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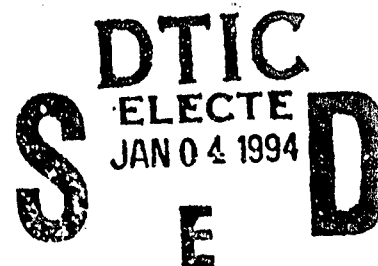
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A QUALITY PROCESS APPROACH TO ELECTRONIC SYSTEM RELIABILITY: Handbook Procedure

McDonnell Douglas Aerospace and Hughes Radar Systems Group

Paul B. Hugge (McDonnell Douglas Aerospace) Bob Johnson and Ed Malmberg (Hughes Radar Systems Group)



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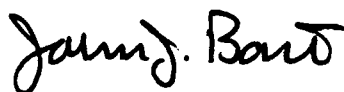
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13. ABSTRACT (Maximum 200 words) This handbook defines a new approach to reliability assurance and control based on principles of Total Quality Management. The new approach is process oriented with the elements of the process tailored to each DoD acquisition phase. The handbook provides, for each acquisition phase, a time phased description of all critical activities necessary for reduction and elimination of all potential product and process defects. For each critical activity, relevant inputs, outputs, customers and suppliers are defined. Elements required to attack all sources of defects are combined in the process with linkages across the diverse functional specialties required to implement a coordinated concurrent engineering process. Tracking metrics are recommended and defined for each DoD acquisition phase. The new process outlined in the handbook requires a pre-award supplier quality assessment. Volume II contains criteria and procedures for supplier quality assessment, certification and audit. The procedures parallel the highly accepted Malcolm Baldrige Award Criteria. They define a scoring system, a methodology and a set of detailed evaluation sheets with scoring instructions included. DoD Program Managers can use the handbook set for the construction of Requests For Proposals, Instructions to Offerors, Statements of Work, and Evaluation Criteria for electronic systems procurement. DoD contractors and commercial developers					
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can use the information for subcontract documents and the development of internal processes that implement the contents of the handbook. Both DoD and industry management can use the handbook contents for the development of design reviews and systems engineering event criteria in order to track and control programs.

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EXECUTIVE SUMMARY

This guide has been prepared for use by Department of Defense (DoD) and Defense Contractor Program and Engineering Managers. It is intended to provide guidance for the implementation of a process for reliability assurance that incorporates the principles and practices of quality management. Paragraphs 2 through 6 herein provide, for each DoD Acquisition Phase, a time phased description of the activities, their input and output products, and tracking metrics recommended for a quality management based approach to reliability assurance and control. DoD managers can use the information for the construction of Requests for Proposal, Instructions to Offerors, Statements of Work, and Evaluation Criteria for electronic systems procurement. DoD contractors can use the information for subcontract documents and the development of internal processes that implement the contents of the handbook. Both DoD and contractor management can use the handbook contents, specifically including the recommended metrics, for the development of design review and systems engineering event criteria in order to track and control programs.

Total Quality Management (TQM) is an approach to management that embraces two basic principles: 1) customer satisfaction, and 2) continuous improvement. These principles drive several primary operating characteristics. Customer satisfaction dictates that customer needs be identified and translated into product design and manufacturing requirements in a systematic and comprehensive manner. Once these requirements have been identified, they should be implemented in a manner that is directed at achieving nearly defect free products. The principle of continuous improvement requires that design and manufacturing processes be clearly defined and understood. This provides the framework for both the execution of these processes by trained and empowered employees and the improvement of these processes through benchmarking.

The document that is the current basis for DoD electronic product reliability programs is MIL-STD-785, "Reliability Program for Systems and Equipment Development and Production." While this document contains many essential and value-added tasks, current implementation practices and insufficient coverage in some key areas limit the effectiveness of the programs guided by this document.

The reliability process, described in this guide for each DoD acquisition phase, combines the primary operating characteristics of quality management with an emphasis on the engineering and manufacturing analysis and development tasks required for the prevention of product defects. Essential, value-added tasks such as planning, supplier control, development testing, stress screening and Failure Reporting Analysis and Corrective Action have been retained and enhanced in the reliability process descriptions. Particular attention has been paid to defining the reliability process for the critical early acquisition phases that precede Engineering and Manufacturing Development (EMD).

Traditional reliability programs have concentrated on minimizing and then predicting the rate of occurrence of "inherent" failures. The fundamental problem with "traditional" reliability programs is the narrow definition of reliability. Product defects are presently treated by various functional specialties without integration and with varying degrees of attention. There has also been inadequate emphasis on the reliable performance of self-test functions and the variability of parts and manufacturing processes. The tools are available to correct these problems. What is required is the insistence of DoD customers and contractor management on a multidiscipline attack on all defect sources using the principles and tasks outlined in this handbook. While there is a significant gap between current performance and the state envisioned by this handbook, the cultural changes needed for changing the traditional reliability process are already taking place. This handbook provides a focus and sense of direction for those changes. The reliability processes in this guide retain requirements for quantitative predictions but expand the focus of both prediction and prevention to include defects arising from all sources. This approach requires the cooperative and concurrent efforts of a wide variety of functional specialties. Consequently, the processes of this guide must be implemented by the actions of a multidiscipline team, under the leadership of a process owner.

The traditional reliability program task of Electronic Parts/Circuits Tolerance Analyses deals with examining the effects of parameter variability. This task has been necessarily expanded in the processes of this guide to encompass variability control, both in design and manufacturing. The Motorola Six Sigma concept has been adopted as a benchmark for this variability control.

Fundamental TQM concepts such as Quality Function Deployment, Benchmarking, Training, Software Capability Maturity Model, and Quality Evaluations, based on Malcolm Baldrige Award criteria, have been included in the reliability process. These are the core elements of Quality Management that are essential to both customer satisfaction and continuous improvement.

This guide is comprised of two volumes. Volume One defines the details of the reliability process. Volume Two contains Certification and Audit Procedures for an enterprise wide quality assessment patterned after the Malcolm Baldrige Award criteria.

Chapter 1 of Volume One provides an overview of the revised reliability phases. It summarizes the basic intent of the new process, describes the preferred metrics for process control, and provides recommendations for ownership of the elements of the new process.

The process descriptions contained in Chapters 2 through 6 are based on identifying critical activities, for each acquisition phase, along with their inputs and outputs. Detail descriptions of the activity's purpose and the characteristics of each input and output are included as part of the process description. In addition to simplifying the process description, the technique provides a focus on the issue of customers and suppliers

A QUALITY PROCESS APPROACH TO ELECTRONIC SYSTEM RELIABILITY

and allows an evaluation of the quality of the entire process. The level of detail of the process descriptions is sufficient to provide an understanding of what is required to create documents such as statements of work. At the conclusion of each acquisition phase process chapter is a description of appropriate control and audit metrics.

Chapter 7 provides a case history example of the application of the revised reliability process.

Chapter 8 describes the application of the process principles, defined in Chapters 2 through 6, to the development of defect free software.

Implementation of the processes defined in this guide cannot, in general, be accomplished by referencing existing specifications, standards or data items. The significant departure from current practice described herein, requires careful and individual consideration for application to specific programs.

1.0 INTRODUCTION

Volume I of this handbook defines major revisions to the traditional reliability process. The handbook is divided into seven chapters. Chapter 1 provides an overview of the revised process, key elements of the process and implementation guidances.

Chapters 2 through 6 provide detail definition of tasks to be performed for each of the DoD acquisition phases plus the Pre-Concept Exploration Phase (pre Milestone 0). Chapter 7 provides a fact-based implementation example.

The handbook provides the detail necessary to create a comprehensive multidiscipline approach to reliability assurance and control. It incorporates and expands the principles of MIL-STD-785 and includes some fundamental practices required for continuous improvement. A salient feature of the handbook is its expansion of the term "Reliability" to encompass product defects arising from all sources (e.g., parts and design defects, excess stress, fatigue, drift, manufacturing and assembly defects, and part and manufacturing variability). Consequently, the handbook describes some essential tasks that may exceed the traditional practices of Reliability specialists. In these cases, the Reliability specialist should provide a leadership/training role to ensure accomplishment of the described task.

This handbook deals exclusively with issues affecting electronic product reliability, with the term reliability used in the broad sense noted above. Wherever terms are used in the handbook that could infer broader issues, it is intended that these terms apply to reliability issues. For example, the term "Technical Objectives" applies to those objectives which relate to product reliability.

1.1 PROCESS OVERVIEW

Figure 1-1 provides a generic description of the revised reliability process. The process is driven by both a commitment to quality operations and customer requirements. The activities of planning, design and analysis, and test convert the customer requirements into a product.

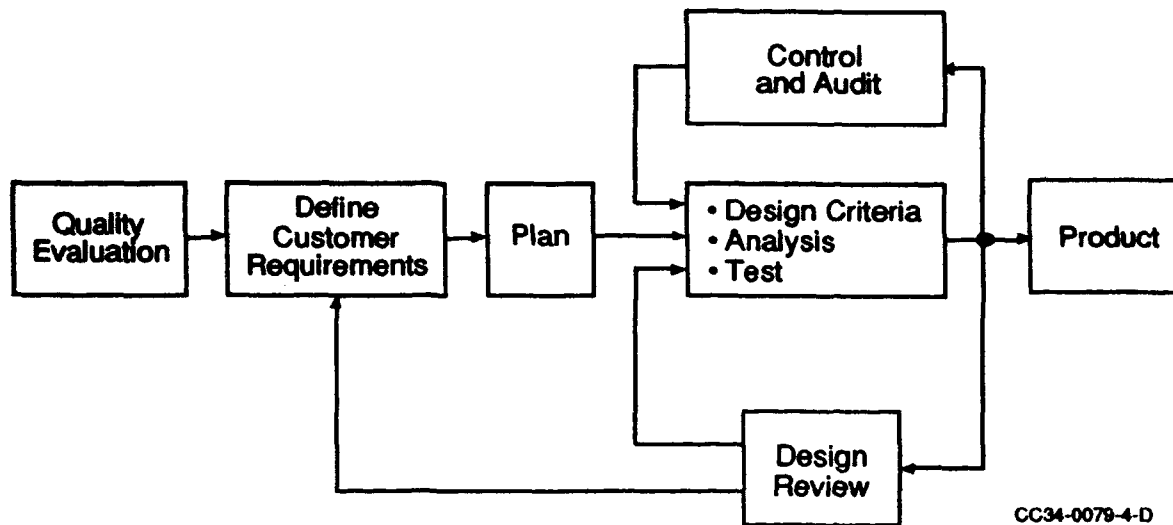


Figure 1-1. Process Overview

The dual feedback elements of design review and auditing provide control of the process and continuous comparison of results to customer requirements. This generic process has been applied to the DoD Acquisition Phases by constructing, for each phase, a series of critical activities, with each of these activities having required input and output products, and providing auditing requirements, including metrics with quantitative objectives. Every activity is defined in terms of its purpose, objectives, and requirements. All inputs and outputs for each activity are described in sufficient detail to permit execution. The detail covers such issues as the technical content of the input or output product, the specialty or function providing/receiving the products, the purpose of the product, requirements for determining the acceptability of the products and their intended uses. The detail descriptions of the activities, inputs and outputs, and auditing methods for each DoD Acquisition Phase are provided in Chapters 2 through 6 in this handbook. Each of these chapters also contain graphics depicting the linkage of the phase activities, the time phasing of the activities within a phase, and all inputs to and outputs from each activity.

The material in Chapters 2 through 6 defines what is required for the implementation of a TQM approach to reliability assurance control. The process descriptions define both the critical activities

CRITICAL TASKS

directed at a comprehensive approach to defect elimination and the activities required to promote customer involvement and continuous improvement. These latter items include requirements for a Quality Evaluation in accordance with Malcolm Baldrige Award criteria, explicit interpretation and deployment of customer needs, benchmarking plans, training plans, and design reviews that are focused on customer requirements.

Recommendations for further customer involvement are also contained within the text descriptions of the process items. These noted items, when combined with clear and comprehensive descriptions of existing internal processes, form a minimum framework for continuous improvement. The remaining items in the process descriptions are the critical technical data, analysis, and tests, directed at defect prevention/elimination, and produced primarily by the functional specialties of Reliability, Design, Diagnostics Design, and Manufacturing.

The process definitions of Chapters 2 through 6 cover the entire range of DoD electronic products in terms of both complexity, technical maturity, and application environments. Clearly, tailoring is a necessity. For example, some equipment development will begin in EMD as a result of low complexity or technical maturity. In this case, Concept Exploration and Demonstration Validation process descriptions should be reviewed for applicability of selected Activities, Inputs, or Outputs. Similarly, if application environments are relatively benign, several of the detailed stress and fatigue analyses will not be applicable.

It is not necessary, nor is it expected, that all of the Activities/Inputs/Outputs will be uniquely created for every program. Maximum use of existing information must be accomplished. Furthermore, those suppliers who are most aware of customer needs and problems and most committed to the practice of TQM principles will have the easiest time of implementing the processes of Chapters 2 through 6.

TAILOR THE PROCESS

1.2 CONTROL AND AUDIT

PROCESS FEEDBACK

Each acquisition phase process description defines a procedure for auditing and control. The auditing methods are tailored to both the objectives of each

CHAPTER 1

PRACTICING CONTINUOUS IMPROVEMENT

DoD acquisition phase and the level of detail design and manufacturing information available during these phases. The procedures are directed at promoting customer/supplier involvement, especially during the early acquisition phases where most of the product's reliability attributes are established. Similar to the process itself, the audit procedures require the participation of multiple disciplines whose focus is on the integration of tasks essential to defect prevention and elimination.

