will be a critical factor in assessing the system's readiness for production.

Operational Test and Evaluation (OT&E) is the field test, under realistic conditions, of any item (or key component) of weapons, equipment or munitions for the purpose of determining the effectiveness and suitability for use in combat by typical military users; and the evaluation of the results of such tests. Operational testing is accomplished in an environment as operationally realistic as possible. The entire diagnostic capability should be assessed during OT&E as well as the integration of the diagnostic capability.

PREPARATION OF THE TEMP	REQUIREMENT #6.1

The Test and Evaluation Master Plan (TEMP) must clearly specify development and operational test events. However, DT&E and OT&E are not necessarily serial phases in the evolution of a weapon system. During critical acquisition cycle transitions, elements of DT&E and OT&E may be combined or occur in parallel, but not at the expense of either development or operational test realism nor before sufficient DT&E can reasonably assure that the system is ready to enter dedicated operational testing. DT&E may continue into the Production and Deployment Phase, along with OT&E, to address system enhancements, correction of deficiencies, or modifications. In all cases, test planning for all test phases must be addressed in the system TEMP.

Test and evaluation planning is initiated at the inception of the development process to ensure adequate planning, programming and budgeting of test resources and to facilitate test scheduling to support major program decision milestones. Reliability assurance should be well underway before the initiation of system performance tests. System deficiencies must be addressed through a dynamic, well-documented, and tightly managed test-analyze-fix and retest program. The evaluation of embedded diagnostic elements should be injected into these reliability assurance tests.

A TEMP is required for all major defense acquisition programs. The TEMP defines and integrates test objectives, critical issues, systems characteristics, responsibilities, resources and schedules for test and evaluation. Test resource requirements must be addressed in the TEMP, along with a critical analysis of any shortfalls that will impede the full test and evaluation of the system. The need for and the availability of the various diagnostic elements which make up the diagnostic capability is addressed in the TEMP. Plans to correct existing or anticipated test resource limitations are also included, as is a listing of evaluation criteria delineating critical parameters permitting continuous oversight and independent assessment.

DoD 5000.3-M-1 contains the guidelines for the preparation of the TEMP. Detailed guidance on the diagnostic inputs to the TEMP are provided below.

Detailed Guidance - Diagnostic Inputs to TEMP

Part I - System Details

Section 2b, Interfaces

Establish diagnostics as a system that is required to accomplish the mission.

Section 3 - Required Technical Characteristics

Include diagnostic performance levels in the listing of key technical characteristics, performance goals and thresholds.

Section 4 - Required Operational Characteristics

Include diagnostics performance parameters as key operational effectiveness and suitability characteristics, goals and thresholds.

Part II - Program Summary

Section 1 - Management

Identify organizational elements responsible for diagnostics T&E.

Section 2 - Integrated Schedule

Ensure Diagnostics T&E are included and conform to System T&E schedule.

Part III - DT&E

Define in detail the diagnostics-related test objectives for DT&E. Relate those objectives to system operational concept.

Section 1 - Critical Technical Characteristics

Discuss the availability of diagnostic elements as it impacts the ability to evaluate the total diagnostic capability. Determine the criticality of the availability of the diagnostic elements. Describe diagnostic workarounds and the risks (associated with those workarounds) being taken by not being able to evaluate the diagnostic capability provided by the integration of all of the diagnostic elements.

Section 2 - DT&E to Date

Summarize diagnostics-related DT&E already conducted.

Describe test articles, with emphasis on how they differ from planned production articles.

Section 4 - Future DT&E

Discuss all remaining diagnostics DT&E planned, including description of system diagnostics and diagnostics resources to be utilized in DT&E. Identify how these differ from the production unit/system and diagnostic resources. Define detailed diagnostics DT&E objectives, DT&E events, scope of testing and basic scenarios. Relate test objectives to test procedures.

Part IV - OT&E

Discuss all planned diagnostics-related OT&E activities and their objectives. Include planning from IOT&E through the FOT&E during initial production and deployment which address:

- o The ability of the diagnostic capability to support operational effectiveness and suitability
- o Identification of diagnostic deficiencies in the production system (including deficiencies in all diagnostic elements).

Include diagnostic OT&E considerations in the following sections.

Section 1 - *Critical Operational Issues*
Section 2 - OT&E to Date
Section 3 - Future OT&E
b. OT&E Objectives
c. OT&E Events/Scope of Testing/Basic Scenarios

Part V - Test and Evaluation Resource Summary

Identify the key resources for diagnostic capability DT&E, OT&E and Production Acceptance Test and Evaluation (PAT&E) that are unique to the program.

Section 1 - Test Articles

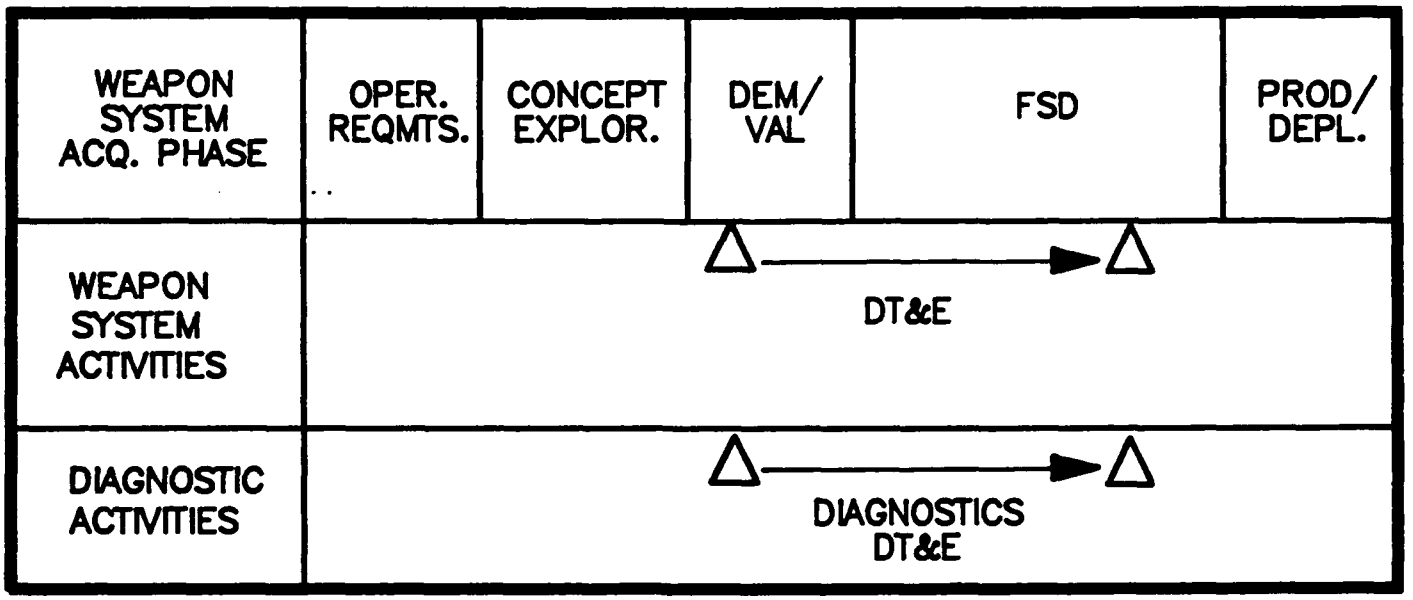
Analyze the system TEMP to identify the actual number of test articles planned for DT&E, OT&E and PAT&E and the type of article planned (prototype, pilot production, production articles). Determine if this is sufficient for diagnostics-related DT&E, OT&E and PAT&E.

Section 2 - Test Support Equipment

Briefly describe the special support resources (instrumentation, test sites, facilities, military maintenance manpower) required for diagnostics T&E, and briefly describe the steps being taken to acquire them.

CHECKLIST

- ☑ Have diagnostics–related inputs to the TEMP been prepared?
- ☑ Is planning for diagnostics T&E consistent with system–level planning?
- ☑ Have all diagnostics–related T&E risks, critical items and special resource requirements been adequately resolved?
- ☑ Does planned diagnostic element T&E relate closely to the actual diagnostic elements to be deployed with the system?
- ☑ Is there a logical relationship between diagnostic T&E activities and the Diagnostic Maturation Program (i.e., are diagnostic T&E results going to be used as a basis for the maturation of the diagnostic capability)?
- ☑ Have all T&E activities been analyzed to assess the feasibility of evaluating the diagnostic capability of the system (e.g., can Reliability Growth Testing contribute any diagnostic related T&E information)?



DIAGNOSTIC ACTIVITY

Evaluate diagnostics performance characteristics during Development Test and Evaluation (DT&E) activities in order to determine diagnostic capabilities achieved and to identify deficiencies in the diagnostic capability. Diagnostics DT&E should also attend to the capability achieved by the integration of the various planned diagnostic elements (performance monitors, BIT/SIT, testing: automatic and manual, maintenance aids, technical information and training (skills)) into a comprehensive, cohesive, diagnostics subsystem.

PROCEDURE

Development Test and Evaluation is the T&E conducted by the contractor throughout various phases of the acquisition process to ensure the acquisition and fielding of an effective and supportable system by assisting in the engineering design and development and verifying attainment of technical performance specifications, objectives and supportability.

Development Test and Evaluation also includes T&E of components, subsystems and preplanned product improvement (P^3I) changes, hardware-software integration and related software, as well as qualification and production acceptance testing. Test and evaluation of compatibility and interoperability with existing or planned equipment and systems is emphasized. Development Test and Evaluation encompasses the use of models, simulations, and testbeds, as well as prototypes or Full-Scale Development models of the system.

GUIDANCE

The thrust of the Integrated Diagnostics Process with respect to DT&E is to include/inject diagnostic performance evaluation into the mainstream of DT&E activities. This is done such that diagnostic performance can be evaluated, deficiencies pinpointed, and corrective action implemented while the system is still in development.

The diagnostics DT&E effort assists the diagnostic design and development process, and verifies attainment of diagnostic technical performance specifications, requirements, and objectives. As such, it is an integral part of the weapon system design process. Through the provision of diagnostics DT&E data, there is a feedback reiterative loop back into the integrated diagnostics activities in process, including the diagnostic system engineering analysis; diagnostic risk analysis, allocation of diagnostic goals; diagnostic trades for system optimization; diagnostic design trades; and the identification and performance of diagnostic design tasks. Through this methodology, the diagnostic design is corrected, improved, or updated, and the diagnostic design matures.

Sufficient diagnostics DT&E must be accomplished before the Milestone III decision to proceed to production. This will ensure that the major specified diagnostics design and development requirements for the Full-Scale Development Phase have been met, with respect to performance requirements and specifications contained in program documents.

The Contractor Program Manager should be as actively involved in diagnostics DT&E to ensure that valid tests are being performed, valid results documented, and valid data accumulated and to ensure that a closed-loop analytic approach is used to pinpoint and correct diagnostic deficiencies. The Contractor Program Manager should also ensure that every opportunity is being taken to evaluate diagnostics-related parameters. This may involve a wide range of test activities, including reliability tests, performance tests, human factor tests, etc. Basically whenever a system, subsystem or component is being operated, it is subject to a failure. The diagnostics requirements associated with dealing with the failure should be viewed as an opportunity to assess the diagnostic capability.

The Contractor Program Manager should evaluate the results and data from DT&E. Based upon the results and data, critical areas should be identified. Appropriate modifications should be made to the TEMP with respect to planning for OT&E activities. Any significant deviations from the Diagnostic Maturation Plan and attainment of specified diagnostic capability levels should be tracked.

The Contractor Program Manager must determine, based upon the scope, basis and results of the T&E activity, what the degree of confidence is that the deployed diagnostic capability will achieve operational suitability and logistic supportability requirements of the system. If either the scope of testing, the basis of testing, or the results of testing are far from the deployed capability, then confidence should be low, and

diagnostics should be identified as a risk item in the TEMP. Specific efforts should be taken to resolve or reduce this risk. Scope of testing here refers to the evaluation of the diagnostic capability achieved as a result of the integration of diagnostic elements across system assembly levels and maintenance levels. Therefore, the full scope of diagnostics T&E is:

The scope of diagnostic T&E should include fault detection and isolation accuracy and timeliness provided by performance monitoring, BIT/SIT, automatic and manual testing, technical information and maintenance aids, maintenance procedures, manpower, personnel and skill levels at the system, subsystem, LRU/LRM, SRU levels across planned maintenance echelons (Organizational, Intermediate and Depot).

Any deviation from this full scope of T&E means that full confidence cannot be ascribed to the planned diagnostic capability.

These factors must be evaluated in terms of their interrelationships also. For example, the Depot-level test capability may be deemed a low-risk, non-essential portion of the diagnostics capability. Suppose then that the false alarm rate proves to be high and the ambiguity resolution proves to be poor. Soon, the Depot capability becomes critical, with large numbers of UUTs awaiting test, and spares supplies being depleted.