Traditional approaches to the audit function have involved review and approval of specifically designated data items. The data are typically requested by diverse functional groups. This approach is generally late in terms of its capability for influencing the process. Evaluation of data is entirely focused on an output product and often does not require an evaluation of the quality of required inputs. Finally, it does not ensure that data affecting reliability but developed by different functional specialties is integrated with the review of reliability data.

The audit procedures described herein consist of five elements tailored to the program phase. These are: 1) Risk Assessment, 2) Defect Rate, 3) Six Sigma Design, 4) Six Sigma Manufacturing, and 5) Product Performance Assessment. Figure 1-2 shows the application of these elements in the contracted DoD Acquisition Phases. Each of the elements provides a trackable measure of merit for controlling the process within a phase. As shown in the figure, more than one metric is required to assess the status of the reliability process. The metrics support each other and provide a comprehensive assessment of the process status.

Control Element	Concept Exploration	Demonstration Validation	EMD	Production	User Support	Metric(s)
Risk Assessment						• Risk Factor
Defect Rates						• Service Life • Mean Time Between Maintenance • False Alarm Rate • Could-Not-Verify Rate • Failure Rate
Six Sigma Design						• Capability Index
Six Sigma Manufacturing						• Capability Index
Product Performance Assessment						• Defect Rate/Defects Per Unit

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Figure 1-2. Tailored Auditing Elements

The key to the successful implementation of the control procedures defined herein is maximum customer/supplier involvement. Most of the auditing elements are not subject to rigid rules or specifications. The audit elements provide quantitative results which must be interpreted within the context of the overall quality of the process. The customer is responsible for assessing the credibility of the quantitative results.

1.3 IMPLEMENTING THE PROCESS

RESPONSIBILITY FOR THE PROCESS

Figure 1-3 (pages 1-8 through 1-16) presents a suggested Customer/Supplier matrix which provides an overview of the customers and suppliers for each Reliability Process input or output identified within the roadmaps provided in Chapters 2 through 6.

The Block Number in the far left column identifies the acquisition phase block number within each roadmap. The first digit of the block number defines the specific phase of the acquisition process; e.g., 2 is the Pre-Concept Exploration Phase, 3 is the Concept Exploration and Definition Phase, etc.

CHAPTER 1

PRACTICING CONTINUOUS IMPROVEMENT

The Input/Output (I/O) column identifies the item as an input (from a supplier) or an output (to a customer).

The columns to the right of the I/O column identifies the customers and suppliers for each input or output item.

Figure 1-4 identifies the major functional area customers and suppliers utilized within the matrix and typical subdivisions of these areas.

- | | | |
|----------------------------------|------------------------------|--|
| • Reliability Engineering | • Logistics Support Function | • Test and Evaluation Engineering |
| | – Logistic Support Analysis | |
| • Design Engineering | – Field Service Engineering | • Subcontractors/Suppliers |
| – Electrical Design | | |
| – Mechanical Design | • Manufacturing | • Program Management |
| – Structural Design | – Manufacturing Engineering | |
| – Diagnostics/Testability Design | – Product Repair | • External Customer (e.g., DoD,
Prime Contractor) |
| – Support Equipment Design | – Producibility | |
| | – Packaging Engineering | |
| • Engineering Technologies | • Support Groups | |
| – Thermodynamics | – Company and Functional | |
| – Structural Dynamics | Department Library/Archives | |
| – Strength Engineering | – Contract Administration | |
| – Components Engineering | – Engineering Estimating | |
| – Operations Analysis | – Planning and Scheduling | |
| – Maintainability Engineering | – Marketing | |
| – Materials and Process | – Procurement | |
| Engineering | – Data Processing | |
| – System Safety Engineering | | |

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Figure 1-4. Major Functional Areas and Subdivisions

In the cases where either a multiple supplier is shown for the output of an activity, or the output exceeds that traditionally provided by Reliability specialists, the multiple suppliers must function as a multidiscipline team under the suggested leadership of the Reliability Process owner.

The material presented in Chapters 2 through 6 can be assembled into process documentation for internal use, applied in Statements of Work or Requests for Proposal for contracted work, or used for the establishment of design/program review entry and/or exit criteria.

The primary focus of continuous improvement is customer satisfaction. This implies a customer responsibility to accurately and completely identify

DATA ITEMS

his needs. In order to foster this responsibility, unique data item descriptions and requirements, specific to each contract, are recommended over the current "cookbook" approach. Data items may be identified based on Figure 1-3 for those items where an external customer is a "customer" of input or output data. The descriptions of these items contained in the paragraphs shown in Figure 1-3 should be used as the basis for creating tailored Contract Data Requirements Lists and Data Item Descriptions.

CHAPTER 1
PRACTICING CONTINUOUS IMPROVEMENT

Reliability Process Pre-Concept Exploration Phase		Customer (C) Supplier (S)											
		Input (I) Output (O)	Reliability Engineering	Program Management	Design Engineering	Engineering Technologies	Logistics Support Function	Manufacturing	Support Groups	Test and Evaluation Engineering	Subcontractors/ Suppliers	External Customer	
Block	Title												
2.1.1 Interpret Customer Needs													
2.1.1.1	Customer Needs and Objectives	I	C	C	C		C					S	
2.1.1.2	Experience Data	I	S	C	C	C	S						
2.1.1.3	Technical Objectives	O	S		C	C	C					C	
2.1.1.4	Research Requirements	O	S	C	C	C		C				C	
2.1.1.5	Trade Study Candidates	O	S		C	C	C	C				C	
2.1.2 Program Planning													
2.1.2.1	Funding Profiles	I	C	S	C	C	C	C					
2.1.2.2	Contract or Research Requirements	I	C	C	C	C	C	C				S	
2.1.2.3	Technical Objectives	I	S		C	C	C					C	
2.1.2.4	Trade Study Candidates	I	S		C								
2.1.2.5	Tailored Program Plan	O	S	C	S			S				C	
2.1.2.6	Computer-Aided Engineering Tools	O	S	C	S	S		S	C				
2.1.2.7	Technical Objectives Flowdown	O	S		C	C	C					C	
2.1.2.8	Continuous Improvement Plans	O	S	C	S	S		S	C				
2.1.3 Assess Technologies and Identify Risks													
2.1.3.1	Technical Objectives	I	S		C	C	C						
2.1.3.2	Technology/Concept Data	I	C		S	S	S	S					
2.1.3.3	Experience Data	I	C/S		S	S	S		S			S	
2.1.3.4	Technology Assessment Report	O	S	C	S	S	C	S		S		C	
2.1.3.5	Risk Assessment Report	O	S	C	S	S		S		C		C	
2.1.3.6	Research Recommendations	O	S	C	S	S	S	S				C	
2.1.4 Tradeoff Analysis													
2.1.4.1	Technical Objectives	I	S		C	C	C						
2.1.4.2	Trade Study Candidates	I	S		C		C	C					
2.1.4.3	Technology/Concepts Alternative Data	I	C		S	S	S	S					
2.1.4.4	Trade Study Reports	O	S	C	C		C	C				C	

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Figure 1-3. Customers and Suppliers Matrix

Reliability Process Pre-Concept Exploration Phase		Customer (C) Supplier (S)											
		Input (I) Output (O)	Reliability Engineering	Program Management	Design Engineering	Engineering Technologies	Logistics Support Function	Manufacturing	Support Groups	Test and Evaluation Engineering	Subcontractors/ Suppliers	External Customer	
Block	Title												
2.1.5 Concept Development													
2.1.5.1	Technical Objectives	I	S		C	C	C						
2.1.5.2	Technology Assessment Report	I	S	C	S	S	C	S		S			
2.1.5.3	Risk Assessment Report	I	S	C	S	S		S		C			
2.1.5.4	Trade Study Reports	I	S	C	C		C	C					
2.1.5.5	Preferred System Concept Report	O	S	C	C	C	C	C				C	
2.1.6 Requirements and Design Reviews													
2.1.6.1	Activity Outputs (2.1.1, 2.1.3, 2.1.4, 2.1.5)	I	S	C	S	S	C	S					
2.1.6.2	Design Review Procedures	I	C	S	C	C	C	C					
2.1.6.3	Design Review Reports	O	S	C	C	C	C	C				C	

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Figure 1-3 (Continued). Customers and Suppliers Matrix

CHAPTER 1
PRACTICING CONTINUOUS IMPROVEMENT

Reliability Process Concept Exploration Phase		Customer (C) Supplier (S)										
		Input (I) Output (O)	Reliability Engineering	Program Management	Design Engineering	Engineering Technologies	Logistics Support Function	Manufacturing	Support Groups	Test and Evaluation Engineering	Subcontractors/ Suppliers	External Customer
Block	Title											
3.1.1 Quality Evaluation												
3.1.1.1	Evaluation Instructions	I	C	C	C	C	C	C	C	C		S
3.1.1.2	Evaluation Criteria	I	C	C	C	C	C	C	C	C		S
3.1.1.3	Quality Evaluation Report	O	S	S	S	S	S	S	S	S		C
3.1.2 Interpret Customer Needs												
3.1.2.1	Customer Needs and Objectives	I	C	C	C		C					S
3.1.2.2	Experience Data	I	S		C	C	S					C
3.1.2.3	Technical Objectives	O	S		C	C	C					C
3.1.2.4	Research Requirements	O	S	C	C	C		C		C		C
3.1.2.5	Trade Study Candidates	O	S		C	C	C	C				C
3.1.3 Program Planning												
3.1.3.1	Funding Profiles	I	C	S	C	C	C	C				
3.1.3.2	Contract Requirements	I	C	C	C	C	C	C				S
3.1.3.3	Technical Objectives	I	S		C	C	C	C				
3.1.3.4	Trade Study Candidates	I	S		C	C	C	C				
3.1.3.5	Tailored Program Plan	O	S	C	S	C	C	S	C	C		C
3.1.3.6	Computer-Aided Engineering Tools	O	S	C	S	S		S	C			
3.1.3.7	Technical Objectives Flowdown	O	S		C	C	C					C
3.1.3.8	Benchmarking and Training Plans	O	S	C	S	S	S	S				
3.1.3.9	Subcontractor Control Plan	O	S	C	S		S	S	C		C	C
3.1.4 Assess Technology and Identify Risks												
3.1.4.1	Technical Objectives	I	S		C	C	C					
3.1.4.2	Technology/Concept Data	I	C		S	S	S	S		S		
3.1.4.3	Experience Data	I	C/S		S	S	S	S	S			S
3.1.4.4	Environment and Use Data	I	C		S	S	S			C		S
3.1.4.5	Technology Assessment Report	O	S	C	S	S	C	S		C		C
3.1.4.6	Risk Assessment Report	O	S	C	S	S		S		C		C
3.1.4.7	Critical Functions and Parameters	O	S		S/C		C	C				S/C

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Figure 1-3 (Continued). Customers and Suppliers Matrix

Reliability Process Concept Exploration Phase		Customer (C) Supplier (S)		Input (I) Output (O)	Reliability Engineering	Program Management	Design Engineering	Engineering Technologies	Logistics Support Function	Manufacturing	Support Groups	Test and Evaluation Engineering	Subcontractors/ Suppliers	External Customer
		Block	Title											
3.1.5 Tradeoff Analysis														
3.1.5.1 Technical Objectives				I	S		C	C	C					
3.1.5.2 Trade Study Candidates				I	S		C	C	C	C				
3.1.5.3 Technology/Concepts Alternatives Data				I	C		S	S	S	S				
3.1.5.4 Trade Study Reports				O	S	C	C	C	C	C				C
3.1.6 System Requirements and Configuration Recommendation														
3.1.6.1 Technical Objectives				I	S		C	C	C					
3.1.6.2 Technology Assessment Report				I	S	C	S	S	C	S		C		
3.1.6.3 Risk Assessment Report				I	S	C	S	S		S		C		
3.1.6.4 Trade Study Reports				I	S	C	C		C	C				
3.1.6.5 Updated Technical Objectives				O	S	C	C		C	C				C
3.1.6.6 Risk Reduction Plans				O	S	C	S	S	S	S		C		C
3.1.7 Requirements and Design Reviews														
3.1.7.1 Activity Outputs (3.1.2 Through 3.1.6)				I	S	C	S	S	C	S				
3.1.7.2 Design Review Procedures				I	C	S	C	C	C	C				
3.1.7.3 Design Review Reports				O	S	C	C	C	C	C				C

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Figure 1-3 (Continued). Customers and Suppliers Matrix