"Basis of testing" refers to the extensiveness of test and the procedures utilized for T&E. The basic issue is whether the T&E was performed such that confidence can be ascribed to the results of the test. It is usually unrealistic to plan for exhaustive testing of diagnostics because of the many and varied failure modes to which the system is subjected. Fault simulations and analytic models are often used to evaluate test effectiveness. The Contractor Program Manager must evaluate the meaningfulness and the realism of the "basis for testing."

Even with a reasonably large sample of inserted faults, a demonstration can yield only limited data on actual test effectiveness. However, a demonstration is also useful in validating some of the assumptions and models that were used during the earlier testability analysis, and prediction efforts which were based upon a much larger fault set. If certain assumptions or models are invalidated by the demonstration or T&E activity, appropriate portions of test effectiveness predictions and analyses should be repeated and new predictions should be made.

Diagnostics DT&E requirements are performed in accordance with the System TEMP.

The major approaches of DT&E for diagnostics include actions :

- o To proceed in phase with the system and support equipment development, so that Built-In Test (BIT) is tested and evaluated concurrently with system

performance; BIT and System Integration Test (SIT) tested and evaluated concurrently with subsystem integration and system testing; and, system integration and safety testing are concurrent with diagnostic testing of BIT and SIT features.

- o To implement with the Diagnostics Maturation Program so that deficiencies, ambiguities, and additional failure modes identified during DT&E are recorded in a timely manner to ensure traceability and appropriate corrections are made to the integrated diagnostic procedures.

- o To evaluate embedded diagnostic design as a separate entity in order to assure that it has been incorporated adequately as part of the system design.

- o To evaluate for 100% diagnostic capability in selected critical areas of system design using fault insertion techniques.

- o To analyze the system design hierarchy of test tolerances (e.g., between system BIT and LRU and SRU-level BIT) in order to minimize false alarms.

- o To complete feasibility DT&E on prototype and preproduction units in order to assess technical risks and develop solutions to remedy deficiencies.

During FSD, specific diagnostic capability segments of DT&E efforts include the following requirements:

- o When available, ATE shall be evaluated for initial use supporting build and check-out of systems. Manual procedures and associated operational prototypes shall be developed for support of test activities.

- o Engineering evaluation of the diagnostic elements capability at subsystem and system levels shall be conducted in concert with system integration testing activities, including evaluation tests in the engineering laboratory and system integration test facilities.

- o Effective development of a diagnostic capability requires that testing of diagnostic capabilities proceed concurrently with prime and support equipment development in an orderly and planned time-phased manner. The object of the following diagnostics testing approach is to provide a viable Organizational- and Intermediate-level diagnostic capability for use in support of flight and operational testing activities to provide for early maturation of the diagnostic capability. It should also be a program objective to validate the diagnostic capability, as well as initial reliability and maintainability requirements before production.

- During early equipment development tests, built-in test features should be tested and evaluated concurrently with equipment performance testing. BIT performance is just as essential to overall weapon system performance as the usually emphasized aspects of equipment performance. Simulated equipment failures should be used to assist in BIT testing and evaluation.

- As equipment progresses to subsystem integration and performance testing, BIT and System Integrated Test (SIT) features should be concurrently tested, evaluated, and corrected. Simulated or emulated equipment failures should again be used for BIT/SIT testing and evaluation.

- System integration and safe-for-flight testing of equipment should include diagnostic testing of BIT and SIT features to assure readiness of this capability for Flight Test Support. Concurrently, Organizational-level support equipment required for diagnostic support should be tested to enable its use in the test program, together with Preliminary Maintenance Manuals for Initial Operational Test and Evaluation. Simulation of equipment failures to evaluate diagnostic capabilities should be included in this testing effort.

- Qualification testing of both prime and support equipment shall include validation of diagnostic capability, which is a required aspect of both equipment and system performance. Simulated equipment failures should be included in the diagnostic validation test program. Evaluation of BIT/SIT should also be conducted during environmental extreme testing of the prime equipment and support equipment, to assure its proper functioning throughout the required equipment performance envelope.

CHECKLIST

- ☑ Does the Integrated Test Plan provide adequate detail concerning specific T&E procedures, data bases, models, test articles and scope of testing?
- ☑ Have critical or high risk items related to diagnostic capability been identified and highlighted?
- ☑ Are the necessary test articles available to conduct realistic, timely tests?
- ☑ Is the level of government involvement in diagnostics DT&E adequate to ensure validity of tests performed, results documented, data accumulated?
- ☑ Is there a direct feedback loop in the engineering development effort to deal with diagnostic deficiencies?
- ☑ Has every opportunity to evaluate diagnostics during DT&E activities been identified?
- ☑ Are diagnostics–related DT&E activities consistent with the Diagnostics Maturation Plan?

OPERATIONAL TEST AND EVALUATION	REQUIREMENT #6.3

WEAPON SYSTEM ACQ. PHASE	OPER. REQMTS.	CONCEPT EXPLOR.	DEM/ VAL	FSD	PROD/ DEPL.
WEAPON SYSTEM ACTIVITIES				△ IOT&E	△ FOT&E
DIAGNOSTIC ACTIVITIES				△ DIAGNOSTICS OT&E	△

DIAGNOSTIC ACTIVITY

Diagnostic performance characteristics must be evaluated in a realistic operational environment during Operational Test and Evaluation (OT&E) activities in order to determine diagnostic capabilities achieved and to identify deficiencies in the diagnostic capability. Diagnostics OT&E should focus on the capability achieved by the integration of the various planned diagnostic elements into a comprehensive, cohesive diagnostics subsystem. The Contractor Program Manager should provide any required assistance.

PROCEDURE

Operational Test and Evaluation (OT&E) is the field test, under realistic conditions, for the purpose of determining the effectiveness and suitability of the system or equipment for use in combat by typical military users; and the evaluation of the results of such tests.

GUIDANCE

Operational Test and Evaluation (OT&E) activities include Initial OT&E (IOT&E) and Follow-on OT&E (FOT&E). The results of DT&E activities should be analyzed by the Contractor Program Manager to ensure consistency and continuity of T&E activities. Operational Test and Evaluation (OT&E) must be accomplished by a separate government facility prior to the Milestone III decision. Diagnostics OT&E is performed to provide a valid estimate of the operational effectiveness and suitability of the system's integrated diagnostics design and procedures using test items sufficiently representative of the expected production items.

Major approaches to diagnostics OT&E include:

- o Testing in an environment as operationally realistic as possible
- o OT&E initiated as early as possible during the FSD Phase
- o Testing for adherence to overall OT&E objectives, with respect to diagnostics
- o Continued coordination with the Diagnostics Maturation Program
- o Evaluation for 100% diagnostic capability in selected critical areas
- o Random diagnostics testing in noncritical areas
- o Further analysis of test tolerances related to the system hierarchy and embedded/external diagnostic procedures in order to minimize false alarms.

Testing (particularly operational tests) and data collection should focus on the diagnostics requirements. Testing and data collection should also evaluate the specified parameters; namely, identification of critical failures, the false alarm rate, the percentage of faults detected and isolated automatically or manually, associated repair times, the unnecessary removal rate, consistency of test results, and the adequacy of personnel skills considering all maintenance incidents.

Use of the diagnostic capability that is planned for field maintenance personnel should be required whenever there is a need for system maintenance. This applies to maintenance performed by either the contractor or the user. Thus contractors should use the diagnostic capability in acceptance and qualification tests and in the manufacturing and quality assurance process to the maximum extent possible. In addition to contributing to the maturation of the diagnostic capability, it is anticipated that greater contractor use of diagnostics in these processes could result in production cost savings.

The diagnostic capability should be evaluated with respect to the levels planned and set forth in the Diagnostics Maturation Plan. Based upon the difference between planned levels of capability and actual levels of capability, Diagnostics T&E and corrective action may need to be accelerated or adjusted. (See Requirement #7.1 for more information.)

During OT&E, system performance, operational suitability and supportability factors are evaluated in an operationally realistic environment. There are two types of information that can be obtained for Diagnostics T&E: 1) faults within the system and how those faults were identified (diagnosed); and, 2) faults/deficiencies within the diagnostic capability. For the latter, this includes evaluation of each element which contributes to the total diagnostic capability, as well as the capability, achieved by integration of the

diagnostics elements. Focused, detailed T&E activities discussed in Requirement # 6.2 should be continued. The former type of data can be obtained as a result of Reliability Growth Testing. The following specific information should be evaluated for each fault occurrence.

1. How did the failure manifest itself?
2. Was the manifestation due to stressing of the system beyond normal operational limits?
3. If a BIT alarm occurred, was it the result of a confirmed failure?
4. What techniques were used to isolate the fault?
5. How long did fault isolation take using those techniques?
6. Was the failure mission or operation critical?
7. Was it a new or unplanned failure mode? Was BIT supposed to detect the failure? Did it?
8. Is this failure mode expected to be encountered in the operational system?
9. Should provisions be included in the diagnostic capability to deal with this failure mode?
10. Will this involve a modification/addition to BIT? ATE? Manual Test Equipment? Maintenance Procedures? Skill Levels? Technical Data? Maintenance Aids?
11. Is an ECP required?
12. Is further investigation required?
    If yes - What plans have been made?
    If no - Why not? (brief description)
13. Is correction of the diagnostic deficiency part of contractual requirements? Tied to incentive or warranty provisions?

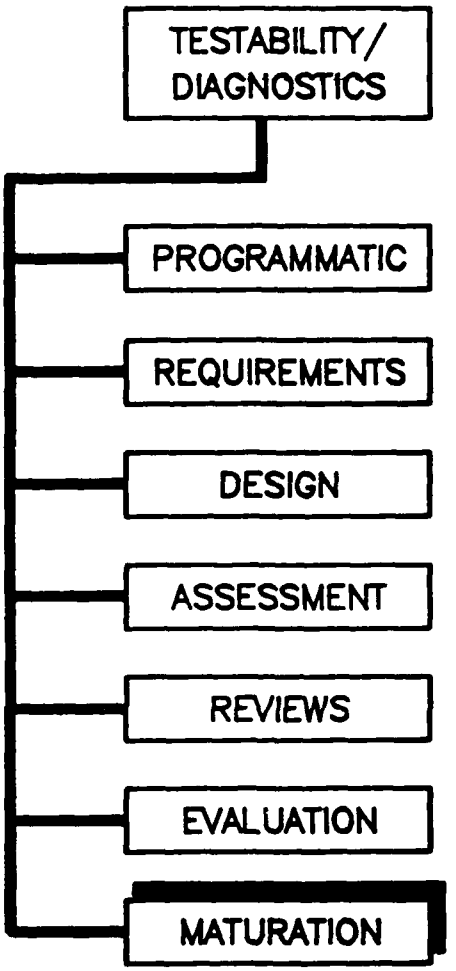
CHECKLIST

- ☑ Are diagnostics OT&E test articles sufficiently representative of the expected production items?
- ☑ Is the diagnostics OT&E environment as realistic as possible?
- ☑ Do diagnostics OT&E plans include evaluation for 100% diagnostic capability in selected critical areas?
- ☑ Do OT&E plans include analysis of test tolerances related to the system hierarchy and off-line/on-line diagnostics procedures in order to minimize false alarms?
- ☑ Is diagnostics evaluation included in a broad spectrum of OT&E activities (e.g., Reliability Growth Testing)?
- ☑ Is the scope of diagnostics OT&E broad enough to realistically do a preliminary evaluation of the fielded diagnostic capability provided by the combination of all the diagnostic elements?

MATURATION OF THE DIAGNOSTIC CAPABILITY

OVERVIEW

Historically, often a weapon system's diagnostic capability does not meet its performance requirements prior to deployment. The basic reason for this is that all faults cannot be predicted and, thus, adjustment of the diagnostic capability is required during the first few years after deployment. Essentially, this requires a well-planned maturation period, which allows for the growth of the diagnostic capability. Closely coupled with this maturation is the requirement for collection and analysis of data relating to the performance of this diagnostic capability, both in the field and in the factory. Care must be exercised by both the government and the contractor to assure that proper and detailed data is collected. Early planning for this maturation period is a must.