**CHAPTER 1
PRACTICING CONTINUOUS IMPROVEMENT**

Reliability Process Demonstration and Validation Phase		Customer (C) Supplier (S)											
		Input (I) Output (O)	Reliability Engineering	Program Management	Design Engineering	Engineering Technologies	Logistics Support Function	Manufacturing	Support Groups	Test and Evaluation Engineering	Subcontractors/Suppliers	External Customer	
Block	Title												
4.1.1 Quality Evaluation													
4.1.1.1	Evaluation Instructions	I	C	C	C	C	C	C	C	C		S	
4.1.1.2	Evaluation Criteria	I	C	C	C	C	C	C	C	C		S	
4.1.1.3	Quality Evaluation Report	O	S	C/S	S	S	S	S	S	S		C	
4.1.2 Interpret Customer Needs													
4.1.2.1	Customer Needs and Objectives	I	C	C	C		C					S	
4.1.2.2	Experience Data	I	S		C	C	S						
4.1.2.3	Technical Objectives	O	S		C	C	C					C	
4.1.2.4	Trade Study Candidates	O	S		C	C	C	C				C	
4.1.3 Program Planning													
4.1.3.1	Funding Profile	I	C	S	C	C	C	C					
4.1.3.2	Contract Requirements	I	C	C	C	C	C	C				S	
4.1.3.3	Risk Reduction Plan	I	S	C	S	S	S	S		C			
4.1.3.4	Technical Objectives	I	S		C	C	C	C					
4.1.3.5	Trade Study Candidates	I	S		C	C	C	C					
4.1.3.6	Tailored Program Plan	O	S	C	S	C	C	S	C	C		C	
4.1.3.7	Updated Risk Reduction Plan	O	S	C	S	S	S	S				C	
4.1.3.8	Technical Objectives Flowdown	O	S		C	C	C					C	
4.1.3.9	Supplier Selection and Control Plan	O	S	C	S	S	S	S	C		C	C	
4.1.3.10	Benchmarking and Training Plan	O	S	C	S	S	S	S			C		
4.1.3.11	Computer-Aided Engineering Tools	O	S	C	S	S	C	S	C				
4.1.4 Reliability Analysis and Risk Reduction													
4.1.4.1	System Design Data	I	C		S	S	S	S					
4.1.4.2	Technical Objectives	I	S		C	C	C						
4.1.4.3	Experience Data	I	C/S		S	S	S	S		S		S	
4.1.4.4	Environment and Use Data	I	C		S	S	S	S		C			
4.1.4.5	Risk Reduction Results	I	C		S	S	S	S		S			
4.1.4.6	Manufacturing Process Description	I	C		C		C	S					
4.1.4.7	Design Criteria Report	O	S		S	S	C	C				C	
4.1.4.8	Critical Functions, Parameters and Processes	O	S		S/C		C	C				S/C	
4.1.4.9	Quantitative Reliability Expectations	O	S		C		C	C				C	

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Figure 1-3 (Continued). Customers and Suppliers Matrix

Reliability Process Demonstration and Validation Phase		Customer (C) Supplier (S)										
		Input (I) Output (O)	Reliability Engineering	Program Management	Design Engineering	Engineering Technologies	Logistics Support Function	Manufacturing	Support Groups	Test and Evaluation Engineering	Subcontractors/Suppliers	External Customer
Block	Title											
4.1.5 Tradeoff Analysis												
4.1.5.1 Trade Study Candidates		I	S		C	C	C	C				
4.1.5.2 Technical Objectives Flowdown		I	S		C	C	C					
4.1.5.3 Design Data		I	C		S	S	S	S				
4.1.5.4 Trade Study Reports		O	S	C	C	C	C	C				C
4.1.6 EMD Specification Development												
4.1.6.1 Technical Objectives Flowdown		I	S		C	C	C					
4.1.6.2 Quantitative Reliability Expectations		S		C		C	C					
4.1.6.3 Environment and Use Data		I	C		S	S	S			C		
4.1.6.4 Design Criteria		I	S		S	S	C	C				
4.1.6.5 EMD Specifications		O	S	C	S	S	S	S		S		C/S
4.1.6.6 EMD Risk Reduction Plan		O	S	C	S	S	S	S		C		C
4.1.7 Requirements and Design Reviews												
4.1.7.1 Activity Outputs (4.1.2 Through 4.1.6)		I	S	C	S	S	C	S				
4.1.7.2 Design Review Procedures		I	C	S	C	C	C	C				
4.1.7.3 Design Review Reports		O	S	C	C	C	C	C				C

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Figure 1-3 (Continued). Customers and Suppliers Matrix

CHAPTER 1
PRACTICING CONTINUOUS IMPROVEMENT

Reliability Process Engineering and Manufacturing Development Phase		Customer (C) Supplier (S)											
		Input (I) Output (O)	Reliability Engineering	Program Management	Design Engineering	Engineering Technologies	Logistics Support Function	Manufacturing	Support Groups	Test and Evaluation Engineering	Subcontractors/ Suppliers	External Customer	
Block	Title												
5.1.1 Quality Evaluation													
5.1.1.1	Evaluation Instructions	I	C	C	C	C	C	C	C	C		S	
5.1.1.2	Evaluation Criteria	I	C	C	C	C	C	C	C	C		S	
5.1.1.3	Quality Evaluation Report	O	S	S	S	S	S	S	S	S		C	
5.1.2 Interpret Customer Needs													
5.1.2.1	Customer Requirements	I	C		C		C	C				S	
5.1.2.2	Experience Data	I	S		C	C	S	S				S	
5.1.2.3	Product Design and Manufacturing Rqmts	O	S		S	S	S	S		C		C	
5.1.2.4	Trade Study Candidates	O	S		C	C	C	C				C	
5.1.2.5	EMD Risk Reduction Plan	O	S	C	S	S	S	S		C		C	
5.1.3 Program Planning													
5.1.3.1	Funding Profile	I	C	S	C	C	C	C					
5.1.3.2	EMD Risk Reduction Plan	I	S	C		S	S	S	S		C		
5.1.3.3	Contract Requirements	I	C	C	C	C	C	C		C		S	
5.1.3.4	Product Design and Manufacturing Rqmts	I	S		C	C	S	S		C			
5.1.3.5	Tradeoff Candidates	I	S		C	C	C	C					
5.1.3.6	Tailored Program Plan	O	S	C	S	C	C	S	C	C		C	
5.1.3.7	CAE Tools	O	S	C	S	S	C	S	C				
5.1.3.8	Requirements Flowdown	O	S		C	C	C	C				C	
5.1.3.9	Subcontractor Selection and Control Plan	O	S	C	S	S	S	S	C		C	C	
5.1.3.10	Integrated Test Plan	O	S	C	S	S		C		C		C	
5.1.3.11	Benchmarking and Training Plan	O	S	C	S	S	S	S					
5.1.4 Detail Design Reliability Analysis													
5.1.4.1	Product Design Data	I	C		S	S	S	S					
5.1.4.2	Design Criteria	I	S		S	S	C	C					
5.1.4.3	Requirement Flowdown	I	S		C	C	C	C					
5.1.4.4	Environment and Use Profiles	I	C		S	S	S	C		C			
5.1.4.5	Development Test Results	I	C		C	C		C		S			
5.1.4.6	Stress Analysis and Predictions	O	S		S	S	C	C				C	
5.1.4.7	Variability Analysis	O	S	C	S		C	S		C		C	
5.1.4.8	Critical Product Characteristics and Manufacturing Processes	O	S		S		C	S		C		C	
5.1.4.9	Design for Manufacturing Guidelines	O	C		S			S/C					

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Figure 1-3 (Continued). Customers and Suppliers Matrix

Reliability Process Engineering and Manufacturing Development Phase		Customer (C) Supplier (S)											
		Input (I) Output (O)	Reliability Engineering	Program Management	Design Engineering	Engineering Technologies	Logistics Support Function	Manufacturing	Support Groups	Test and Evaluation Engineering	Subcontractors/ Suppliers	External Customer	
Block	Title												
5.1.5 Tradeoff Analysis													
5.1.5.1	Trade Study Candidates	I	S		C	C	C	C					
5.1.5.2	Requirements Flowdown	I	S		C	C	C	C					
5.1.5.3	Design and Manufacturing Alternatives	I	C		S	S	S	S					
5.1.5.4	Trade Study Reports	O	S	C	C	C	C	C				C	
5.1.6 Manufacturing Process Control													
5.1.6.1	Design for Manufacturing Guidelines	I	C		S			C/S					
5.1.6.2	Critical Product Characteristics and Manufacturing Processes	I	S		S		C	S		C			
5.1.6.3	Manufacturing Process Description	I	C		C			S					
5.1.6.4	Manufacturing Experience Data	I	C		C			S					
5.1.6.5	Manufacturing Process FMECA	O	S		C			C					
5.1.6.6	Manufacturing Process Control Plan	O	C		C			S				C	
5.1.7 Development and Verification Tests													
5.1.7.1	Integrated Test Plan	I	S		S	S				C			
5.1.7.2	Environment and Use Profiles	I	C		S	S	S	S		C			
5.1.7.3	Test Reports and Design Changes	O	S		S		C	C		S		C	
5.1.8 Production Specifications													
5.1.8.1	Stress Analysis and Predictions	I	S		S	S	C	C					
5.1.8.2	Mfg Process Control Plan	I	C					S					
5.1.8.3	Test Reports	I	S		S	C	C	C		S			
5.1.8.4	Product Performance Specifications	O	S	C	S	S	S	C		S		C	
5.1.8.5	Mfg Specifications	C	C	C	C	C		S				C	
5.1.9 Design Reviews													
5.1.9.1	Activity Outputs	I	S	C	S	S	C	S					
5.1.9.2	Design Review Procedures	I	C	S	C	C	C	C					
5.1.9.3	Design Review Reports	O	S	C	C	C	C	C				C	

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Figure 1-3 (Continued). Customers and Suppliers Matrix

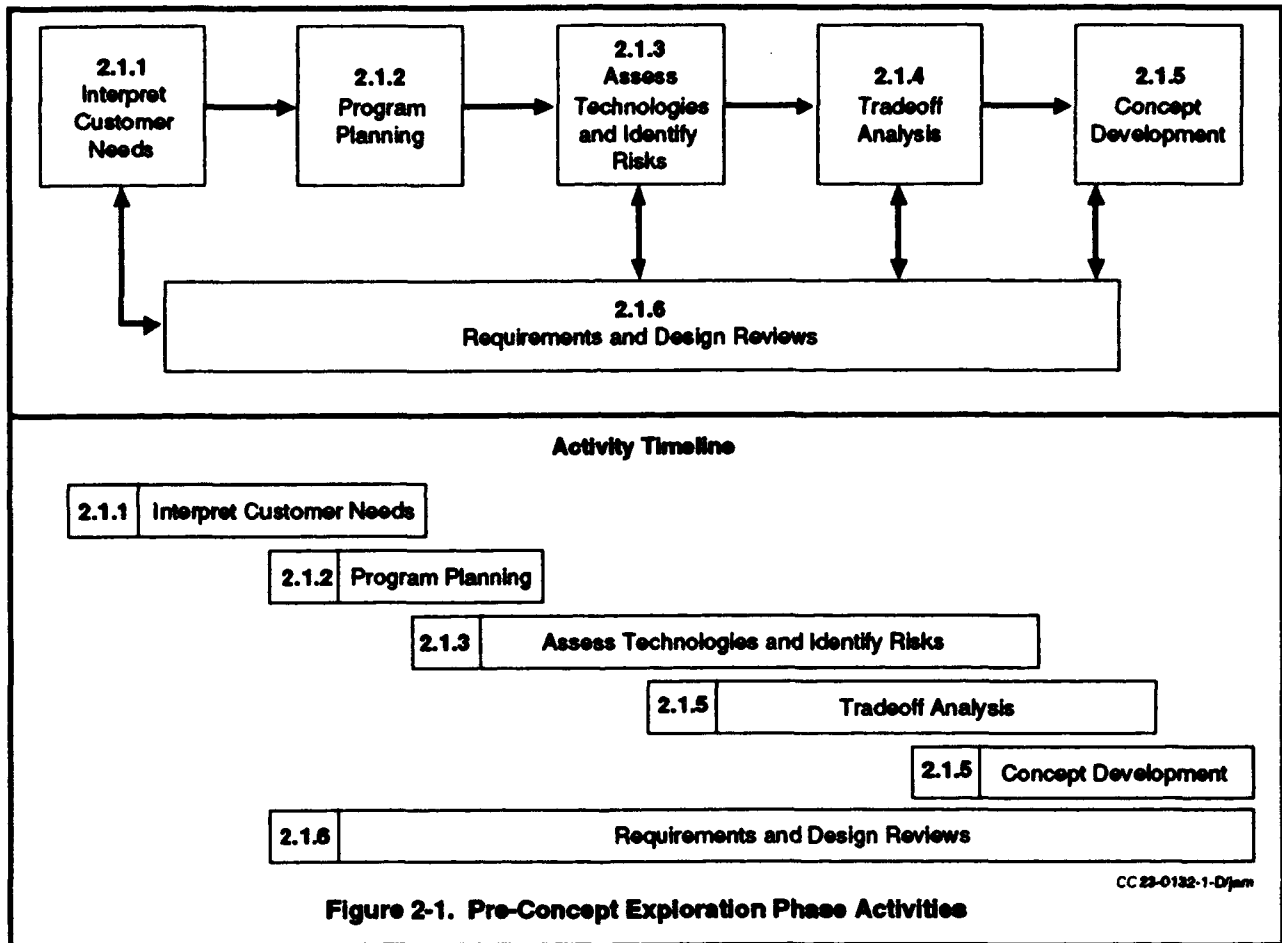
CHAPTER 1
PRACTICING CONTINUOUS IMPROVEMENT

Reliability Process Production and Support Phase		Customer (C) Supplier (S)										
		Input (I) Output (O)	Reliability Engineering	Program Management	Design Engineering	Engineering Technologies	Logistics Support Function	Manufacturing	Support Groups	Test and Evaluation Engineering	Subcontractors/ Suppliers	External Customer
Block	Title											
6.1.1	Quality Evaluation											
6.1.1.1	Evaluation Criteria	I	C	S	C	C	C	C	C	C		
6.1.1.2	Quality Assessment Report	O	S	C	S	S	S	S	S	S		
6.1.2	Program Planning											
6.1.2.1	Funding Profiles	I	C	S	C	C	C	C		C		
6.1.2.2	Product Performance Specifications	I	S	C	S	S	S	C		S		
6.1.2.3	Manufacturing Requirements	I	C	C	C	C	C	S				
6.1.2.4	Contract Requirements	I	C	C	C	C	C	C		C		S
6.1.2.5	Tailored Program Plan	O	S	C	S	C	C	S	C	C		C
6.1.2.6	Failure Reporting Analysis and Corrective Action Plan	O	S	C	C		C	C		C		C
6.1.2.7	Benchmarking and Training Plan	O	S	C	S	S	S	S		S		
6.1.2.8	Customer Feedback Plan	O	S	C	C	C	S	C		C		C
6.1.3	Production Reliability Control											
6.1.3.1	Manufacturing Process Description	I	C		C	C		S				
6.1.3.2	Supplier Control Results	I	C	C	C						S	
6.1.3.3	Pre-Delivery Test Results	I	S	C	C		C	C			S	
6.1.3.4	Manufacturing Process Changes	O	C		C	C	C	S				C
6.1.3.5	Parts and Materials Changes	O	C		S	C	C	C				C
6.1.4	Customer Support											
6.1.4.1	Logistics Support Plan	I	C	C	C		S	C				
6.1.4.2	Customer Data Feedback	I	C	C	C	C	C	C				S
6.1.4.3	Design Changes	O	C		S		C	C				C
6.1.4.4	Manufacturing Process Changes	O	C		C		C	S				C
6.1.5	Design and Manufacturing Reviews											
6.1.5.1	Manufacturing Process Capability Indices	I	C	C	C			S				
6.1.5.2	Pre-Delivery Test Results	I	S		C		C	C				
6.1.5.3	Customer Data Feedback	I	C	C	C	C	C					S
6.1.5.4	Product Improvement	O	S	C	S							C
6.1.5.5	Support System Change Proposals	O	C	C	C	C	S					C

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Figure 1-3 (Concluded). Customers and Suppliers Matrix

CHAPTER 2
PRE-CONCEPT EXPLORATION PHASE



2.0 INTRODUCTION

APPLICATION OF ACTIVITIES, INPUTS, AND OUTPUTS

This chapter defines the Activities related to the development of reliability attributes that should take place during the Pre-Concept Exploration phase. This phase provides the necessary basis for all succeeding phases of development and acquisition. Figure 2-1 identifies the Activities and provides a general time line for the sequencing of those Activities. In any organization, there will usually be several Pre-Concept Exploration programs taking place simultaneously. These programs will be a mixture of contracted R&D and independent R&D. All of these programs should be conducted in accordance with the principles described in paragraphs 2.1.1 through 2.1.6. When the research is contracted R&D, the customer may wish to incorporate tailored versions of the Activities, Inputs, and Outputs into technical documentation, such as Specifications, Data Item Descriptions, and Statements of Work. The customer should also look for evidence that the principles of paragraphs 2.1.1 through 2.1.6 are being applied to other related, but noncontract, R&D. The implementation of several of these activities may be governed by a single set of organization wide rules or practices. The procedures governing design reviews are an example of such organization-wide practices. In all cases, the inputs and outputs of the activities of programs being conducted in parallel must be coordinated to avoid duplication and maintain a consistent focus on customer satisfaction.

2.1 SUMMARY OF ACTIVITIES

The key focus of all Pre-Concept Exploration phase activity is the development of affordable and militarily useful technology. The Activities, Inputs, and Outputs of paragraphs 2.1.1 through 2.1.6 support this focus by emphasizing the definition of customer requirements, the development of defect reduction design and manufacturing techniques, and the creation of risk reduction plans. The phase activities also emphasize the development of plans and products that affect the quality of the work performed in all subsequent acquisition phases. The six phase Activities are:

CHAPTER 2

PRE-CONCEPT EXPLORATION PHASE

- (1) Interpret Customer Needs
- (2) Program Planning
- (3) Assess Technologies and Identify Risks
- (4) Trade Off Analysis
- (5) Concept Development
- (6) Requirements and Design Reviews

The most critical of these activities is the interpretation of customer needs and the translation of these needs into technical objectives. Both the customer and supplier must focus on the accurate, systematic, and documented definition of customer needs. Active customer participation in this activity is a requirement for success.

DEFINE THE NEEDS OF THE CUSTOMER

Program Planning should be a natural result of broadly applicable, organization-wide process descriptions. In a high quality organization it should be expected that existing process descriptions would address most of the Activities, Inputs, and Outputs described in paragraphs 2.1.1 through 2.1.6.

Assessing Technologies and Identifying Risks is the second critical activity of the Pre-Concept Exploration phase. All technology development requires the concurrent characterization of reliability attributes, including the definition of manufacturing technology for the purpose of initiating process control techniques. This characterization must focus on defect prevention and plans for maturing the reliability attributes.

DEFECT PREVENTION

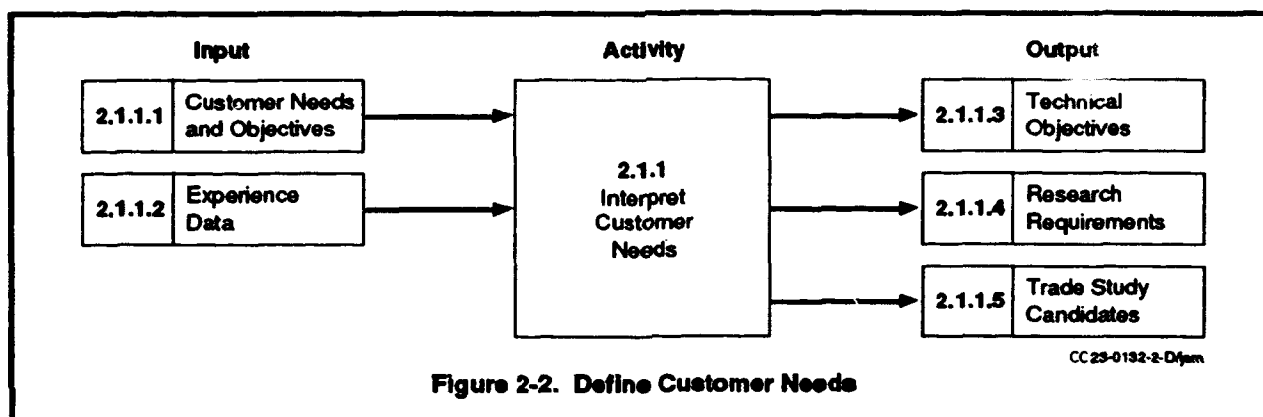
Trade Studies are the vehicle for achieving balanced designs. They should be based on interactions among technical objectives, and the weights assigned to the measures of merit used to evaluate the goodness of the design alternatives must be traceable to customer defined priorities.

Concept Development synthesizes the results of the above activities into recommended systems implementations.

Requirements and Design Reviews bring discipline and a focus on achieving objectives into the technology development process. These are the vehicles for maintaining a focus on the satisfaction of customer needs.

CUSTOMER SATISFACTION

This phase does not contain a requirement for a formal quality evaluation activity. World Class organizations will have already defined the quality level of their operations and have adopted plans for continuous improvement. For organizations that have not performed these tasks, the Program Planning activity includes requirements for implementing internal evaluations. If, in the view of the customer, a quality evaluation is required for a specific contract, the Quality Evaluation Activity of paragraph 3.1.1 should be implemented.



2.1.1 ACTIVITY - INTERPRET CUSTOMER NEEDS

A systematic, comprehensive process for defining customer needs, the priorities associated with these needs, and the translation of these needs into quantified technology objectives must be implemented for this phase. Quality Function Deployment is the recommended tool for implementing this activity. This technique should be applied to both contracted and independent R&D. There should be evidence of a coordinated approach to assembling definitions of customer needs from a variety of sources, such as marketing, customer visits, and existing programs. Customer obligations for this activity consist of completely defining all needs and objectives for contracted technology research.

QUALITY FUNCTION DEPLOYMENT

2.1.1.1 INPUT - CUSTOMER NEEDS AND OBJECTIVES

VOICE OF THE CUSTOMER

The supplier must have a program for broad and frequent direct customer contact to supplement documented expressions of customer needs, such as Air Force Technical Area Plans, Technology Transition Demonstrators, and Navy Broad Agency Announcements, and, for contracted research, Mission Descriptions, Statements of Work, and Technical Specifications. All personnel who will have customer contact must be made aware of the need to identify the comprehensive range of customer needs and priorities, inclusive of reliability attributes and manufacturing issues. The supplier must also have a method for transmitting customer needs information across all research programs.

2.1.1.2 INPUT - EXPERIENCE DATA

The supplier must ensure that planned technology research is subject to review by experts in all areas so that all customer needs are identified and properly translated into technical objectives. The experience data base should include a thorough and documented understanding of both good and bad customer experience with current products as a preferred method for aiding in the identification of needs and constraints.

2.1.1.3 OUTPUT - TECHNICAL OBJECTIVES

The supplier provides a definition of specific technical attributes and parameters that will satisfy all customer needs. Quality Function Deployment is the recommended method for defining and documenting technical objectives. This definition includes quantitative objectives for each of the attributes and parameters. The customer needs must be given weighting factors which represent priority levels. These factors will be used to define weighting factors for each of the technical attributes and parameters. At this early stage of development, it is important that quantified attributes and parameters be treated as objectives rather than requirements.

2.1.1.4 OUTPUT - RESEARCH REQUIREMENTS

RELATED RESEARCH

The supplier, in concert with the customer, must, for the technology or system being developed, list and

describe all related research in order to avoid duplication and maximize resources. As the research effort proceeds, additional research necessary to enable the developing technology must be identified for inclusion in future plans. These lists of related and enabling research are to be maintained by the suppliers.

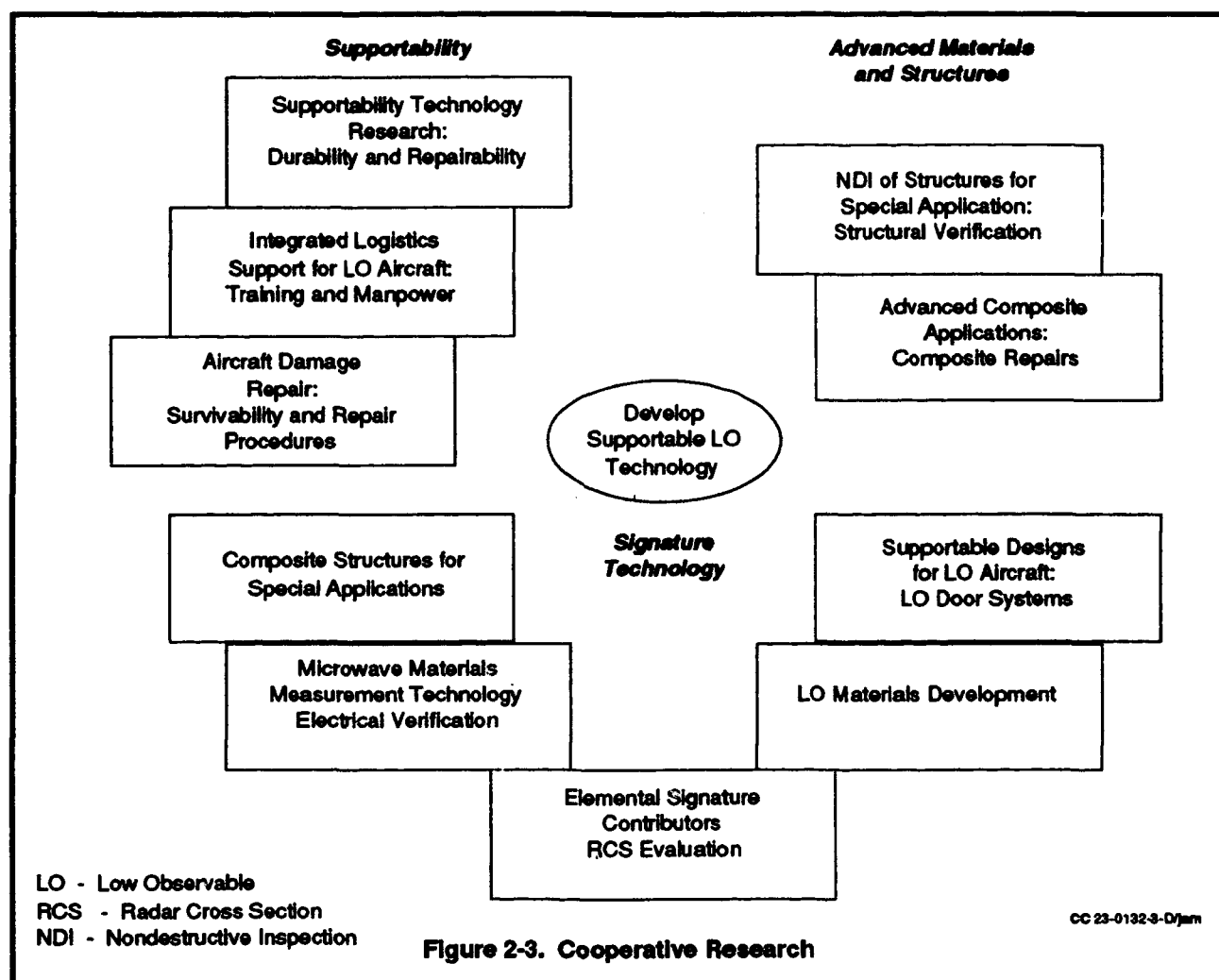
2.1.1.5 OUTPUT - TRADE STUDY CANDIDATES

The supplier must identify candidates for trade studies to be performed during the research program. The Quality Function Deployment technique can assist in defining these candidates by evaluating the interactions among technical objectives. Trade Off Analyses are used to optimize a technical attribute or parameter that interacts with other technical attributes or parameters. For example, radar detection range is a function of power, weight, volume, receiver sensitivity, reliability, and cost. These analyses are also used to select between alternative technologies or system concepts.