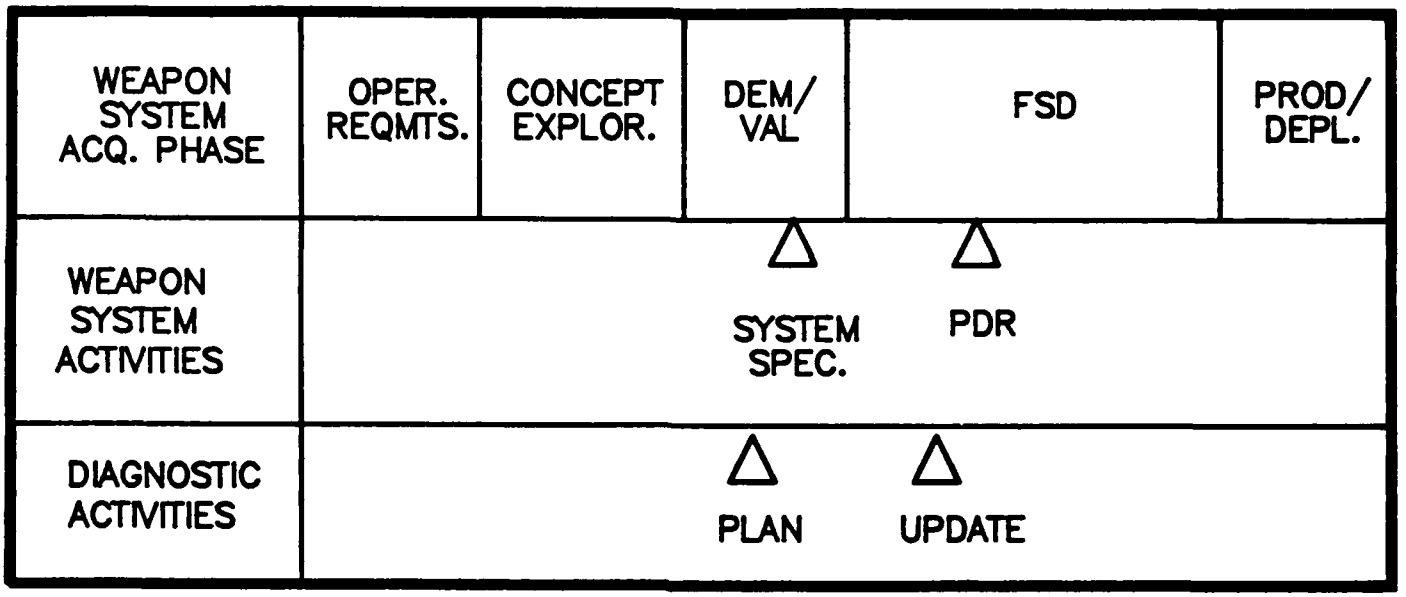


IMPORTANT CONSIDERATIONS TO BE ADDRESSED

Reqmt.

7.1 Prepare a detailed Diagnostics Maturation Plan early in the acquisition process.

7.2 Determine the diagnostic data collection requirement and establish a system for collection and analysis.



DIAGNOSTIC ACTIVITY

Most diagnostic implementations, no matter how well conceived, require a period of time for identification of problems and corrective action to reach specified performance levels. This requirement is established in order to formalize the diagnostics maturation and to allow the maturation to be initiated early in the test and evaluation process. This requirement is initiated early so that early identification, tracking, and correction of diagnostic problems is achieved. The planning for this activity is formalized by the development of a Diagnostic Maturation Plan or other appropriate document.

PROCEDURE

It is the Contractor Program Managers responsibility to prepare the Diagnostic Maturation Plan.

The Contractor Program Manager must ensure that the plan is:

1. Comprehensive

   - o Across all diagnostic elements
   - o Includes the integration of the elements

2. Timely

   - o Is initiated early to plan for the required resources and implement corrective actions
   - o Maturation is completed by Milestone IV, per DoD-Instruction-5000.2

3. Coordinated

   - o Includes coordinated activities from the "ilities"
   - o Utilizes standard data collection systems

4. Cost Effective

   - o Allows data collection to be transferable and usable by government (i.e., DT&E and production test data).

GUIDANCE

A program to mature the diagnostic capability should be planned for the early fielded production systems. A one-to-three-year maturation program should be planned for complex weapon systems which have extensive automatic testing capability. For major weapon systems, the coordination with Milestone IV, Logistic Readiness and Support Review (DoD-Instruction-5000.2) is essential. This program should include provisions for on-site collection of diagnostic performance data, with engineering follow-up to provide corrective actions.

The plan should define an approach and methodology to assure that as development, test and evaluation, and early operational use of the system progress, problems presented by new failure modes, test voids, ambiguities, and test tolerance difficulties are recognized and defined, and their solutions are traceable to diagnostic software and manual procedure updates. The plan should recognize that such occurrences are expected and normal and, therefore, should concentrate on problem recognition, definition, and correction, with appropriate tracking for traceability.

The approach and methodology defined should recognize that a basic element of the integrated diagnostics concept is identification of the set of faults which are known or expected to occur. The methodology shall provide for definition of this set, initially through Failure Modes and Effects Analysis, Testability Analysis, and other tools and experience. Provision for growth of this set, as new failure modes are encountered during testing and deployment, should be incorporated in the plan, together with explicit criteria to be used in deciding whether or not a newly encountered fault shall be added to the set of faults for which explicit diagnostic procedures (as opposed to more general procedures) are provided for detection and isolation of the fault. The life cycle cost effectiveness of adding explicit diagnostic procedures for the newly encountered fault shall be one factor considered in the decision.

The plan should provide for an orderly development and maturation process for diagnostic software and manual procedures throughout the development, test and evaluation, and early operational use time periods of the weapon system and its subsystems. Methodology to assure timely and continuing technical support for this maturation process by both contractor and government activities, with a minimum of

administrative delays, should be a feature of the plan. Orderly transition of technical responsibilities from the contractor to the government should also be addressed.

The plan should present milestones to be met. This will assure that the final system achieves the required degree of diagnostic capability. The plan shall show the time phasing of each task and its interrelationship with other tasks. It should identify required data review, verification, and utilization to accomplish the required tasks and to report progress, problems, and tradeoffs. The plan should assure the proper implementation of diagnostic design features by designers and subcontractors.

This plan will enable the procuring activity to monitor and evaluate the contractor's progress toward achieving the required diagnostic capability through the system design, development, test, and evaluation process. The government may establish contractual incentives for appropriate milestones throughout the diagnostic development, test, and evaluation process. Milestones selected shall include completion of design for testability assessment and other diagnostic system design assessments; completion of diagnostic test element and diagnostic system evaluations, in concert with equipment design evaluation testing at the LRU/subsystem level; and diagnostic system testing, in concert with systems integration test facilities and during the operational test program. The plan should also provide for government evaluation and final acceptance of the automatic test programs and manual troubleshooting procedures in maintenance technical publications.

During the Dem/Val Phase, maturation planning is centered on preliminary planning for data collection, analysis and coordination with similar requirements for reliability, maintainability, logistics, data collection, analysis systems, etc. Specifically, this planning should identify potential data sources, such as:

- o Laboratory testing
- o Developmental testing
- o Operational test and evaluation
- o Acceptance testing
- o Preproduction testing
- o Production testing
- o Operation.

The requirement for diagnostic data collection should be coordinated with similar requirements, such as:

MIL-STD-785

Task 104 - Failure Reporting Analysis and Corrective Action (FRACAS)
Task 105 - Failure Review Board
Task 301 - Environmental Stress Screening
Task 302 - Reliability Development/Growth Test (RDGT)

MIL-STD-470
Task 104 - Data Collection, Analysis, and Corrective Action

MIL-STD-471
Maintainability Verification/Demonstration/Evaluation

MIL-STD-1388-1
Task 501 - Supportability Test, Evaluation, and Verification

MIL-STD-781
Reliability Testing for Engineering Development, Qualification and Production

MIL-STD-2155
Failure Reporting, Analysis, and Corrective Action System

MIL-STD-2165
Task 103 - Testability Data Collection and Analysis Planning

No standard format for the Diagnostics Maturation Plan exists. The plan may be incorporated in another plan, such as the SEMP. The guidance provided above should be completed with the data collection and feedback system (Requirement #7.2) established in the preparation of this plan.

CHECKLIST

- ☑ Does the Diagnostic Maturation Plan include a strategy for the collection of diagnostic performance data through DT&E, OT&E, Production, Initial Operational Use, and Deployment?
- ☑ Are the data sets collected throughout the above periods realistic, comprehensive, and timely? Is there a logical flow through the data sets to be collected so that, as maturation proceeds, data from one period can be logically used in the next?
- ☑ Does the plan include provisions for all diagnostic elements -- embedded and external -- as well as the integration of the diagnostic elements?
- ☑ Is the integration of the diagnostic elements planned for early enough to allow evaluation and cost-effective corrective action (e.g., prior to production go-ahead)?
- ☑ Do the data sets to be collected allow for government capture and use of the data?
- ☑ Are standard government data collection systems utilized?
- ☑ Is there an appropriate degree of coordination with similar requirements (e.g., if Reliability Growth Testing is a program requirement, is data from that testing planned to be coordinated with Diagnostics Maturation)?
- ☑ Are plans and provisions for dealing with subcontractors and vendors in the Diagnostics Maturation Plan?
- ☑ Are configuration control requirements included in the maturation planning for the prime system, as well as for the diagnostic elements?

CHECKLIST (cont.)

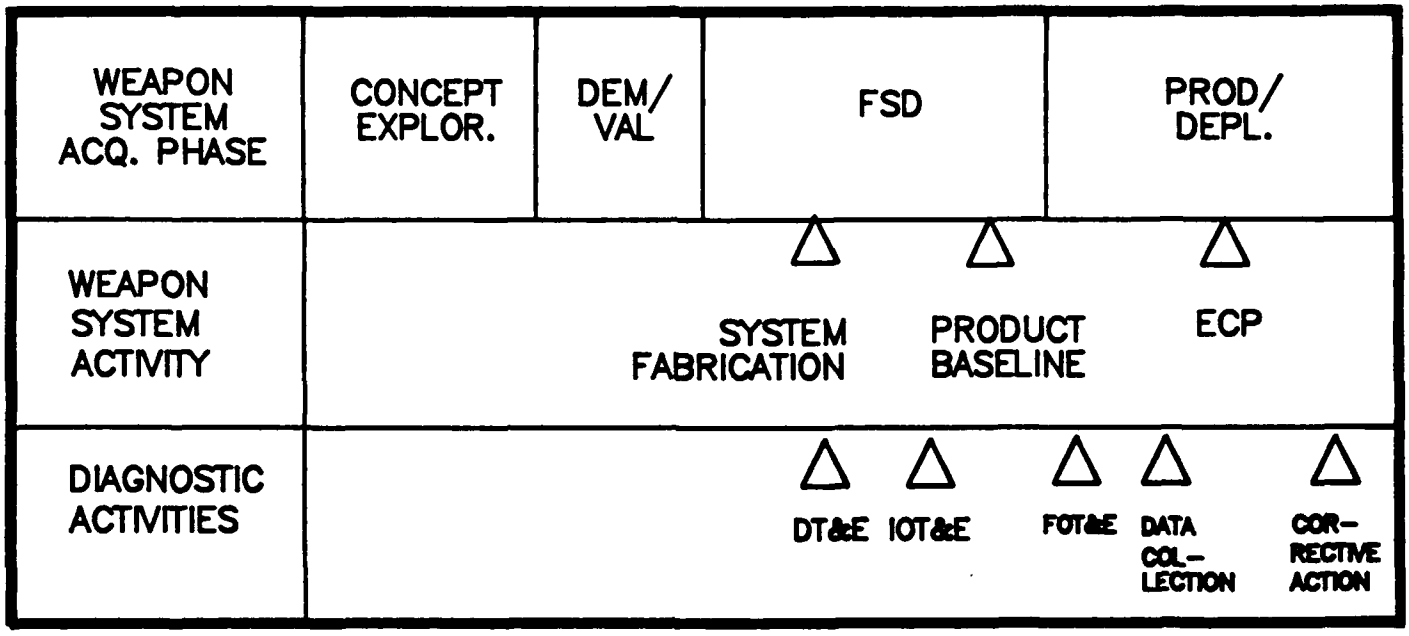
☑ Does Maturation Planning include provisions for both:

1. Adequacy of the diagnostic elements, with respect to the specified allocated capability, and

2. Unplanned failure modes, which may arise throughout OT&E, DT&E, Production Test, and Field Use Test.

☑ Is a structured, closed-loop, analytic process planned for the resolution of any/all deficiencies?

☑ Is it clearly laid out who is responsible for what throughout the various periods of the maturation process (i.e., who (government or contractor) is responsible for: (1) data collection; (2) analysis; and (3) corrective action through DT&E, OT&E, Production Test and Field Use Test).



DIAGNOSTIC ACTIVITY

Data relating to the performance and effectiveness of the diagnostic capability must be collected during development, production, and operation. This data is used as the basis for the evaluation of diagnostics and for the correction of deficiencies.

The key thrust of this activity is definition of appropriate data to be collected, maximum use of data collected, coordination of data collection systems, and a structured approach to corrective action.

PROCEDURE

The Contractor Program Manager is responsible for the implementation of diagnostic data collection and feedback requirements. This includes development and implementation of a cradle-to-grave system for both contractor and government use.

The earlier diagnostic performance deficiencies are identified, the sooner a more cost-effective solution can be implemented. Therefore, diagnostic data collection and feedback is initiated early in the test and evaluation process, continues through production test, and extends into the operational environment. Throughout these phases, different types of data are collected, different data collection procedures and methodologies are used, and different types of analysis technique are conducted.

GUIDANCE

There are no standard methods for data collection and analysis. As indicated under Requirement #7.1, Maturation Planning, the collection of this type of data is controlled by a number of military standards. The requirements for the standards which deal with logistics, reliability, maintainability, testability, human engineering, and safety overlap one another (many times data required by one may, indeed, be required by the other(s)). Thus close coordination among these various data requirements is needed. A single data base is desirable.