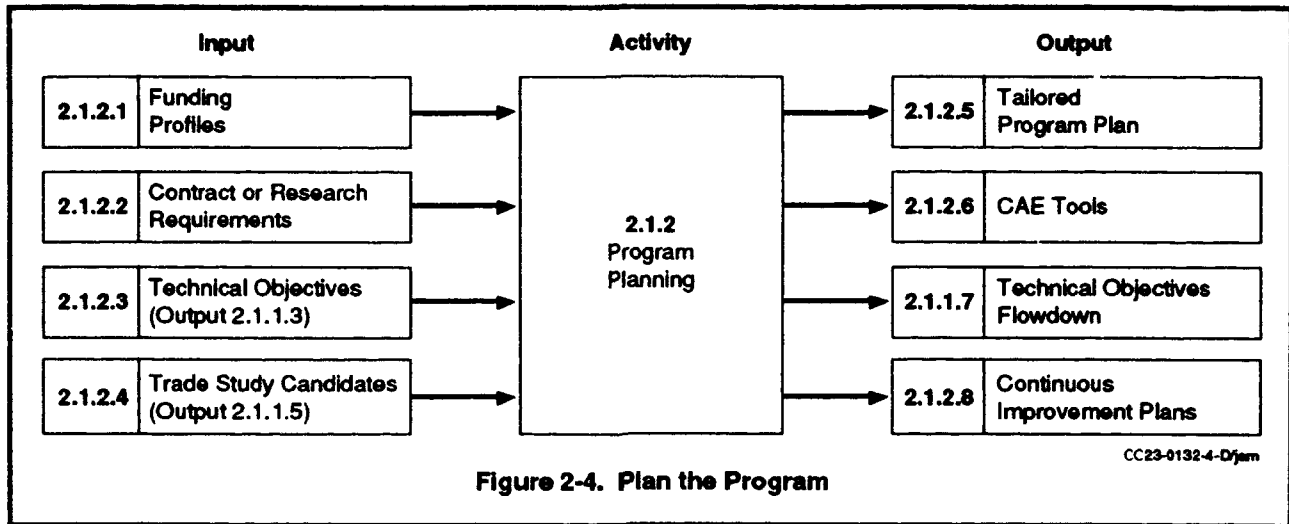
EXAMPLE OF INTEGRATED RESEARCH

Figure 2-3 illustrates the concept of cooperative research. In order to develop reliable signature reduction techniques, a major aircraft company has integrated the research activities of several specialty areas. A signature technology group is responsible for developing basic materials signature properties, the measurement of these properties, and analytic methods for estimating contributions to signature levels. A second specialist group is responsible for research into long-term aircraft application of composite materials, while a third specialty group is responsible for developing technology that enhances reliability and reduces support resources. Each of the specialty groups have research programs directed at specific technology issues. Synergism has been achieved by integrating the research of these diverse groups to emphasize high reliability, low signature aircraft materials and design. For example, aircraft access doors were being designed for optimum signature performance. These designs now accommodate constraints based on access frequency, durability, safety, fastener styles, and cure times for seal

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materials. Research into these issues is now being accomplished as an integral part of design for signature reduction.



2.1.2 ACTIVITY - PROGRAM PLANNING

Program Planning is necessary for each research program in order to define specific inputs and outputs, the responsibility for these inputs and outputs, the schedule for these inputs and outputs, and the resources to be allocated, all based on customer priorities. As a baseline, the plan will consider the Activities, Inputs, and Outputs contained in paragraphs 2.1.1 through 2.1.6. If an organization has a set of clear, comprehensive, and integrated process descriptions, embracing the intent of paragraphs 2.1.1 through 2.1.6, these should be used in lieu of separately prepared program plans. All involved specialty disciplines (functions) must concur with the content of program plans.

2.1.2.1 INPUT - FUNDING PROFILES

The supplier should have a funding process that is interactive, flexible, and responsive to customer needs and priorities. Funding profiles should be an element of initial requirements reviews.

ALLOCATE THE RESOURCES

FUNDING SHOULD BE RESPONSIVE TO CUSTOMER NEEDS

2.1.2.2 INPUT - CONTRACT OR RESEARCH REQUIREMENTS

This input applies to both contracted and independent research. It consists of a complete description of overall program objectives, schedules, task definitions, and deliverables (reports).

2.1.2.3 INPUT - TECHNICAL OBJECTIVES

Output 2.1.1.3 serves as an input to the Program Planning Activity.

2.1.2.4 INPUT - TRADE STUDY CANDIDATES

Output 2.1.1.5 serves as an input to the Program Planning Activity. Additional Trade Study candidates may be identified based on customer needs and supplier experience. The candidate list should define specific measures of merit being evaluated for each alternative technology or design. Reliability attributes should always be included as trade study measures of merit.

2.1.2.5 OUTPUT - TAILORED PROGRAM PLAN

The supplier should prepare program plans for all research programs using the Activities, Inputs, and Outputs of paragraphs 2.1.1 and 2.1.3 through 2.1.6 for guidance. Plans should be tailored based on the complexity and scope of the research programs. Existing organization-wide process descriptions should be used if they are comprehensive and cover the intent of paragraphs 2.1.1 and 2.1.3 through 2.1.6. Plans must always identify acceptance criteria, responsibility, and schedule for both input and output products.

2.1.2.6 OUTPUT - COMPUTER AIDED ENGINEERING (CAE) TOOLS

The supplier must continuously maintain and update the definition of hardware and software design automation tools and the interoperability of equipment and data bases. These plans would generally be done on an organization-wide basis and should include plans and provisions for training. Concurrent Engineering demands automation and the capability for the interchange of data. Consideration of customer/use access to data bases should always be part of these plans.

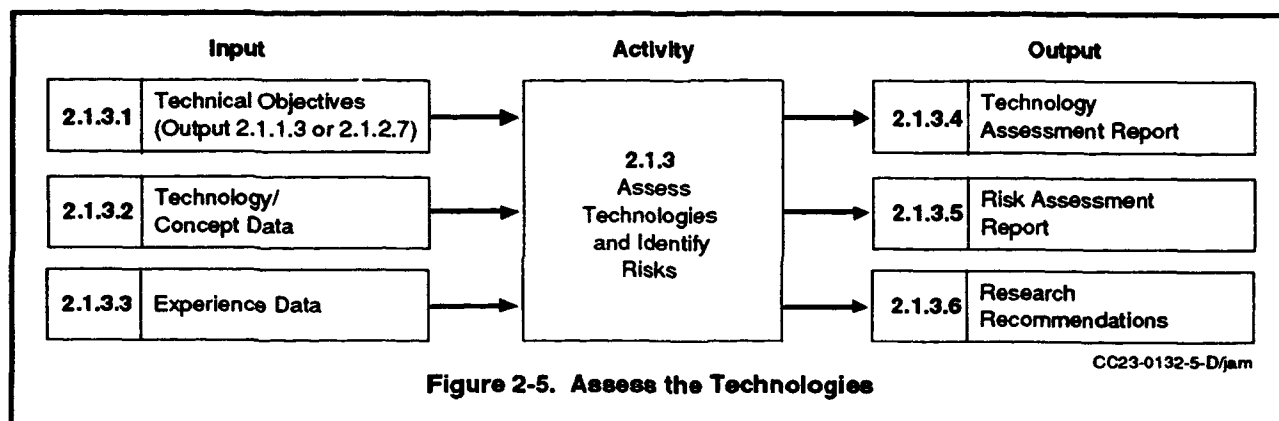
**CONCURRENT
ENGINEERING**

2.1.2.7 OUTPUT - TECHNICAL OBJECTIVES FLOWDOWN

The initial Quality Function Deployment will identify the top level technical attributes and parameters associated with satisfying customer needs, the quantitative objectives for these attributes and parameters, and a quantification of the relative importance of each attribute or parameter based on customer priorities. If required for further analysis or trade studies, these top level attributes and parameters will be decomposed or allocated to lower level parameters and objectives. Traceability to customer needs and quantification of importance based on customer priorities will be maintained.

2.1.2.8 OUTPUT - CONTINUOUS IMPROVEMENT PLANS

The supplier must be developing and implementing organization-wide plans for continuous improvement. Evidence should exist that shows that the supplier has embarked on a program that includes comprehensive and specific process descriptions, an assessment of the quality of operations, benchmarking plans, and training in topics such as QFD, design for manufacturing and variability control.



2.1.3 ACTIVITY - ASSESS TECHNOLOGIES AND IDENTIFY RISKS

The supplier must begin the process of developing methods for preventing or eliminating defects in product reliability attributes (life, durability, defect

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rate, BIT performance). This Activity is applicable to all technology or system concepts research programs. The activity includes identifying initial design, application, and derating criteria, environmental sensitivity, critical parameters and functions, parameter variability, projected manufacturing technology, and quantitative performance expectations for reliability attributes.

2.1.3.1 INPUT - TECHNICAL OBJECTIVES

Output 2.1.1.3 or 2.1.2.7, as appropriate, serve as an input to Activity 2.1.3. This input identifies the technical attributes and parameters and their baseline quantitative objectives.

2.1.3.2 INPUT - TECHNOLOGY/CONCEPT DATA

The new technology or systems concepts must be completely defined, including identification of functionally and/or physically similar existing technologies or systems. These comparisons should define the environmental and use applications for both the existing technology or systems and the new technology or systems. Factors that should be identified for the new technology or systems include first order estimates of environmental and use application, environmental constraints or sensitivities, critical attributes, parameters, or functions, variability range of critical parameters, packaging concepts, and projected manufacturing technologies or processes.

**MISSION
DESCRIPTION**

2.1.3.3 INPUT - EXPERIENCE DATA

The supplier must assemble all potentially relevant experience data. This data includes customer and internal Lessons Learned, user reliability attribute performance data for functionally or physically similar technologies/systems, related research results, existent design and application guides (e.g., derating, design margins), and current manufacturing processes defect rate data. This input should be used as an opportunity for customer interaction.

LESSONS LEARNED

2.1.3.4 OUTPUT - TECHNOLOGY ASSESSMENT REPORT

This report should accomplish two objectives: 1) define, quantitatively, the expected performance levels of the technology or system reliability

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DESIGN AND
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ISSUES**

attributes, and 2) provide an initial definition of design constraints and application guides which will prevent defects. Quantitative performance expectations are to be based on comparisons to user-experienced performance levels for functionally or physically comparable current technology or systems. These estimates are to be supported by specific engineering rationale that include causal analysis of existing performance deficiencies in reliability attributes. All critical parameters and/or functions should be identified via Failure Modes Effects or similar analyses. Initial estimates of allowable parameter variability should be made. The report will include descriptions of applicable lessons learned, constraints and application guidelines/design margins, definition of environmental stress sensitivities, and required manufacturing technologies and processes.

2.1.3.5 OUTPUT - RISK ASSESSMENT REPORT

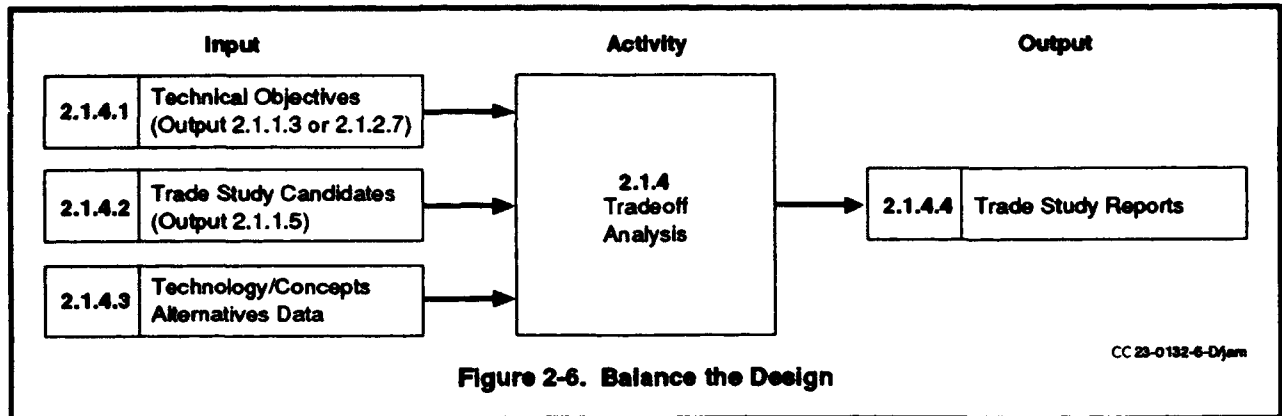
RISK REDUCTION

This report should identify areas of uncertainty relative to achieving the technical objectives for reliability attributes, and the plans for eliminating those uncertainties. These risk areas include critical parameter variability, environmental stress sensitivities, the absence of design and application criteria, and the lack of definition of manufacturing processes and technology. Reliability performance expectations that are not justified by engineering rationale should be considered a risk area. Inadequate substantiation of reliability attributes (life, durability, defect rates, testability potential, parameter variability, and manufacturing defect rates) for new technologies are always a risk area.

2.1.3.6 OUTPUT - RESEARCH RECOMMENDATIONS

A supplier should have procedures in place that cause the results of current research to influence and guide future research. Each research or development activity requires a roadmap to define further related research, particularly into areas identified as risks in Output 2.1.3.5.

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2.1.4 ACTIVITY - TRADE-OFF ANALYSIS

Trade-Off analysis is a formal method for making cost-effective decisions during the development. Each research program must have an identified list of trade studies, the measures of merit to be compared for alternative technologies or system concepts, and a weighting factor for each measure of merit that is traceable to customer priorities. Measures of merit would include such things as weight, processing speed, sensitivity, cost, failure rate, etc. For the purpose of reaching a trade study conclusion each of the measures of merit are assigned a weighting factor representing the relative importance of the measure of merit to the customer. Trade study candidates are developed during the Definition of Customer Need Activity (2.1.1). One or more of the reliability attributes and measures of merit representing manufacturing technologies must be considered for all trade studies. The supplier must have a well defined trade-off process that is linked to the Requirements and Design Review Activity (2.1.6).

2.1.4.1 INPUT - TECHNICAL OBJECTIVES

Output 2.1.1.3 or 2.1.2.7 serves as an input to the Trade-Off Analysis Activity. These are the quantified technical attributes or parameters that satisfy customer needs and include a further quantification that represents customer priorities.

BALANCED DESIGNS

2.1.4.2 INPUT - TRADE STUDY CANDIDATES

Output 2.1.1.5 serves as an Input to the Trade-Off Analysis activity. The list of candidates may change during the course of the program and should be responsive to changes in customer needs or priorities.

2.1.4.3 INPUT - TECHNOLOGY/CONCEPTS ALTERNATIVE DATA

Accurate information regarding the relationships among technical attributes and parameters (e.g., weight versus reliability attributes) and description of alternative technologies or system concepts is key to valid Trade-Off conclusions. The claimed relationships among technical attributes and parameters should be validated by experiment or extensive analysis. The data defining alternative technologies or systems concepts should approximate the depth and quality described in paragraph 2.1.3.2, TECHNOLOGY/CONCEPT DATA. Weighting factors assigned to the measures of merit used to compare alternatives should be traceable to customer priorities defined during Activity 2.1.1. Specific reliability and manufacturing attributes are to be considered for all trade studies.

2.1.4.4 OUTPUT - TRADE STUDY REPORTS

These reports provide a complete record of trade off analysis results. This includes the selected technology or system concept, quantitative values, technical objectives, the trade study alternatives, methods, and selection criteria. The report should describe how the selection clearly satisfies customer needs and priorities.

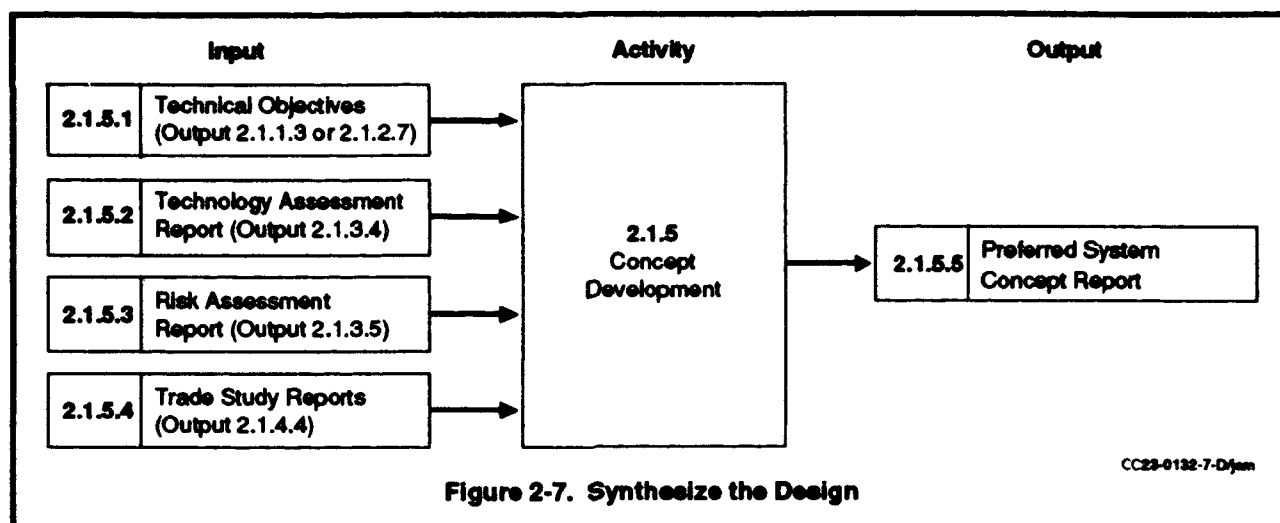


Figure 2-7. Synthesize the Design

2.1.5 ACTIVITY - CONCEPT DEVELOPMENT

All research programs should include a summary report which defines the quantified technical objectives for the technology or systems concept and summarizes risk issues requiring further research and/or analyses.

DESIGN SYNTHESIS

2.1.5.1 INPUT - TECHNICAL OBJECTIVES

Output 2.1.1.3 or 2.1.2.7 serves as an input to the Activity. These data define baseline quantified technical objectives.

2.1.5.2 INPUT - TECHNOLOGY ASSESSMENT REPORT

Output 2.1.3.4 serves as an input to the concept development activity. This input defines the performance expectations for reliability attributes, justified by engineering rationale, and supported by design rules.

2.1.5.3 INPUT - RISK ASSESSMENT REPORT

Output 2.1.3.5 serves as an Input to Activity 2.1.5. The data summarizes the risks associated with achieving expected performance levels for the reliability attributes and the plans for the control of these risks.

2.1.5.4 INPUT - TRADE STUDY REPORTS

Output 2.1.4.4 serves as an input to Activity 2.1.5

2.1.5.5 OUTPUT - PREFERRED SYSTEM CONCEPT REPORT

All research programs require a summary report defining the technology applications or system concept and the linkage between quantified technical objectives and customer needs. Specific constraints or defect prevention conditions are defined, as are risk issues and risk control plans. Projected manufacturing technologies or processes are also identified. This report will reflect a set of customer needs and priorities that have been validated during the Requirements and Design Review Activity.

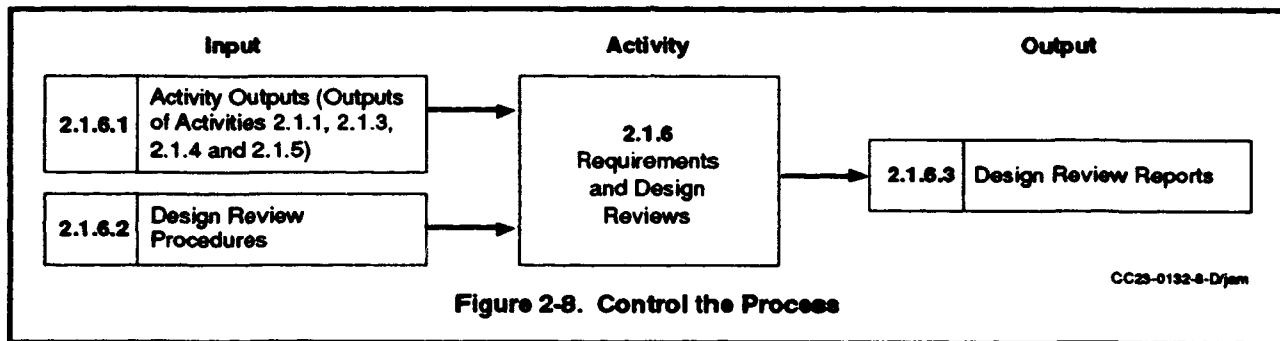


Figure 2-8. Control the Process

2.1.6 ACTIVITY - REQUIREMENTS AND DESIGN REVIEWS

PROCESS DISCIPLINE

This activity must maintain an essential discipline throughout the activities of this phase and ensure that the "voice of the customer" is defined and heeded. The supplier should have a documented design review procedure that ensures consistency and thoroughness. The definition for the timing of Requirements and Design Reviews takes place during the Planning Activity (2.1.2). The Inputs to the reviewed activities should serve to define entry criteria for reviews with the Outputs providing the source of exit criteria.

2.1.6.1 INPUT - ACTIVITY OUTPUTS

The outputs of Activities 2.1.1, 2.1.3, 2.1.4, and 2.1.5 should be subject to the review process. This includes both internal reviews and, in the case of contracted research, customer reviews.

2.1.6.2 INPUT - DESIGN REVIEW PROCEDURES

The supplier must have an established and documented procedure for conducting internal review of requirements and design. The procedure covers review frequency, entry and exit criteria, definition of participants, agenda requirements, and closure plans for action items. Reviews should always have an agenda which defines the customer needs to be reviewed and specific review entry and exit criteria. With customer concurrence, these review procedures will serve as the basis for customer reviews for contracted research. Every review must include a definition of applicable customer needs and a demonstration of satisfaction of those needs.

2.1.6.3 OUTPUT - DESIGN REVIEW REPORTS

All design reviews must have results documented, including a definition of actions, responsibility for action closure, criteria for action closure, closure dates, and final disposition of action items.

2.2 CONTROL AND AUDIT

QUANTIFY THE RISK

While properly conducted Requirements and Design Reviews can provide a significant degree of control, quantitative metrics that represent the effectiveness of the process is a preferred complement to these reviews. The selected metric for the Pre-Concept Exploration phase is Risk Factor. This criteria provides a quantitative score that represents a combination of the likelihood that the reliability process will achieve its intended results and the consequences of failing to achieve intended results. The methodology for determining the Risk Factor score follows the principles of the Defense Science Management College Risk Assessment technique. Figure 2-9 illustrates the concept and shows the significance of risk factor scores.

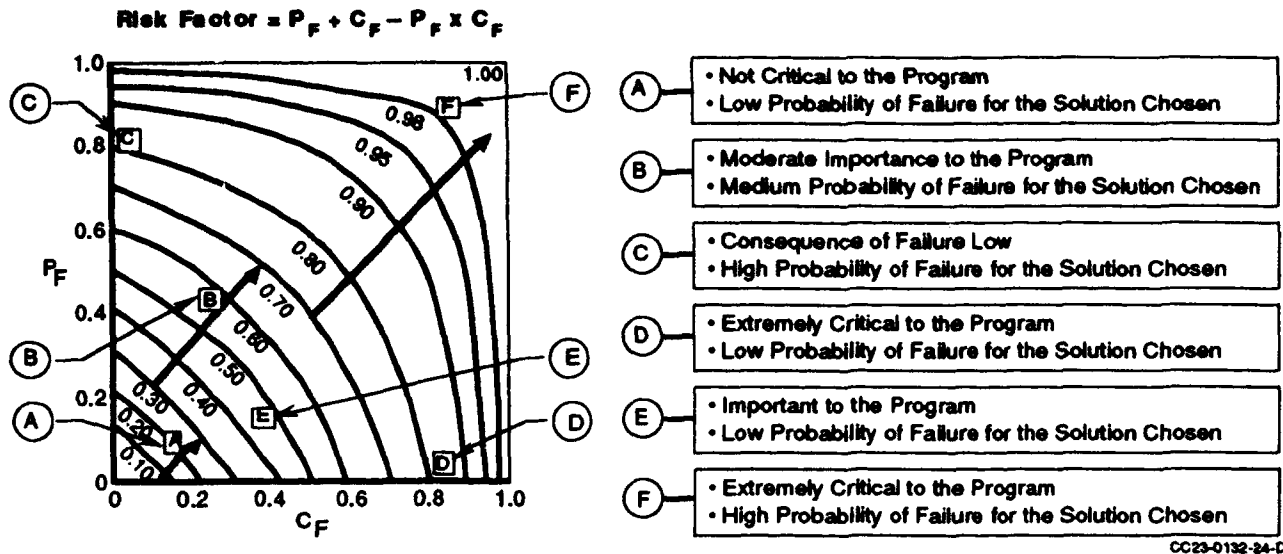


Figure 2-9. Isorisk Contours Highlight Critical Uncertainties

The risk factor formula is: $\text{Risk Factor} = P_{(F)} + C_{(F)} - P_{(F)} \times C_{(F)}$. In this case, $P_{(F)}$ is the probability that the reliability process will not achieve its intended results (fail). The consequence of failure ($C_{(F)}$) is a measure of the importance of the technology or system concept being developed. The likelihood that the process will fail is the sum of the weighted likelihood that each critical process activity will fail. Weighting is determined by the relative importance of each Activity within the acquisition phase. The applicable formulae, terms, and weight factors are shown in Figure 2-10 (page 2-20). As indicated in the figure, the most important Activities for the Pre-Concept Exploration Phase are the Interpretation of Customer Needs and Technology Assessment activities. The latter activity includes the identification of technical risk and proposed solutions. Scores for the individual activity failure probabilities and the consequences of failure, shown in Figure 2-10, are determined by specific criteria shown in Figures 2-11 through 2-15. The criteria in Figures 2-11 through 2-14 (pages 2-21 through 2-25) are directly related to the quality of the inputs and outputs of Activities 2.1.1, 2.1.3, 2.1.4, and 2.1.6.

FAILURE OF CRITICAL ACTIVITIES

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These scoring criteria can be tailored to the needs of individual research programs.

For any specific research program, the Risk Factor score for the reliability process should not exceed 0.7. Risk reduction plans for reliability attributes are required when this rule is violated.

Risk factor evaluation can be implemented as part of the Requirements and Design review process. For objectivity reasons, it is recommended that risk factor scores be developed by parties not directly involved in the research program. Evaluation and scoring is a customer responsibility for contracted research.

Figures 2-10 through 2-15 completely describe the evaluation methodology.