In addition, these data systems are required during system development, as well as after the system is deployed. There must be compatibility between the contractor's data system and the follow-on government data system, so that traceability exists from cradle-to-grave.

The data collection procedures closely follow the test and evaluation functions. As explained in DoD Directive 5000.3, Test and Evaluation, the time periods and sequences for Development Test and Evaluation and Operational Test and Evaluation vary from program-to-program. They can overlap and even be done as a combined test and evaluation. Thus there are no standard guidelines that specify the exact points in the weapon system acquisition phase where data is to be collected. The system must be flexible to incorporate data as data is generated.

The Contractor Program Manager should ensure that the proper data is collected and that corrective actions are pursued. Care must be taken to collect only that data required to assure that the diagnostic capabilities are performing as required. Automated data collection systems can be employed. Usually these are more effective, as they are less dependent on human motivation to supply the required information.

Corrective analysis and actions should be in a closed-loop system, so that each deficiency identified remains an open item until it is formally documented as being corrected.

The data collection and feedback system should be designed so that specific information is collected on the performance of the entire diagnostic capability, as well as for each of the diagnostic elements that make up the diagnostic capability. The information must be collected in quantitative form, if possible, and related to System Specification requirements. Thus the following guidelines on the type of data to be collected need to be tailored so that the information can be related to System Specification requirements and so that it is clearly apparent who is to supply the information and when this information is to be supplied. Examples of the type of data to be collected follow.

Diagnostic Data Feedback

- o Effectiveness and efficiency of each diagnostic element
- o Effectiveness and efficiency of the diagnostic elements as an integrated system
- o Operational/support impact of the diagnostic deficiencies
- o Corrective action(s) which should be taken or have been taken.

BIT Effectiveness

- o Fault isolation time.

Tracking of False Alarms

- o Type of alarm
- o Frequency of alarm occurrence
- o Cause (if known)
- o Potential consequences of ignoring the alarm (crew safety, mission reliability)
- o Operational costs of responding to false alarms (aborted missions, degraded mode operation, system down time)
- o Support costs associated with the false alarm
- o Operational environment when alarm occurred.

ATE Effectiveness Feedback

- o Workarounds required to overcome mechanical or electrical deficiencies in the UUT/ATE interface
- o Consistency of ATE FD results with initial BIT indications
- o Repeatability of ATE test results
- o Ambiguity size
- o Fault isolation time.

Integration of Diagnostic Elements

- o Consistency of diagnostic resources with the training/skill levels of assigned personnel?
- o Effect of false alarms and unnecessary removals on operational availability and maintenance workload
- o Shop throughput
- o Adequacy of technical information
- o Logistic delay time
- o BIT reliability
- o ATE reliability.

Diagnostic data collection and diagnostic capability performance assessment may lead to the requirement for corrective action. Corrective action may involve redesign of prime equipment, test equipment, interface devices, maintenance documentation, built-in test circuits, diagnostic software, and ATE test programs. All changes must be made under strict configuration control.

CHECKLIST

- ☑ Has the data collection system been designed to collect only the required data? In quantitative terms?
- ☑ Are the government, contractor, and subcontractor data collection systems compatible?
- ☑ Is there direct communication back and forth between the person who reports a problem and the person who is responsible for correcting the problem?
- ☑ Will all known failures be reported?
- ☑ Will all failures be analyzed to sufficient depth to identify failure causes and necessary corrective actions?
- ☑ Will all failure analysis reports be closed out within 30 days of failure occurrence or rationale provided for any extensions?
- ☑ Will corporate management be automatically alerted to failures exceeding close-out criteria?

LESSONS LEARNED

DESIGNING A NEW SYSTEM

I. INTRODUCTION

A young Air Force technician assigned to maintain one of today's sophisticated weapon systems is on his way to another day of work. As he travels his prescribed route, he reflects on the intricacies of the equipment with which he works. He sighs in amazement regarding how easily and accurately he knows what to replace when things go wrong.

Shortly after arriving at his duty station, he enters his code at a computer terminal and is provided with a work order for his first task of the day. The work order concerns a malfunction which was detected during a flight completed just one-half hour earlier. A quick glance at the work order reveals which system failed, what time it occurred, and the Line Replaceable Unit (LRU) which is to be replaced to correct the problem. After a quick trip to a supply point for a serviceable LRU, with tool box and checklist in hand, he departs for the flight line. The defective LRU is changed within minutes after his arrival. A quick operational check, using the checklist and on-board test system, confirms that no other failures have occurred, and the system is declared operational.

Back at the intermediate shop, the flight line portion of the work order is closed. This is quickly done, with a minimal amount of information input at the computer terminal regarding the work accomplished. The defective LRU is placed on its corresponding automatic test equipment (ATE). Keys within the LRU provide identification information to the computer contained within the ATE. Failure conditions and symptoms recorded on-aircraft at the time of the failure are also transferred to the ATE computer via the computer network. The ATE rapidly goes through a set of tests specifically tailored to the reported failure conditions and the failed single component is identified.

The failed component is replaced with a new component obtained from the bench stock located within the shop. After being checked again with the ATE to verify serviceability, the LRU is given a quality control inspection and returned to the supply point, where it once again becomes a serviceable asset.

The above scenario (or parts thereof) has been a goal of military services for many years. Great strides have been made in diagnostics toward its achievement, yet even total success in limited areas does not lie immediately at hand.

The reasons that success is fleeting are many. They include budget constraints, a relative lack of importance, political considerations, time, and the complexity of the task--just to mention a few. This appendix presents a few glimpses of diagnostic activity on recent programs, results obtained, and lessons learned.

The information presented is a composite of program experiences derived major aircraft systems, as well as, strategic missile systems.

A. Contractor Program Manager Concerns

Experience has shown that Contractor Program Manager difficulties in obtaining good diagnostics lie in two main areas. The first is succeeding within man-derived constraints, which limit the emphasis, the amount of resources which can be applied, and program efficiency related to diagnostics. The second major area of concern is the technical difficulties involved. Specifically for the Contractor Program Manager, this relates to the development of a clear understanding of diagnostics requirements and assuring their achievement in the hardware/support system design.

Both of the above areas are demonstrated in the following pages of this document.

B. Time Frame

This appendix presents lessons learned information from all phases of an equipment's life cycle, in consonance with the scope of the Program Managers Guide, to which it is attached. As such, it describes activities which may have taken place over the last 20 years, or more, even though we are mainly addressing recently deployed weapon systems.

C. Constraints, I. e., Time, Money, and Political

The lessons learned described in this document, in almost every instance, have something to do with trying to succeed within constraints imposed on the program due to limited resources and other political considerations. One major aircraft program poses an excellent example of the usual limited resource problems, compounded by political decisions not in the best interest of the program. The original development effort was accomplished from 1971 through 1977, at which time the program was canceled. Four-and-one-half years later, in March 1982, the program was reinstated. In order to make up for lost time, a concurrent Full-Scale Development and Production Program was contracted. The initial expectations were that the earlier effort would allow for this concurrence. The reality was that there were hardware changes and other development efforts required which, if time had permitted prior to production, would have resulted in fewer production problems and better diagnostics at first deployment.

II. INTERPRETING/ENFORCING REQUIREMENTS

What is specified in the procurement specification and the contractual Statement of Work is what the government expects to receive. In the area of diagnostics, the government experience on past programs has not been the best. Systems have been introduced into the inventory with diagnostics that have proven to be incomplete, unable to test to the desired level, or simply do not operate as advertised. The basic foundation upon which all other successes or failures are directly dependent is the clear understanding of the actual requirements.

A. Need Statements and Work Statements

All of the programs surveyed in the preparation of these documents seem to have an item in common dealing with their diagnostic requirements. That commonality factor is that the quantitative diagnostic requirements imposed are derived without a great deal of thought and analysis. Typically, diagnostic requirements are more what has been judged by someone to be realistic values, rather than a product of the various studies performed to determine these requirements.

DoD-Instruction 5000.2 and other related documents describe a structured acquisition process beginning with, among other things, the development of a Mission Area Analysis and a Mission Need Statement. Included in the Mission Need Statement is a discussion of the Mission and Threat, Alternative Concepts, and Technology involvement. Subsequently, during the Concept Exploration Phase, studies are conducted to develop a System Concept Paper which more thoroughly defines possible alternatives, and a selected concept. Many items are taken under consideration during this time frame including readiness, maintainability, manpower and training.

It is this process which generally drives the development of the procurement specifications. These functions are primarily the concern of Contract Program Manager however inputs are sometimes requested from the contractor. Failure to consider testability when providing these inputs may limit chances for successful diagnostics implementation later in the program. Overall diagnostic and testability in general should be given more concern at this early stage of development.

B. Cost-Effective Requirements

Specifications sometime create requirements either greater or less than those actually required to meet the needs of diagnostics. This is very expensive, from a taxpayer's point of view, considering that excessive requirements increase costs in every acquisition phase, i.e., development, procurement, and support. Specifications which impose values less than those required to fulfill the basic need of diagnostics, cause excessive costs, mainly in the operational phase. These come from developing work

arounds, not being able to fulfill mission needs, and driving more assets into the repair and support system.

MIL-STD-1388-1A (Logistics Support Analysis) describes specific tasks to be performed to develop those considerations. These tasks include a use study, a comparative analysis with existing systems, consideration of standardization, investigating technological opportunities, and trade-off analysis. This process is geared to the development of specifications which is driven by inputs performed under the previous contract phase.

This Standard, issued in 1983, was not available to be imposed on any of the programs covered by this appendix. However, judging from programs developed using the MIL-STD-1388-1A process, it is a consensus, that improved diagnostics requirements and program plans would have resulted had this process been available. the Contractor Program Manager plays a key role in this process by ensuring that tasks performed under this standard are completed and submitted in a timely manner. It is an iterative process of definition, synthesis, trade-offs, test, and evaluation which influences requirements for the next phase of the contract. A good point to remember is that it is very difficult for the Contractor Program Manager to proceed to the next phase while waiting on inputs from the present phase.

C. Specification Interpretation

The proper diagnostic specifications necessary to meet the mission need is one thing. Describing them in such a way that they will be interpreted properly is another.

The following is one of the diagnostic requirements imposed on the aircraft developer. The On-Board Test System shall provide an assurance of 95% to the aircrew that the system performance is operationally acceptable or that the indicated failure is valid during in-flight performance and ground readiness tests. It shall provide fault isolation to an LRU, with a certainty of at least 75% in the ground fault isolation mode."

Another requirement stated that "false alarms could not exceed 2%." Both seemingly good requirements, but two problems ensued in their accomplishment. First and foremost was the problem in the definition of the percent base. Percentages are often used in defining requirements. But when so used, it must be stated as a percent of what. False alarms, as a percent of the possible alarms, give one result. False alarms, as a percent of the number of total alarms indicated, give another. When written, one must assume that achievement based on the definition of the writer would meet mission needs. In reality, when achieved based on a legal and implied definition, the results were far from those required by the operational command.

A second problem, but in this case a lesser problem, was a conflict between the requirements. The first requirement above allows a 5% false alarm rate (100 minus the 95% accuracy). The second allows only 2%. Specification ambiguity leads to interpretation which will not necessarily end with the desired result.

III. STRUCTURING DESIGN CONCEPTS/CONSTRAINTS

A. Controlling vs. Constraining the Contractor

Today's trend in specification and contractor direction is to provide the contractor with the maximum leeway in meeting specified requirements. The objective is to allow the contractor to define alternatives, select from the alternatives those which he can best implement, and provide a product which meets all of the requirements.

Existing systems covered by this document were all developed under a more structured specification approach. The previous school of thought was, generally speaking, that the more things which can be controlled by the specifications, the more chance the end product will be produced as desired. Experience with that approach has led to the more open trend. This is because the tighter approach did not allow the contractor to make maximum use of his many possible alternatives.

Good, easy, and frequent communications between the customer and contractor diagnostics personnel is a must. A specific item, noted almost unanimously with personnel, is the importance of the function provided on that program by devoted diagnostic managers in both the Air Force and customer organizations. The shortfall, however, was that these managers did change from time-to-time. On long programs this is to be expected. The lesson to Contractor Program Managers is to provide for these changes. Close coordination with potential backups and well-documented decisions will minimize upsets due to personnel changes.

Another important point noted was that these diagnostic managers need some very special skills besides those of a skillful manager. Each should be an experienced engineer, with a thorough understanding of the hardware involved, diagnostic methods, and support concepts.

B. Establishing and Designing to the Maintenance Concept

The logistic support analysis tasks of MIL-STD-1388-1 which are concerned with the development of maintenance concepts and constraints are very important for the diagnostics community. The Contractor Program Manager should ensure that these tasks are completed, as appropriate, and that the resulting maintenance concept is well understood by all. The MIL-STD-1388-1 tasks are structured to ensure consideration of

existing resources, compatibility with deployment and operational requirements, and the use of trade studies.