Probability of Failure				
Parameter	Probability of Failure Caused by:	Weight Factor	Activity	Scoring and Criteria
P ₍₁₎	Inadequate Definition and Update of Customer Requirements	0.3	2.1.1 2.1.6	Figure 2-11
P ₍₂₎	Faulty Planning	0.2	2.1.2	Figure 2-12
P ₍₃₎	Incomplete or Inadequate Technology Assessment	0.3	2.1.3	Figure 2-13
P ₍₄₎	Inadequate Trade Studies	0.2	2.1.4	Figure 2-14
P _(F)	$0.3P_{(1)} + 0.2P_{(2)} + 0.3P_{(3)} + 0.2P_{(4)}$			

Consequence of Failure			
Parameter	Consequence of Failure	Weight Factor	Scoring and Criteria
C _(F)	Reliability Expectations Not Achieved	1.0	Figure 2-15

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Figure 2-10. Risk Factor: Pre-Concept Exploration Phase

$$\text{Risk Factor} = P_{(F)} + C_{(F)} - P_{(F)} \times C_{(F)}$$

Probability of Failure	Criteria for Activities 2.1.1 and 2.1.6
0.1	Customer needs have been identified and prioritized in a systematic manner and translated into product technical objectives. Trade study candidates have been identified. Design reviews have clearly defined exit criteria, customer needs are reviewed and updated, compliance with customer needs are shown. Related research and additional enabling research identified and documented.
0.3	Customer needs have been identified in a systematic manner and translated into product technical objectives. Trade study candidates have been identified. Customer needs reviewed and updated at design reviews. Compliance with customer needs are shown. Related research and additional enabling research identified and documented.
0.5	Customer needs have been identified and translated into product technical objectives. Trade study candidate list is incomplete. Design reviews show compliance with customer needs. Incomplete identification and documentation of related research and additional enabling research.
0.7	Customer needs only partially identified with no clear traceability to product technical objectives. Trade study candidate list is incomplete. Design reviews not thoroughly focused on customer needs. Very limited identification and documentation of related research and additional enabling research.
0.9	Limited customer/supplier interchange. Customer needs not validated with customer, design reviews do not specifically address customer needs. No clear integration of current research or definition of additional enabling research.

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Figure 2-11. Probability of Failure $P_{(1)}$: Customer Needs Interpretation

Probability of Failure	Criteria for Activity 2.1.2
0.1	Funding profiles are influenced by customer needs and priorities. All contract/technical requirements have been addressed. Phase tasks are tailored to customer priorities. Customer needs clearly transmitted to all personnel. Training needs/plans, benchmarking plan for continuous improvement identified, CAE tools available and data bases integrated. Allocated technical objectives "flowed down" and clearly traceable to customer needs.
0.3	Funding profiles are partially influenced by customer needs and priorities. Contract/technical requirements have been addressed. Customer needs not adequately transmitted to all personnel. Training not specifically addressed. No benchmarking plan. CAE tools list not complete. Allocated technical requirements partially traceable to customer needs.
0.5	Funding profiles not matched to customer needs and priorities. Contract/technical requirements have been addressed. Limited transmittal of customer needs to all personnel. Limited CAE tools defined and data bases are not integrated. Allocated technical requirements not traceable to customer needs.
0.7	Funding inadequate. Contract/technical requirements partially addressed. Very limited transmittal of customer needs to all personnel, very limited CAE tools.
0.9	Funding inadequate. Contract/technical requirements partially addressed. No evidence of transmittal of customer needs to personnel. Extremely limited use of CAE tools.

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Figure 2-12. Probability of Failure $P_{(2)}$: Program Planning

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Probability of Failure	Criteria for Activity 2.1.3 To Determine the Aggregate Score, Sum the Individual Scores and Divide by Six (6)
	<i>New Technology Definition</i>
0.1	New technologies/design concepts are fully described. Positive and negative features and gaps in the knowledge base are defined. Expected operating environment defined and traceable to customer mission description.
0.3	New technologies/design concepts are partially described. Positive and negative features not adequately defined. Gaps in the knowledge base are partially addressed. Expected operating environment defined and traceable to customer mission description.
0.5	New technologies/design concepts are partially described. Some positive features, few negative features defined. Limited definition of gaps in the knowledge base. Expected operating environment does not consider maintenance operations.
0.7	Superficial description of new technologies/design concepts. Negative features not addressed. No description of gaps in the knowledge base. Limited description of expected operating environment.
0.9	New technologies/design concepts proposed without a clear assessment of positive or negative features. No description of gaps in the knowledge base. Limited description of expected operating environment.
Probability of Failure	<i>Expected Reliability Performance</i>
0.1	Quantitative performance level estimates based on comparison to current customer experienced levels of performance of existing comparable equipment. Clear engineering rationale is provided for all expected improvements. Initial definition of design/application criteria complete. Lessons learned data is available (e.g., derating, environmental sensitivity).
0.3	Quantitative performance level estimates based on comparison to current levels of performance of existing comparable equipment. One or more key performance parameters (e.g., life, fatigue, false alarm rate, etc.) is not identified. Clear engineering rationale is provided for all expected improvements. Initial definition of design/application criteria complete. Lessons learned data is available (e.g., derating, environmental sensitivity).
0.5	Quantitative performance level estimates based on comparison to current levels of performance of existing comparable equipment. Key performance parameters missing and engineering rationale for expected improvements is weak. Initial definition of design/application criteria complete. Lessons learned data is available (e.g., derating, environmental sensitivity).
0.7	Quantitative performance level estimates have limited reference to the performance levels of existing comparable equipment. Engineering rationale for expected improvements is weak. Limited definition of design/application criteria or lessons learned.
0.9	No definition of existing comparable equipment design/application criteria or lessons learned.
Probability of Failure	<i>Critical Parameters or Functions</i>
0.1	Failure modes effects analysis or similar analyses have been conducted to identify critical parameters or functions. Fault detection and fault tolerance approaches systematically defined and related to critical parameters or functions. Variability of critical parameters have been estimated.
0.3	Failure modes effects analysis or similar analyses have been conducted to identify critical parameters or functions. Fault detection and fault tolerance approaches systematically defined and related to critical parameters or functions. Variability of critical parameters not estimated.
0.5	Failure modes effects analysis or similar analyses have been conducted to identify critical parameters or functions. Fault detection and fault tolerance approaches partially related to critical parameters or functions and not accomplished concurrently with failure modes effects analysis.
0.7	Failure modes effects analysis or similar analyses have been conducted to identify critical parameters or functions. No evidence of linkage between this analysis and the definition of fault detection and fault tolerance approaches.
0.9	Failure modes effects analysis or similar analyses not conducted or not linked to identifying critical parameters or functions, fault detection or fault tolerance approaches.

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Figure 2-13. Probability of Failure $P_{(3)}$: Technology Assessment

Probability of Failure	Criteria for Activity 2.1.3
Manufacturing Technology	
0.1	New packaging concepts and manufacturing technologies identified. Sources of variability have been identified.
0.3	New packaging concepts and manufacturing technologies identified. Variability not addressed.
0.5	New packaging concepts and manufacturing technologies only partially addressed.
0.7	New packaging concepts partially addressed. Limited description of manufacturing technologies.
0.9	Slight attention to new packaging concepts or manufacturing technologies.
Risk Reduction Plans	
0.1	All risk areas clearly identified (unproven technologies, packaging concepts, or manufacturing technologies, major differences between customer needs and the justified performance of the equipment). Risk reduction plans include "measures of merit" to be tracked and tests and analyses to be conducted.
0.3	All risk areas clearly identified (unproven technologies, packaging concepts, or manufacturing technologies, major differences between customer needs and the justified performance of the equipment). Risk reduction plans partially defined, missing one or more of the following: "measures of merit" to be tracked and tests or analyses to be conducted.
0.5	Risk areas not clearly identified (unproven technologies, packaging concepts, or manufacturing technologies, major differences between customer needs and the justified performance of the equipment). Risk reduction plans partially defined, missing one or more of the following: "measures of merit" to be tracked. Tests or analyses to be conducted.
0.7	Few risk areas identified (unproven technologies, packaging concepts, or manufacturing technologies, major differences between customer needs and the justified performance of the equipment). Risk reduction plans incomplete.
0.9	No risk reduction plan.
Follow-On Research	
0.1	Areas for further research defined. Process in place for incorporating these in company-wide research programs.
0.3	Areas for further research defined. No specific process for incorporating these in company-wide research programs.
0.5	Areas for further research partially defined. No specific process for incorporating these in company-wide research programs.
0.7	Areas for further research partially identified. No evidence of incorporation in company-wide research programs.
0.9	Limited definition of requirements for further research.

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Figure 2-13 (Continued). Probability of Failure $P_{(3)}$: Technology Assessment

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Probability of Failure	Criteria for Activity 2.1.4
0.1	Trade study effort comprehensive. Candidates selected based on conflicts in satisfying customer needs. Alternative technologies/designs evaluated in a manner similar to that done for the baseline. Trade study parameter weights are traceable to priorities identified during customer needs interpretation activity.
0.3	Trade study effort comprehensive. Candidates selection not completely traceable to conflicts in satisfying customer needs. Alternative technologies/designs evaluated in a manner similar to that done for the baseline. Trade study parameter weights are not completely traceable to priorities identified during customer needs interpretation activity.
0.5	Trade study effort limited. Candidate selection not completely justified. Alternative technologies/designs evaluation not as thorough as done for the baseline. Trade study parameter weights are not traceable to priorities identified during customer needs interpretation activity.
0.7	Trade study effort limited. Candidate selection not justified. Limited effort in evaluating alternative technologies/designs. Trade study parameter weights not related to customer priorities.
0.9	Trade study effort very limited. Results not credible.

CC23-0132-14-DJm

Figure 2-14. Probability of Failure $P_{(4)}$: Tradeoff Analyses

Consequence of Failure Score	Criteria for the Consequences of Failure
0.1	Little or no improvement over the reliability attributes performance of current technology is needed or expected.
0.3	Some improvement over the reliability attributes performance of current technology is expected (up to 1.5 times better).
0.5	Significant improvement over the reliability attributes performance of current technology is expected (from 1.5 to 3 times better).
0.7	Substantial improvement over the reliability attributes performance of current technology is expected (from 3 to 5 times better).
0.9	Major improvement over the reliability attributes performance of current technology is expected (more than 5 times better).

CC23-0132-15-DJm

Figure 2-15. Consequences of Failure

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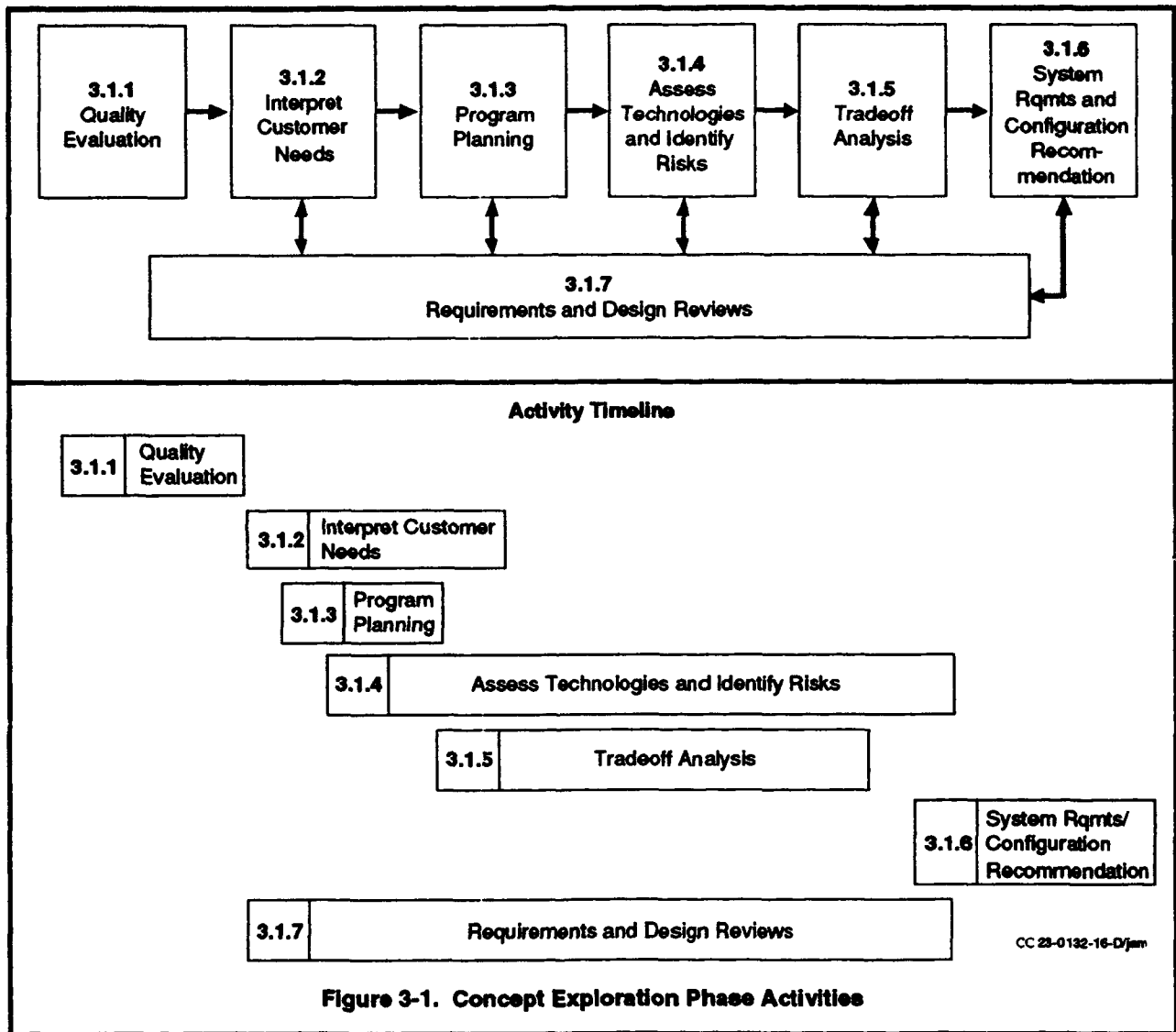


Figure 3-1. Concept Exploration Phase Activities

3.0 INTRODUCTION

This chapter defines the Activities that should take place during the Concept Exploration Phase to ensure the attainment of product reliability attributes. Figure 3-1 shows the essential activities and a general time line for the implementation of these activities. Most of the phase activities are iterative: Trade-Off Analyses affect the assessment of technologies and risks; these activities both affect the recommendations of configurations and requirements; all activities must be continuously compared to customer needs. Detailed descriptions of the activities and their required inputs and outputs are contained in paragraphs 3.1.1 through 3.1.6. There are several similarities between these descriptions and the ones contained in paragraphs 2.1.1 through 2.1.5. However, while the activities of Chapter 2 are applied to a potentially broad range of research programs, a concept exploration program is contracted work that is focused on a set of customer needs for fulfilling a specific mission.