The tie between the diagnostic method and the maintenance concept is bidirectional. They need to be established in unison. The maintenance concept is developed based on expected diagnostic capabilities. The diagnostic design ultimately forces the real maintenance concept.

Established Air Force maintenance policies generally utilize system operation as the final determinant of the need for maintenance. If the system is functioning within tolerance, don't fix it. A unique situation has developed on the aircraft. Due to redundancies designed in the systems, overall operation appears to be normal, while some specific parts thereof are not functioning as they should. The diagnostics says these parts should be replaced. System operation appears to indicate everything is OK. To date, partially due to the lack of confidence in the aircraft diagnostics and partially due to established habits, often these type malfunctions are not being repaired. Generally the diagnostics is believed to be faulty and no maintenance action is taken until something else happens to make the system inoperative.

This experience shows that changing existing practices is slow. If it is confused with the lack of confidence in the diagnostics, the change is even more difficult.

The logistics manager, ATE manager, and automatic test equipment designer are all vital elements in determining what off-equipment testing is required. Once the option for automated testing is confirmed, the ATE designers must convince the Unit Under Test (UUT) designer to incorporate "design to" criteria for maintainability, reliability, and testability. Care must be taken to define the need for ATE, how the ATE is to be used, how the UUT will be designed for built-in test, and interfacing abilities. ATE effectiveness is directly and immediately dependent on this co-development with the UUT.

IV. Meaningful Prediction and Assessment Methodology

In-process assessment of diagnostics achievements has, in the past, been less than adequate. In fact, one of the most definitive and often repeated lessons is the need for an operational period to mature the diagnostic design. That lesson is described in paragraph VII below. Prediction and assessment techniques have, in the past, failed to provide sufficient information to uncover all of the inadequacies and shortcomings. Significant emphasis is currently being placed on testability analysis, reliability, and maintainability assessment tools under the umbrella of Computer-Aided Acquisition and Logistics Support (CALS). With that emphasis, one should expect great improvements in assessment techniques. The point for the Contractor Program Manager on this subject is

to ensure that predictions and assessments performed are sufficient to demonstrate that diagnostic requirements are being fulfilled.

A. Methodology

The CALS initiative would include diagnostics design as an integral part of the CAE/CAD design. The concept is that rules and techniques would be established in the computer workstation. As a specific item is designed, it is constantly checked for test access, built-in test capability, and other established rules.

This concept works fine for evaluating the diagnostic characteristics of a single electronic assembly. Evaluation of a weapon system's on board test system is another question. For the above aircraft, a complete integration lab was developed to test the diagnostics software in a functional environment. That process was useful, but still under the best of lab conditions some things cannot be developed to the optimum level. An excellent example is the philosophy for checking the thrust of a jet engine. Simulated lab conditions equate more to an aircraft being on the ground where thrust is compared to a reference schedule of gross thrust versus turbine blade temperature at two discrete operating points. These two operating points are the intermediate and maximum power setting. To develop an in-flight thrust check, a reference has to be calculated to monitor performance across the entire power range. This reference is obtained by comparing the engines in synchronization to one another in flight. This reference requirement, plus many preconditions necessary for calculating or examining thrust, dictates actual flight testing for development of a valid check.

B. Review and Feedback Structure

Time and management emphasis are both needed to assure that the design benefits from the assessment process. Logically, one does not need a whole lot of experience to understand this. However, it was proved once again on the aircraft. Concurrent Full-Scale Development and Production meant that funding for studies and analysis occurred so late that the results could not be implemented.

Management direction is also needed or results will go unheeded. If the decision is between getting an aircraft into the air on schedule or improving the diagnostic capability, what will the Program Manager's decision be?

V. DESIGN REVIEWS

Formal Design Reviews provide the opportunity for the customer to accept what the contractor is offering or insist on improvements. If the contractor can demonstrate that he is meeting the specifications, the customer can ask no more. At this point, it is the role of the Contractor Program Manager to assure that sufficient analysis has been performed,

prior to design reviews, which demonstrates with a high degree of confidence that diagnostic requirements are being met.

A. Scheduling

It's either too early or too late. Picking the optimum time for reviews is very important. Reviews need to be conducted after the design is sufficiently defined to make the evaluation (the type of evaluation being determined by the type of review), but before it is too late to make changes.

The only identified lesson learned from experience is that the scheduling for formal reviews is typically performed at the beginning of the program. The stage of the design for the review is then whatever it is at the scheduled time. This is not necessarily bad, because typically the designers work toward having a reviewable product on the established schedule. Usually, reviews cannot be delayed without jeopardizing delivery schedules.

B. Format

Diagnostics usually involve the "whole" picture. This should be considered in developing the review agenda. Prior to the diagnostics portion of the review, a full understanding of the hardware/software design and maintenance concept is required.

C. Contractor Emphasis

Messages are sent to the contractor telling him where he should put his emphasis, based on the importance an item has in the review. If the Government program Manager and his review team place little emphasis on diagnostics, the contractor gets that message and typically follows suit. A sure fire way to hinder the progress of the diagnostic design team is to indicate to the Contractor Program Manager that diagnostics are "not important." This has often been done unintentionally, in the past, by quickly passing over the subject in the review, or otherwise indicating a minimal concern. The Contractor Program Manager must emphasize the importance of diagnostics, especially in case the Government Review Team has placed little emphasis on the subject.

VI. Demonstrations

Demonstrations are, in general, another form of a formal review. Thus most of the points made in the previous section also apply here.

A. Timeliness

The opportune time for final demonstration of diagnostics does not exist, if a purpose of the demonstration is to identify corrective actions. Efforts to schedule demonstrations early enough to minimize the impact of "failure" have, in the past, resulted in the simulation of too many conditions and resources. To perform a complete diagnostics demonstration, all operational diagnostics tools must be in place. This includes support equipment--if appropriate--training, technical publications, and any other applicable diagnostic tool. Attempts to simulate or work around the absence of these operational items does not provide for a complete demonstration.

B. Simulated vs. Operational Conditions

The problem can be demonstrated by experience with a recent modification program on a fighter Attack Radar. The modification was major--mainly made to improve reliability and maintainability. One significant portion of the modification was the rework of the built-in test (BIT) capabilities.

The design job seemed to be done very well. Design Reviews were passed. Demonstrations of the new BIT performance in the laboratory exceeded the specifications and expectations. All looked like a job well done, and the contract was considered complete.

The problem was that on the aircraft, in operational conditions, the BIT does not do so well. The BIT serves two functions, one being to advise the aircrew if the selected mode is operational, the other serving as a diagnostics aid to maintenance personnel. The aircrew function performs well, which is not surprising, being part of the basic operational requirement. However, the diagnostics portion of the software used in the fault isolation process has required extensive rework. At first glance, one is led to believe that the simulated and operational conditions must differ greatly. This being the case, how does one explain that problems reported during field operations can later be demonstrated under laboratory conditions? Simulated conditions may in fact create problems at times, but like in this case, why do they generally appear in the area of diagnostics? Performing demonstrations with the primary objective of showing operational requirements are being fulfilled, with diagnostics given secondary concern only delays finding problems in that area. An important point to remember is that diagnostics must be given equal consideration to operational requirements and the Demonstration Phase is another chance to identify this problem.

C. Providing for Resources

Scheduling/obtaining resources for the demonstration is an early program function. This requirement has often been overlooked or minimized in the past. Contractor Program Managers need to be fully aware of the demonstration plan/requirements and assure that they are included in the very earliest top-level planning documents.

VII. MATURATION

Maturation is a phase which has been identified as necessary primarily during development of new systems/technology for the embedded and external diagnostic capability. One especially critical area for these systems is the inherent requirement for testing under actual operating conditions. Maturation becomes necessary to refine test method/fault limits/diagnostics logic embedded within the diagnostic software programs that operate these systems. The predicted operating characteristics of the various on-board systems must be compared to the operation of these systems as they interface with other systems and during varying environmental conditions.

A. Early Planning

The Contractor Program Manager lesson demonstrated is to plan for considerable time and resources to allow maturation. The original development plan was to mature the diagnostic system on 70 FSD flights. That would, it was thought, provide a mature system at the time of the first deployment to an Air Force Main Operating Base. Early in the Full-Scale Development Phase, it became evident that that plan would not be sufficient. A new plan was developed to use 468 sorties over the years 1985 and 1986. The wing did not fly the required number of sorties over that time period and the program was extended through November 1987. Additional aircraft deliveries and an increase in sortie generation rate produced a total of 1060 sorties by the end of that period. With that number of sorties, sufficient data had been gathered to indicate a more-than-acceptable level of performance. At this point, it is estimated that as a general rule, at least 400 to 500 sorties will be required to mature an on-board test system.

B. Operational or Flight Test Environment

How does one plan for 500 sorties prior to production? Is a plan to fly four FSD aircraft on the average of once every three calendar days for a year reasonable? Is a limited production block appropriate for maturation? These are questions for which the Contractor Program Manager must get answers early in program planning.

Experience has identified one additional consideration to be included in making these planning decisions. That consideration is the impact a partially working diagnostic

system has on the maintenance technician. If technicians lose confidence in a diagnostic aid, they will not use it. Further, it is hard to convince them that the item has been improved and that now they can have confidence in it. Many maintenance technicians, who have been exposed to inaccurate diagnostic methods, have never been convinced to use an "improved" version. All operating bases may have the same current version of the diagnostic systems. Field data shows, however, that the bases exposed to the earliest and poorest version continue to have the highest false alarm and cannot duplicate maintenance rates. This is due to the lack of trust still carried from the early experience. Thus it is important to arrange for maturation away from the majority of operational technicians, if possible.

C. Implementing Maintenance Concept

Special training will need to be provided, if the maintenance concept utilizing the planned diagnostics is significantly different from that with which the established technician is familiar. Trends are also in place today to isolate to and replace modules on the aircraft rather than the large "boxes" of the past. Utilizing the diagnostic indication produced during the flight, without further ground verification, is also a current trend. Each of these "new" concepts must be thoroughly understood by the technicians, so that the maturation results are consistent with the planned fielded maintenance concept.

VIII. SUMMARY

Diagnostics must be a simple matter, since everything always works at the end of the program. However, this is not the case, and the perfect situation portrayed in the Introduction has yet to be achieved. Instead of the capability to identify the one LRU, often the ambiguity group is as much as four LRUs. The ATE which can isolate the failure to a single failed component would be the ideal solution, but more likely than not, it will only be to one or sometimes several shop replaceable units (SRUs) or a particular group of SRUs. The steps covered here are only some of the very basic ones required to ensure good diagnostics. However, looking at many different programs, one finds even these simple steps have been omitted, or perhaps accomplished at a time too late to have the desired results. The reasons are many: poor communication of needs or goals, time frame restrictions, money, and failure to properly consider the importance of diagnostics. To ensure diagnostics, it must be addressed at all phases and be given equal importance to other performance requirements. If the system cannot be maintained, it can never meet its operational requirements.

Many people were queried in the development of this document. Most expressed very similar lessons learned.

CHECKLIST

- ☑ Does the contractor have one specific person responsible for managing all the diagnostic activities?
- ☑ Does the person filling the above position have a good understanding of logistics, system design, and diagnostics over and above those skills required of a good manager?
- ☑ Have procedures been established within the organization to facilitate communication on a frequent basis among the individuals involved in diagnostic design?
- ☑ Is the timing for the various diagnostic studies and analyses adequate for assuring that results can influence the diagnostic design?
- ☑ Have proper priorities been demonstrated at all levels of management on both the government and industry sides to demonstrate that the management of the diagnostic design is really an important function?
- ☑ Are the diagnostic specifications well defined and represent exactly what is needed?
- ☑ Has sufficient time been allocated for the maturation of the diagnostic capability?

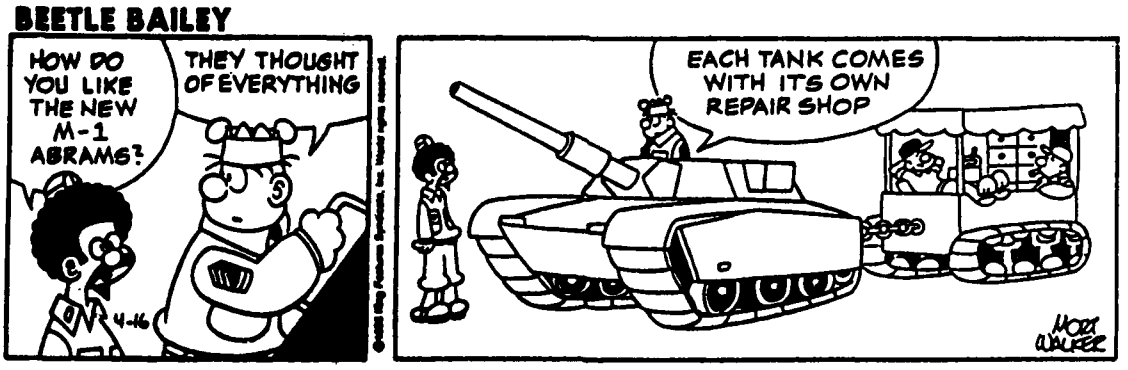
LESSONS LEARNED

RETROFITTING AN EXISTING SYSTEM

I. INTRODUCTION

This guide stresses the need to "design-in" the weapon's diagnostic capability as the design of the prime hardware and software progresses. The concept being "do it right the first time." Unfortunately, the possibility of addressing the design of the diagnostic capability beginning at Concept Exploration and following through to Deployment is becoming less and less possible. New starts are becoming less frequent and modifications to existing systems more prevalent. In addition, retrofits to existing weapon system diagnostic capabilities will continue to be required. The capability to design or improve the diagnostic capability, beginning at any point in the acquisition or deployment of a weapon system, is a must. Thus, the following example of the M-1 Abrams tank.

Deficiencies in the diagnostic capability of the M-1 led to the initiation of an Integrated Diagnostics Improvement Program which is a positive example for improving the diagnostic capability after-the-fact. As with the M-1, dissatisfaction with a fielded diagnostic capability is not limited to just the user. It becomes a technology issue, a cost issue, and certainly a political issue. In the case of the M-1, the maintenance issue became a national issue, draped in negatives.



To develop and implement the necessary improvements, a Joint Working Group for Integrated Diagnostic Improvements was formed with a charter to develop a system engineering approach to the improvement and integration of its diagnostic capability. For

an existing system with diagnostic problems, redesign of the system or subsystems to include testability is a potential solution. Other potential solution areas include improvement of the fielded diagnostic elements, such as test equipment, test programs, test procedures, technical information, maintenance aids, maintenance personnel skill levels, etc. The costs and benefits of these potential solutions must be carefully analyzed. Integration among the diagnostic elements also must be maintained or achieved.

II. SUMMARY OF DIAGNOSTIC PROBLEMS

The first order of business for the Joint Working Group (JWG) was the development of integrated diagnostic improvement objectives and development of a roadmap to achieve the objectives. The JWG objectives are listed below:

- Resolve diagnostic problems related to support of Abrams
- Identify cost-effective solutions to the problem(s) that complement short-term fixes
- Ensure that the diagnostic concept supports future Air Land Battle Doctrine
- Communicate lessons learned to combat/material developers.

The JWG defined their scope of effort to include the man, test equipment, technical information, training and tank interfaces (for embedded and nonembedded diagnostics).

The JWG developed a list of Abrams problems related to diagnostics. The JWG categorized problems according to embedded and nonembedded diagnostic elements. Prioritized embedded diagnostic problems are presented below. Limited Built-In Test (BIT) for the entire vehicle is the most serious embedded diagnostic deficiency. The extent of the BIT deficiency is depicted in Figure 8, M-1 Tank Built-In Test. The mobility system does not have an embedded diagnostic capability. For the remainder of the tank electronic systems, on-line fault detection coverage is only 46 percent. The majority of BIT coverage fault isolates to subsystem functional ambiguity groups. Embedded off-line fault isolation coverage includes 22 LRUs, but only fault isolates to the single LRU 27 percent of the time. BIT fault isolation to the single LRU is limited to the Laser Range Finder and the Thermal Imaging Unit. In most cases, nonembedded diagnostics are still required to fault isolate to a single LRU.

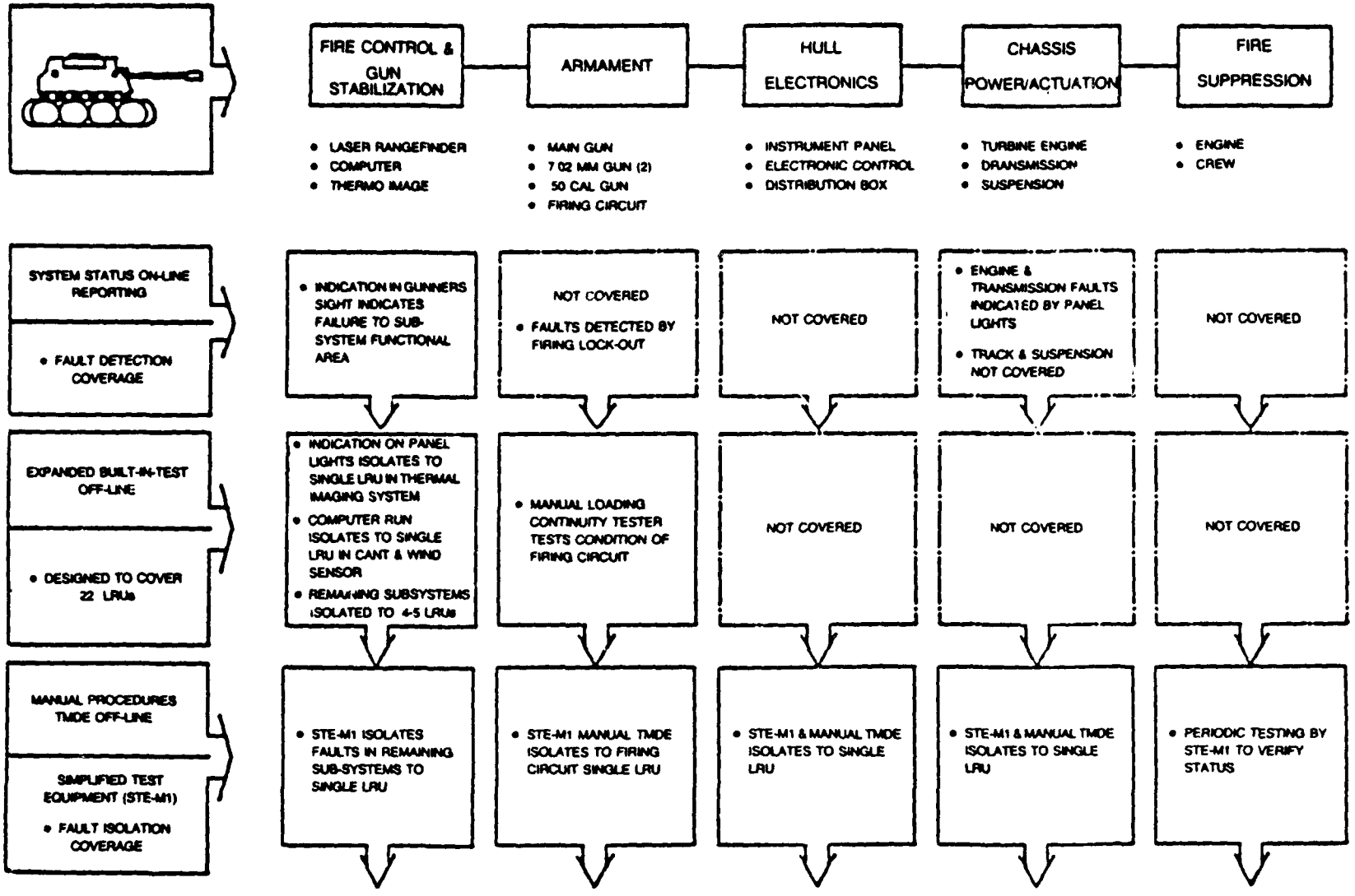


FIGURE 8. M-1 Tank Built-In Test

Diagnostic problems are presented below. A common misconception is that the Simplified Test Equipment (STE) core hardware is the root of all diagnostic problems. The real culprit is tank diagnostic design which contains over 100 unique cable connectors resulting in the proliferation of STE Test Program Set (TPS) cables and connectors.

ABRAMS DIAGNOSTIC PROBLEM SUMMARY

EMBEDDED (TANK)

1. Limited BIT for entire vehicle
   a.No embedded diagnostics for mobility system
   b.No BIT for sensors
2. Not an integrated diagnostic system
3. No standard diagnostic connector assemblies
4. Cannot fault isolate to a single LRU or cable (Non-intrusively)
5. No data recording capability
   a.Intermittent faults
   b.Historical
6. Poor LRU, cable and connector accessibility
7. No standard test connector design
8. Limited embedded sensors for vehicle transmission
9. Limited space for new hardware

NONEMBEDDED DIAGNOSTICS

STE M-1 (specific to the M-1)

Lack of Effectiveness in the Operational Environment

STE - CORE (Generic)

1. Does not meet environmental requirements
2. Display not visible in direct sunlight
3. Self-test takes too long

STE - TEST PROGRAM SETS

1. Requires cumbersome cable connections (bulky)
2. Technical manuals not written for use as TPS documentation with STE (independent action)
3. Test Strategy
   a.Examines failure from component level rather than system level

b.Stops after first fault identified
c.Restart to recover from operator error
d.Experienced mechanic cannot eliminate test steps
e.Does not take advantage of known fault data (e.g., from BIT)

4. Test times do not support doctrinal limits
5. Test messages subject to misinterpretation
6. Test measurements not provided to mechanic

TECHNICAL MANUALS

1. Not user friendly
   a.Volume
   b.Excessive cross referencing
2. Serial symptomatic approach to diagnostics cumbersome and time consuming
3. Paper technical manuals not suited for field use
4. Written only to lowest skill level
5. Time consuming to make changes/difficult to control process

TRAINING/PERSONNEL

1. Mechanics lack theoretical knowledge base (back to basics)
2. Mechanics lack sufficient advanced and sustainment training

III. THE SYSTEM ENGINEERING APPROACH TO ABRAMS INTEGRATED DIAGNOSTICS IMPROVEMENT

In addition to developing a list of Abrams diagnostic problems, the JWG identified 24 diagnostic improvement programs. The question the JWG had to answer was: If the problems are well known and improvement programs are under development, why is there still a diagnostic problem and what can the JWG do that has not been done before?

The answer to the question involves approaching diagnostic improvement from a systems engineering and integrated diagnostics perspective. The JWG discovered that, within Army Materiel Command (AMC), existing diagnostic improvement programs focused on different problem areas. Some improvement programs covered the same problem areas, other improvement programs did not adequately address any problem area. The JWG determined that if they were to add anything to what has already been done, a systematic approach to the problem must be defined and implemented. Their approach to integrating diagnostic programs focuses on treating the diagnostic elements and their

interfaces as a system from the unit through the Intermediate levels of maintenance.

To provide a comprehensive and cost-effective plan for improving the Abrams diagnostic capability, the Group, using a systems engineering approach, developed the integrated diagnostic methodology shown in Figure 9. Based on operational requirements, the Group prioritized the tank's systems and subsystems at the different levels of repair and prioritized the tank's systems and subsystems from a criticality of repair point of view at the different levels of repair.

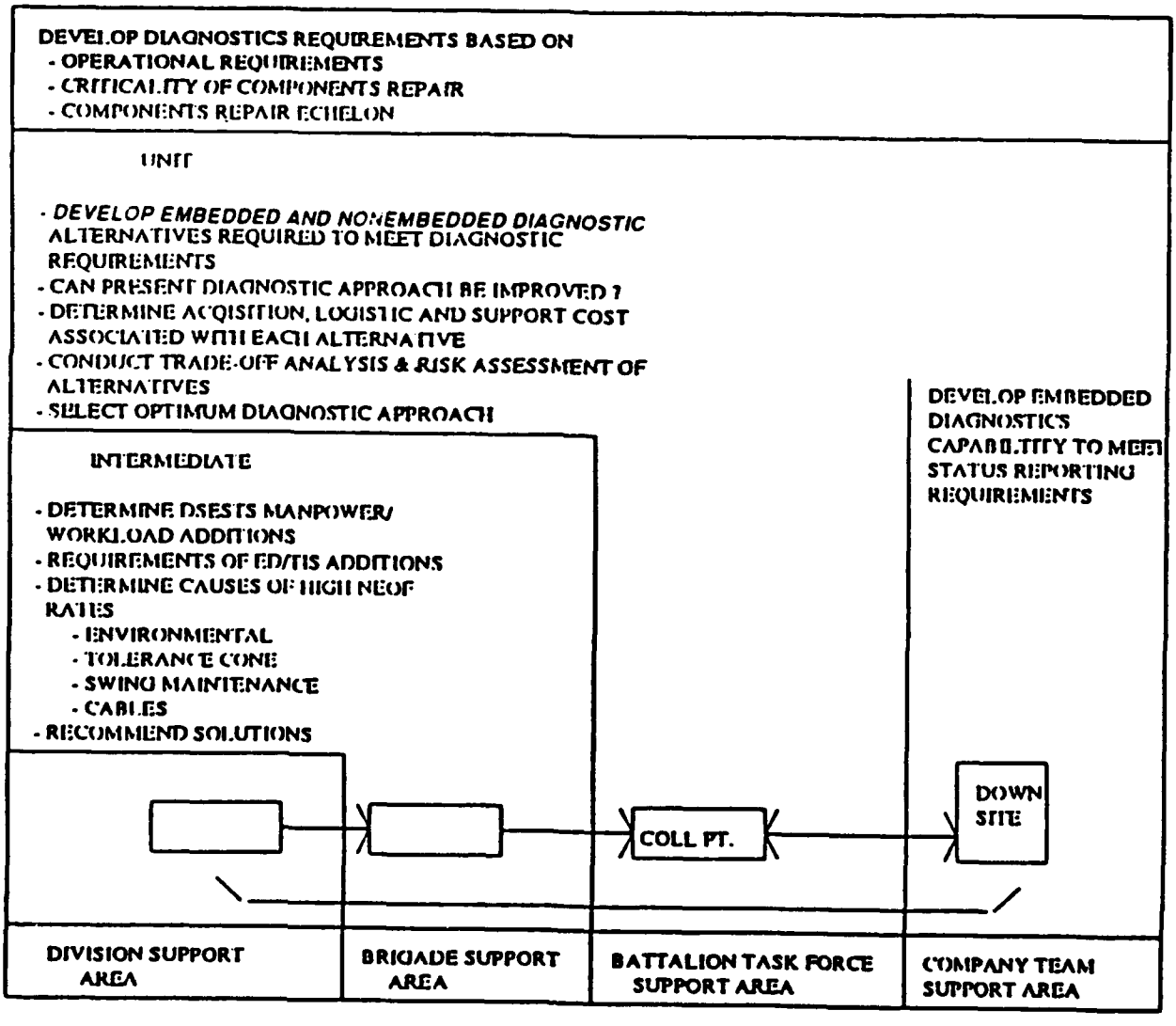


FIGURE 9. Integrated Diagnostic Methodology

The JWG segregated diagnostic improvement into two phases; short-term fixes and long-term solutions. This was necessary to adjust recommendations to the Abrams production schedule.

Short-term fix recommendations are limited to ongoing, government and industry, funded embedded and nonembedded diagnostic programs achievable through 1990.

The JWG recognized that short-term fixes could not possibly address all of the Abrams diagnostic problems. The Group also recognized that certain design problems could not be cost-effectively remedied in the near term, i.e., no standard test connector design, limited embedded sensors for vehicle transmission and poor LRU, cable and connector accessibility. These types of problems will be addressed in the long-term solutions plan.

The Group chose a user perspective to narrow the set of Abrams diagnostic problems to a manageable subset for short-term solutions. From a users perspective, what needs improvement the most (non-prioritized) includes:

- Provide embedded diagnostic capability for mobility system: In a battle zone, an immobile tank is a dead tank. The ability to rejoin the battle or limp home is impaired by the fault detection and fault isolation time required, and by the vulnerability and limited quantity of maintenance teams available to support a tank company. Embedded diagnostics in the tank which can detect and isolate a mobility fault without outside intervention reduces diagnostic time to the minimum and provides each tank with its own "built-in diagnostic team."

- Reduce size and weight of technical manuals and Test, Measurement, and Diagnostic Equipment (TMDE): An M-113 or M-88 does not have the capability to carry mechanics, spare parts, cases of test equipment, cases of cables and connectors, and 12 feet of technical manuals. A tank at the down site cannot be repaired without mechanics and spare parts. The only candidates left for size and weight reduction are the technical manuals and TMDE.

- Reduce dependency on technical manuals and STE: In the Abrams diagnostic history, field workarounds were adopted to circumvent use of the STE and technical manuals. The dedicated contractor support mechanics did not depend on technical manuals and the STE. They were able to diagnose faults based on their expertise with the aid of simple test equipment, system functional flow charts and wiring diagrams. The senior NCOs and Warrant Officers observing these

improvements were convinced there are other approaches to diagnostics. This observation led to the creation of the Master Diagnostician (Master "D") concept. The Master "D" troubleshooting approach reduces the dependency on technical manuals and the STE, allowing the maintenance teams to carry more spare parts. It also reduces the problem of trying to reference a paper manual in inclement weather and reduces diagnostic time by eliminating the requirement to connect bulky test cables and connectors to the tank.

- Reduce requirements for personnel possessing Master "D" skills (expert system instead): The Master "D" is capable of troubleshooting the tank with limited technical information and test equipment. The Master "D" relies on a superior knowledge of operational theory and fault isolation procedures. The problem with Master "D" is the cost of training, limited availability of candidate mechanics and low retention of personnel with Master "D" skills. Given the current state of expert system technology, the logical solution to the Master "D" problem is to incorporate his knowledge of the tank and troubleshooting procedures into an expert system. A "Master D in a box" eliminates the *requirements for a mechanic* with Master "D" skills, reduces training requirements and enhances the average mechanics skill level to that of a Master "D".

- Improve speed of fault diagnosis: In a remove and replace maintenance scenario practiced at the downsite and collection point for electrical and electronic components, fault diagnosis is the bottleneck to system repair. Improvements in fault detection and fault isolation offer the greatest payback in reducing the unit-level maintenance burden. Enhanced speed and ease of diagnostics at the down site and battalion collection point will discourage use of swing maintenance practices. Arbitrary removal and replacement causes unacceptably high No-Evidence-of-Failure (NEOF) rates. It also increases the workload on the battalion maintenance organization and depletes the Prescribed Load List/ Authorized Stockage List (PLL/ASL) inventory.

IV. THE ABRAMS DIAGNOSTIC SYSTEM

Ordnance Center and Armor School JWG representatives rank the battle criticality of tank subsystems as follows:

1. Mobility
2. Firepower
3. Surveillance
4. Survivability
5. Communications.

The JWG endorsed/recommended short-range programs are presented in Figure 10. Diagnostic improvement efforts concentrated on the top three subsystems. Mobility is covered under Hull Embedded Capability. Firepower and Surveillance are covered under Turrent Embedded Capability. All three subsystems are covered under Hull and Turrent Embedded Capability Expansion and Nonembedded Capability.

From a diagnostic point of view, embedded and nonembedded diagnostic capabilities are all encompassing. Embedded diagnostics includes Built-In Test (BIT), Built-In Test Equipment (BITE), and fault data recording functions to support prognostics. Recommended short-range embedded programs are retrofitable to existing Abrams tanks. With the addition of an optional 1553 multiplex data bus, short-range embedded programs are upwardly compatible with Vetronics architecture requirements.

Nonembedded diagnostic recommendations improve current troubleshooting procedures and lead to the development of expert system technology to improve the average mechanics troubleshooting capability. Recommended changes to the nonembedded test strategy decrease diagnostic time and limit the use of cumbersome test equipment. Nonembedded diagnostics procedures begin with the simplest non-intrusive tests possible and progress to the use of intrusive tests possible and progress to the use of intrusive test equipment as a last resort.

The nonembedded troubleshooting process starts with the results of embedded diagnostic capabilities. For instance, if embedded diagnostics fault isolates to an ambiguity group of three of five modules in a system, nonembedded diagnostic should start the troubleshooting procedure by checking out the three identified modules. This does not always occur with current troubleshooting procedures. Next, the mechanic's senses (sight, touch, and smell) are used to locate catastrophic and/or battle damaged components. If further fault isolation is required, a Break-Out-Box (BOB) and a multimeter are employed for improved access to measure signals and compare to good known values. Finally, if all other techniques fail, the STE is used to determine the cause of failure.

The following sections discuss the recommended fixes for each diagnostic area presented in Figure 10, after considering a number of different alternatives.

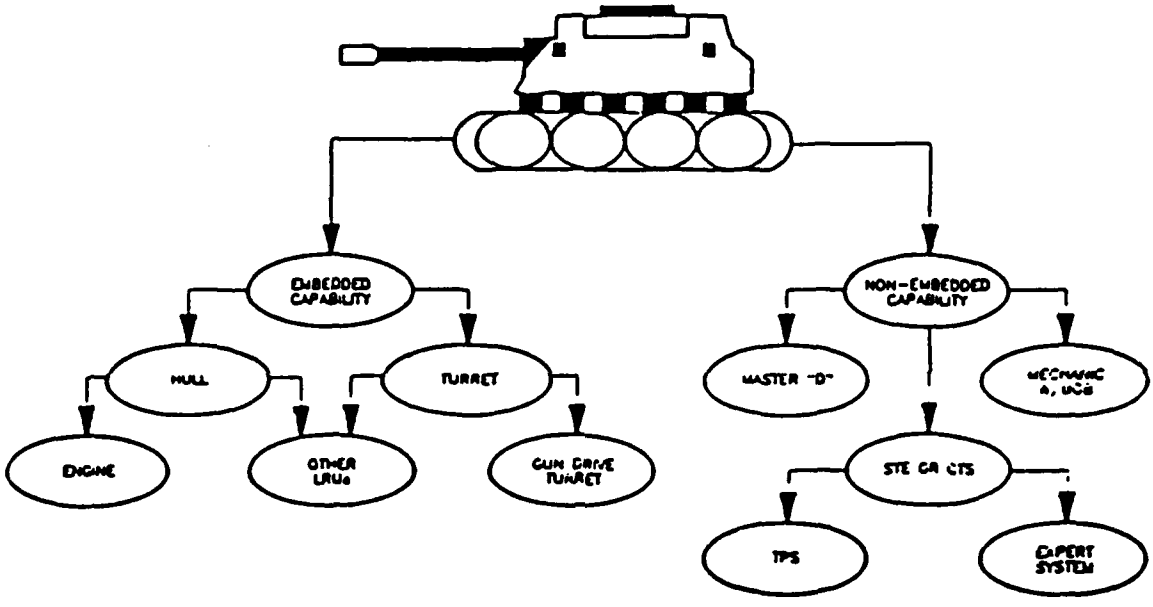


FIGURE 10. Joint Working Group Endorsed/Recommended Programs (Short Range)

A. HULL EMBEDDED CAPABILITY

1. OBJECTIVE

Since mobility is the key to a tank's survival, the top priority of hull diagnostics is to provide embedded diagnostic/prognostic capability to diagnose engine problems. Transmission diagnostics are not addressed due to the expense and complexity of integrating new transmission sensors into existing tanks.

2. RECOMMENDED FIX

The recommended fix for engine diagnostics is the digital Electronic Control Unit (ECU) embedded in the digital Drivers Instrument Panel (DIP), which can monitor engine system signals continuously and record out-of-limit signals continuously. The form, fit, and function permits retrofit. The digital ECU promises to provide significant reductions in O&S cost.

B. TURRENT EMBEDDED CAPABILITY

1. OBJECTIVE

Improvement in Stabilization System diagnostics is the prime objective for turrent embedded diagnostic capability.

The Laser Range Finder and Thermal Imaging Unit contain BIT which fault isolates to the LRU. The complexity of the Fire Control System and Stabilization System prohibits all but the most experienced mechanics (senior NCO) and Master "D"s from troubleshooting these systems without the use of the STE. The initial STE test procedure requires the STE multiple branch adapter. This adapter is cumbersome, bulky, and difficult to connect to the system. Elimination of the multiple branch adapter requirement will improve diagnostic time by reducing test hook-up and run time.

2. RECOMMENDED FIX

The recommended fixes consist of both short- and long-term initiatives. For the short term, recommended continued development and fielding of the STE multiple entry point test program. This, together with other STE enhancements, will reduce test times and increase soldier acceptance of STE in troubleshooting the Stabilization System. The long-term solution is to incorporate Built-In Test (BIT) for the Stabilization System. For any fault not covered by BIT, recommend use of the Break-Out-Box and the Master Fault procedures. STE testing of the Stabilization

System will be retained only if it is determined that BIT and Master Faults do not provide 100% fault coverage.

C. HULL AND TURRENT EMBEDDED CAPABILITY EXPANSION

1. OBJECTIVE

The recommendations presented in Sections (A) (Hull) and (B) (Turrent) cover the most essential subsystems and most pervasive diagnostic problems encountered in the tank. However, the above recommendations do not cover all tank LRUs. The objective of this section is to determine the embedded diagnostic requirements for the remaining LRUs.

2. RECOMMENDED FIX

The recommended approach to accomplishing this objective is based on a systems engineering methodology. The methodology provides an objective means of determining which of the remaining LRUs (if any) are candidates for redesign to increase their embedded diagnostic capability.

The Chrysler Huntsville Automotive Tank and Engine Prognostics System (ATEPS) Program proposes a comprehensive redesign of tank LRUs to improve reliability by digitizing LRU functions, to increase BIT capability, and to provide a standard bus architecture. A complete ATEPS design may be too expensive to implement. However, it may be cost effective to selectively implement specific ATEPS LRUs.

The systems engineering approach to identifying LRUs for redesign includes the following steps:

1. List LRUs which cannot be fault isolated by embedded diagnostics
2. Rank the LRUs by:
   - MTBF
   - MTTR
   - NEOF rate.
3. Select ATEPS LRUs which are form-fit-function replacement for ranked LRUs
4. Quantity realistic reliability and diagnostic improvements for candidate ATEPS LRUs
5. Perform cost analysis for each candidate using the TMDE O&S Analysis Model
6. Select LRUs for redesign based on potential cost avoidance.

D. NONEMBEDDED CAPABILITY

1. OBJECTIVE

The nonembedded diagnostic capability improvement objective at the down site and collection point is to reduce the requirement (dependency) for highly skilled personnel. The approach to meeting this objective also addresses the following user objectives:

- o Reduce requirements for personnel possessing Master "D" skills
- o Reduce size and weight of technical manuals and test equipment
- o Reduce dependency on technical manuals and STE
- o Improve speed of fault diagnosis
- o Reduce fault isolation ambiguity groups to single LRU or cable.

2. ALTERNATIVE FIXES

The following alternatives are candidates for meeting the nonembedded diagnostic objectives:

- o MASTER FAULTS PROGRAM: The existing technical manual troubleshooting approach requires extensive cross referencing which is both time consuming and confusing. Manual-based Master Fault logic will minimize these conditions through two features. First, the mechanic is required to identify the general problem area, rather than select from a myriad of starting points corresponding to hundreds of symptoms. Second, Master Fault logic leads the mechanic through all visual and aural performance indications, to isolate the problem to a single LRU or ambiguity group before test equipment is required to complete troubleshooting.

- o MASTER "D": The Master "D" Program provides advanced diagnostic training to selected senior mechanics. The Master "D" is highly skilled in unit-level diagnostics, troubleshooting and Battlefield Damage Assessment of all primary weapon systems.

- o STE TPS Improvements:

  1. STE Test Program Set Multiple Entry: The STE TPS Multiple Entry is a demonstration program which segments the existing M-1 Stabilization Test 1400. Multiple entry breaks the test program into segments. Each of these segments can be executed

independently. With multiple entry points, it is no longer necessary to run the entire program from beginning to end. The operator selects the segment to be executed, based on failure symptoms. The multiple entry Stabilization Test Program is intended to be run without the multiple branch adapter.

2. STE Test Program Set Multiple Faults: Current test methodology requires correction of each fault before proceeding with a diagnostic procedure. The fault must be corrected and the test reinitiated. The fault may represent a slight "out-of-tolerance" measurement not significant to the actual fault or tank performance. The TPS multiple faults methodology will store all test measurements and pass/fail information through test completion. The STE will evaluate all test results and provide the operator with the most significant faults for follow-on corrective actions. This eliminates current requirement to restart the test program after each fault found.

3. STE Test Program Recovery/Alert Messages: The test program alert message notifies the operator when a measurement has failed "go chain" criteria and the test is proceeding down a "no-go" chain. The error tolerant recovery allows the operator to retest a failed limit measurement when notified by an alert message. When the retest option is selected, the test program automatically branches back to either the most recent block of operator actions or to a previously unexecuted diagnostic word. The test program then provides specific recovery instructions before resuming execution. Alert messages and error recovery allows a mechanic to correct operator errors without reinitializing the test program.

4. STE Test Program Set -20 Technical Manual Automatic Follow-Ons: Present STE testing methodology results in fault isolation to a single LRU or to an ambiguity group of LRUs usually including a wiring harness. Whenever the initial test sequence fault isolates to an ambiguity group, a fault message directs the operator to the technical manual for instructions and follow-on test procedures which identifies the next test program to execute for follow-on testing. Incorporation of the -20 automatic follow-ons will allow the operator to continue with STE testing, including wiring harness testing until a single fault is isolated without referring to the technical manual. This reduces technical manual references and decreases test time.

- o STE VIDEO TRAINING COURSE: The interactive video disc program is intended to teach STE and -20 technical manual use by providing a hands-on training situation through interactive dialogue with the video disc program.

- o STE HEALTH INDICATOR TEST DISPLAY (HITD): Sections of the engine test program can be executed to check the health of the engine in a preventive maintenance mode where no faults are present. Future maintenance actions can be prognosticated based on STE HITD results.

- o -20 TECHNICAL MANUAL REFORMAT: The -20 technical manuals are being reformatted in accordance with MIL-M-6038. Due to elimination of redundant call-outs and pictures, a 35-40% volume reduction is anticipated.

- o MECHANICS HELPER: The scope of this project is to perform a concept study involving present expert system technology and its application in the field of diagnostics and maintenance. Incorporated in this study is an expert maintenance overview and a technology search. This study will be used to examine the potential of expert maintenance in the military environment and to determine if present expert system technology is capable of supporting military maintenance requirements. Upon successful completion of this study, the program will proceed into a limited hardware demonstration. The hardware demonstration will provide a working knowledge of expert maintenance systems which would be applied toward development of a Full-Scale Engineering Demonstration System capable of providing prognostic, diagnostic, and repair information to the mechanic. The expert system should provide the mechanic access to a vast knowledge base which could locate, in a few seconds, the diagnostic, prognostic and repair information that would normally take several minutes (or hours) to locate using current diagnostic techniques. The expert system can be hosted on the Contact Test Set (CTS) being developed under the Intermediate Forward Test Equipment (IFTE) Program.

3. RECOMMENDED FIX

Recommend the following approach to reduce the requirement for highly skilled personnel.

Even though the Master "D" is the epitome of highly skilled personnel, he is also essential to the short-term diagnostic solution. His diagnostic techniques do not depend on bulky technical manuals and test equipment (uses the BOB, multimeter, flow charts, and wiring diagrams). The Master "D" is providing and refining the Master Fault techniques. This is an important step towards a long-term solution of implementing an expert system based on Master Fault techniques.

For the long-term, the Master "D" is not a viable program. The Master "D's" training cost are prohibitive (17 week training program). Retention rate for the Master "D" is expected to be low due to promotion to Warrant Officer and industry recruiting. There is a limited pool of candidates for Master "D" training.

The STE and the STE TPS improvements are endorsed as fixes at the Battalion maintenance echelon.

The long-term solution to nonembedded diagnostic problems is the introduction of an expert system such as the Mechanics Helper to the diagnostic process. The expert system should incorporate the Master Fault diagnostic procedures tested and proven by the Master "D". This solution eliminates the reliance on technical manuals, lowers initial training requirements, and provides a built-in tutor for advanced and sustainment training. Use of the expert system by the Advanced Individual Training (AIT) mechanic guarantees consistent maintenance procedures are followed, provides consistent diagnostic results and minimizes intrusive testing at the down site and collection point. Since the IFTE Contact Test Set design includes an expert system shell, it is a candidate for demonstrating the Mechanics Helper capabilities.

E. SUMMARY

In summary, the systems engineering methodology applied to the Abrams diagnostics improvement resulted in multiple solutions. The overall solution involved/impacted all diagnostic elements. The solution focuses on the integration of the diagnostic elements to provide a comprehensive, cohesive diagnostic capability within the constraints of an existing system design and support design.

CHECKLIST

- ☑ Is a systems engineering approach being used to modify/retrofit the diagnostic capability?
- ☑ Have all feasible alternatives been considered and evaluated?
- ☑ Have emphasis been placed on correcting the items which have a poor diagnostic history?

APPENDIX B

LIST OF ACRONYMS

AFLC	Air Force Logistics Command
AFSC	Air Force Systems Command
AI	Artificial Intelligence
AIT	Advanced Individual Training
AMC	Army Materiel Command
ATE	Automatic Test Equipment
ATEPS	Automotive Tank and Engine Prognostics System
ATPG	Automatic Test Program Generation
BIT	Built-In Test
BITE	Built-In Test Equipment
BOB	Break-Out-Box
C/ATLAS	Common Abbreviated Test Language for All Systems
CAD	Computer-Aided Design
CAE	Computer-Aided Engineering
CALS	Computer-Aided Acquisition & Logistics Support
CAMELOT	Computer-Aided Measure for Logistic Testability
CASS	Consolidated Automated Support System
CDR	Critical Design Review
CDRL	Contract Data Requirements List
CEPS	CITS Expert Parameter System
CFE	Contractor Furnished Equipment
CI	Configuration Items
CITS	Central Integrated Test System
CMOS	Complementary Metal Oxide Semi-Conductor
CND	Cannot Duplicate
CNO	Chief of Naval Operation
COPTR	Controllability-Observability-Predictability-Testability Report
CPCI	Computer Program Configuration Item
CSC	Computer System Component
CSCI	Computer Software Configuration Item
CSDM	Computer System Diagnostic Manual
CSOM	Computer Software Operator's Manual
CTE	Commercial Test Equipment
CTS	Contact Test Set
D-Level	Depot Level
DBDD	Data Base Design Document

DCP	Decision Coordinating Paper
Dem/Val	Demonstration and Validation (Phase)
DFT	Design For Testability
DID	Data Item Description
DIP	Drivers Instrument Panel
DoD	Department of Defense
DoD-D	DoD Directive
DoD-INST	DoD Instruction
DTA	Daisy Testability Analyzer
DSESTS	Direct Support Electrical Systems Test Set
DT&E	Development Test and Evaluation
ECP	Engineering Change Proposal
ECU	Electronic Control Unit
FA	False Alarm
FCA	Functional Configuration Audit
FD	Fault Detection
FEFI	Fraction of Erroneous Fault Isolation Results
FFI	Fraction of Faults Isolated
FFD	Fraction of Faults Detected
FI	Fault Isolation
FIPAD	Failure Identification, Prevention, and Detection
FIS	*Fault Isolation System*
FMEA	Failure Modes and Effects Analysis
FMECA	Failure Modes, Effects and Criticality Analysis
FOT&E	Follow-On Test & Evaluation
FRACAS	Failure Repeating Analysis and Corrective Action
FSD	*Full-Scale Development*
FSM	Firmware Support Manual
FYDP	Five Year Defense Plan
GFE	Government Furnished Equipment
GIMADS	Generic Integrated Maintenance Diagnostics
GPETE	General Purpose Electronic Test Equipment
HW	Hardware
HWCI	Hardware Configuration Item
I-Level	Intermediate Level
IC	Integrated Circuit
ID	Integrated Diagnostics
IDD	Interface Design Document
IDSS	Integrated Diagnostics Support System
IFTE	Intermediate Forward Test Equipment
ILS	Integrated Logistic Support

ILSP	Integrated Logistic Support Plan
IMIS	Integrated Maintenance Information System
IOT&E	Initial Operational Test & Evaluation
IPS	Integrated Program Summary
ITP	Integrated Test Plan
JWG	Joint Working Group
LCC	Life Cycle Cost
LOGMOD	Logic Modeling
LRM	Line Replaceable Module
LRU	Line Replaceable Unit
LSA	Logistic Support Analysis
LSAP	Logistic Support Analysis Plan
LSI	Large Scale Integration
MASTER "D"	Master Diagnostician
MATE	Modular Automatic Test Equipment
MD	Maintainability Demonstration
MIL-STD	Military Standard
MNS	Mission Need Statement
MTBF	Mean Time Between Failures
MTE	Manual Test Equipment
MTTR	*Mean Time To Repair*
NCO	Non-Commissioned Officer
NDI	Non-Developmental Items
NEOF	No-Evidence-of-Failure
NSIA	National Security Industrial Association
O-Level	Organizational Level
OJT	On-the-Job Training
OT&E	Operational Test & Evaluation
OUSD(A)	Office of the Under Secretary of Defense (Acquisition)
P^3I	Preplanned Product Improvement
PAT&E	Production Acceptance Test & Evaluation
PCA	Physical Configuration Audit
PCB	Printed Circuit Board
PDR	Preliminary Design Review
PLL/ASL	Prescribed Load List/Authorized Stockage List
PMRT	Program Management Responsibility Transfer
PPBS	Planning, Programming and Budgeting System
PROD/DEP	Production/Deployment (Phase)
PRR	Production Readiness Review

RADC	Rome Air Development Center
RDGT	Reliability Development/Growth Test
RF	Radio Frequency
RFP	Request for Proposal
RISE	Readiness Improvement Through System Engineering
ROC	Required Operational Capability
RTOK	Retest OK
SCOAP	Sandia Controllability/Observability Analysis Program
SCP	System Coordinating Paper
SDDD	Software Detail Design Document
SDR	System Design Review
SEMP	System Engineering Management Plan
SHARP	Standard Hardware Acquisition Requirement Process
SIT	System Integrated Test
SON	Statement of Need
SOW	Statement of Work
SPM	Software Programmer's Manual
SRA	Shop Replaceable Assembly
SRR	System Requirements Review
SRU	Shop Replaceable Unit
STAMP	System Testability Analysis Maintenance Program
STD	Software Test Descriptions
STE	Simplified Test Equipment
STE HITD	Simplified Test Equipment Health Indicator Test Display
STLDD	Software Top-Level Design Document
STP	Software Test Plans
SUM	Software User's Manual
SW	Software
T&E	Test & Evaluation
T	Testability
TAH	Testability Analysis Handbook
TBD	To Be Determined
TEMP	Test & Evaluation Master Plan
TFOM	Testability Figure of Merit
TI	Technical Information
TISSS	Tester Independent Support Software System
TM	Test and Maintenance
TMDE	Test, Measurement, and Diagnostic Equipment
TO	Technical Orders
TPI	Test Program Instruction
TPS	Test Program Set
TRD	Test Requirements Document
TRR	Test Readiness Review

UUT	Unit Under Test
VHSIC	Very High Speed Integrated Circuit
VLSI	Very Large Scale Integration
WBS	Work Breakdown Structure
WRA	Weapon Replaceable Assembly