3.1 SUMMARY OF ACTIVITIES

The purpose of the concept exploration phase is to develop and evaluate alternative system concepts that satisfy customer needs. A principal phase product is the definition of a preferred system configuration with a set of performance objectives. The development of the preferred concept includes the selection of high and medium risk emerging technologies that offer solutions to customer needs. A second primary phase output is a risk reduction plan for the selected risky technologies. Within the phase, analyses and trade-offs are conducted in order to determine system performance objectives considering expected environments, use, and constraints. These general themes must be supported by the simultaneous development and definition of reliability attributes as defined in paragraphs 3.1.1 through 3.1.6.

The Activities, Inputs, and Outputs of the following paragraphs emphasize the definition of customer requirements, the development of defect reduction design and manufacturing techniques, and the creation of risk reduction plans specifically directed at reliability attributes. The phase activities also

CONCEPT EXPLORATION PURPOSE

CHAPTER 3

CONCEPT EXPLORATION PHASE

demand that the capability for quality processes be measured and that steps be taken to ensure continuous improvement. The seven phase Activities are:

- 1) Quality Evaluation
- 2) Interpret Customer Needs
- 3) Program Planning
- 4) Assess Technologies and Identify Risks
- 5) Trade-Off Analyses
- 6) System Requirements and Configuration Recommendations
- 7) Requirements and Design Reviews

A baseline for continuous improvement is established by means of a pre-award quality evaluation of bidders for the concept exploration contract. This evaluation provides a score reflecting the requisite commitment to total quality by each of the bidders. The evaluation influences source selection and provides a baseline to measure necessary improvement during the concept exploration and follow-on acquisition phases.

The most critical of these above activities is the interpretation of customer needs and the translation of these needs into technical objectives. Both the customer and supplier must focus on the accurate, systematic, and documented definition of customer needs. Active customer participation in this activity is a requirement for success.

INTERPRET THE NEEDS OF THE CUSTOMER

Program planning should be a natural result of broadly applicable, organization-wide process descriptions. In a high quality organization, it should be expected that existing process descriptions would address most of the Activities, Inputs, and Outputs described in paragraphs 3.1.1 through 3.1.7.

Assessing Technologies and Identifying Risks is the second critical activity of the Concept Exploration phase. All technology development requires the concurrent characterization of reliability attributes, including the definition of manufacturing technology for the purpose of initiating process control techniques. This characterization must focus on defect prevention and plans for maturing the reliability attributes.

DEFECT PREVENTION

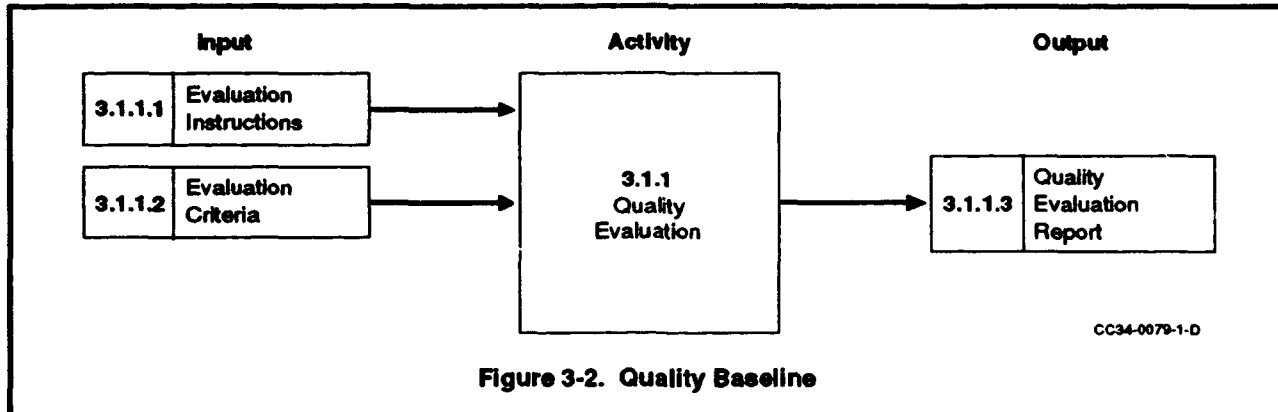
Trade Studies are the vehicle for achieving balanced designs. They should be based on optimizing specific parameters and on interactions among technical objectives. The weights assigned to the measures of merit used to evaluate the goodness of the design alternatives must be traceable to customer defined priorities.

BALANCED DESIGN

The Systems Requirements and Configuration Recommendations Activity synthesizes the results of the prior activities (excluding the Quality Evaluation) into a recommended systems implementation with quantified objectives for reliability attributes. This activity also includes the development of a firm set of risk reduction plans.

Requirements and Design Reviews bring discipline and a focus on achieving objectives into the technology development process. These reviews are the vehicles for maintaining a focus on the satisfaction of customer needs.

CUSTOMER SATISFACTION



3.1.1 ACTIVITY - QUALITY EVALUATION

This pre-contract award Activity establishes a quantitative baseline for continuous improvement. In response to customer instructions, the supplier conducts an internal review of company-wide commitment to quality practices. This evaluation uses criteria derived from Malcolm Baldrige Award criteria. Recommended criteria are provided in Volume II of this guide.

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3.1.1.1 INPUT - EVALUATION INSTRUCTIONS

The customer includes in his requests for proposal a complete set of instructions for conducting the quality evaluation. These include directions in Executive Summaries, detail instructions in the Instructions to Offerors (Evaluation Criteria, Reporting Requirements), and the relationship of the evaluation to source selection award factors. An example of instructions is provided following paragraph 3.1.1.3. Report format requirements for a Malcolm Baldrige Award Application are recommended.

3.1.1.2 INPUT - EVALUATION CRITERIA

The customer supplies the criteria to be used for the quality evaluation. Volume II of this guide provides a set of recommended criteria patterned after the Malcolm Baldrige Award criteria.

3.1.1.3 OUTPUT - QUALITY EVALUATION REPORT

The supplier provides a quality evaluation report in accordance with customer reporting requirements. This report is to be used by both the customer and the supplier. The customer will score the results and use this in source selection. The supplier should similarly score his results and use this evaluation to define weaknesses and plan the required improvements.

EXAMPLE REQUEST FOR PROPOSAL REQUIREMENTS

**RFP DIRECTIONS
FOR A QUALITY
EVALUATION**

- **Sample Executive Summary Language**

The Customer intends to conduct a performance risk assessment as an element of the source selection process. This assessment involves the evaluation of each offeror's company-wide quality effort.

- **Sample RFP Section L Language:**

Volume (XX)-Information for Assessment of Company-Wide Quality Efforts

1.0 General. The Customer intends to consider each offeror's company-wide effort

and its results. Specifically, a performance risk assessment will be conducted to assess the effectiveness of the offeror's company-wide quality efforts.

2.0 Specific Information and Data. The offeror shall provide the information below emphasizing documented, verifiable evidence of the effective implementation of company-wide quality efforts. Actions presently planned shall also be included. Information provided should be applicable to the facilities or location where work under the proposed contract will be performed. The offeror shall describe the application of its practices, tools, and techniques. Additional details are provided in Section (YY). The offeror's proposal should address the following areas:

Leadership - Describe the extent to which the senior executives create and sustain a clear and visible quality value system along with a supporting company-wide quality management system to guide all activities of the company.

Information and Analysis - Describe and demonstrate the scope, validity, and management of data and information that underlie the company's quality management system. In particular, describe how the company uses data to support a prevention-based approach to quality.

Strategic Quality Planning - Describe the company's quality priorities and plans to achieve them.

Human Resources Utilization - Describe the company's practices to develop and utilize the full potential of the work force and to maintain an environment conducive to full participation, continuous process improvement, and personal and organizational growth. Summarize quantitative and qualitatively 1) accomplishments to date and recent trends in employee participation in company-wide quality activity, 2) types of quality education and training provided in

**SAMPLE RFP
LANGUAGE**

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each pertinent employment category, and 3) trends in recognizing employees for contributions to the company-wide quality system.

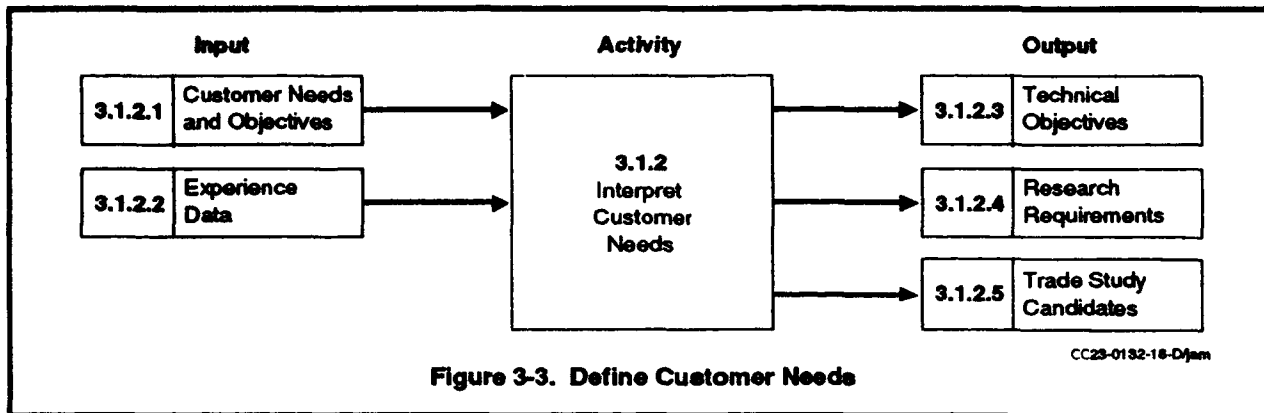
Quality Assurance of Products and Services - Describe how products and services are continuously improved through optimization and improvement of processes. In the area of design and development, where applicable, the description should include information pertaining to the use of methods, tools, and techniques to achieve high quality in design. Include use of such tools and techniques as Concurrent Engineering, Quality Function Deployment, producibility engineering and planning, design of experiments, DoD Directive 4245.7M - Transition from Development to Production, etc. Include a description of how the offeror flows the company's quality focus down to subcontractor levels.

Results - Provide data that show trends in: a) improvement of quality of products and services based on analysis of customer requirements, analysis of quality deficiency reports, cycle time reductions, Material Review Board actions, scrap and rework, etc., and the analysis of internal business operations, and b) improvement in the quality of supplies and services furnished by other companies. Provide evidence of the use of results to overcome and prevent the recurrence of problems. Demonstrate application of the offeror's company-wide quality activities by briefly summarizing several projects that illustrate their breadth and effectiveness.

- **Sample RFP Section M Language**

The Customer will also conduct performance risk assessment based on: 1) **effectiveness** of the offeror's company-wide quality activities and the **applicability** of the offeror's use of quality practices, tools, and techniques, and 2) the offeror's past performance record demonstrated in terms of

actual results.



3.1.2 ACTIVITY - INTERPRET CUSTOMER NEEDS

A systematic, comprehensive process for defining customer needs, the priorities associated with these needs, and the translation of these needs into quantified technical objectives must be implemented for this phase. Quality Function Deployment is the recommended tool for implementing this Activity. This is one of the most critical activities of this phase. The supplier must be prepared to integrate customer needs defined during other research activities with customer inputs for this acquisition phase. Customer contact should have taken place prior to contract award as part of pre-RFP release discussions. Customer needs documented in contract technical material should always be supplemented and validated via direct contact. Customers must encourage and support these contacts.

3.1.2.1 INPUT - CUSTOMER NEEDS AND OBJECTIVES

Customer needs and objectives should be explicitly defined in the contract technical documentation, such as Mission Need Statements, Statements of Work, and preliminary specifications. However, all contract documentation must be reviewed to descriptions of customer needs. Additionally, the supplier must plan for early direct and frequent customer contact to validate and refine the documented needs. These contacts must focus on a multidisciplinary definition of customer needs.

COMPREHENSIVE SEARCH FOR CUSTOMER NEEDS

3.1.2.2 INPUT - EXPERIENCE DATA

The supplier must ensure documented Concept Exploration needs are subject to review by experts in all areas so that all customer needs are identified and properly translated into technical objectives. The supplier must also ensure that customer needs and technical objectives, defined during prior research, is available for application to the Concept Exploration contract. The experience data base should include a thorough and documented understanding of both good and bad customer experience with current products as a preferred method for aiding in the identification of needs.

3.1.2.3 OUTPUT - TECHNICAL OBJECTIVES

The supplier must provide a definition of specific technical attributes and parameters that will satisfy all customer needs. Quality Function Deployment is the recommended method for defining and documenting Technical objectives. This definition includes quantitative objectives for each of the attributes and parameters. The customer needs must be given weighting factors which represent priority levels. These factors will be used to define the relative importance of each of the technical attributes and parameters. It is critical that the interaction between reliability technical attributes and the other technical attributes be identified. At this early stage of development, it is important that quantified attributes and parameters be treated as objectives rather than requirements.

3.1.2.4 OUTPUT - RESEARCH REQUIREMENTS

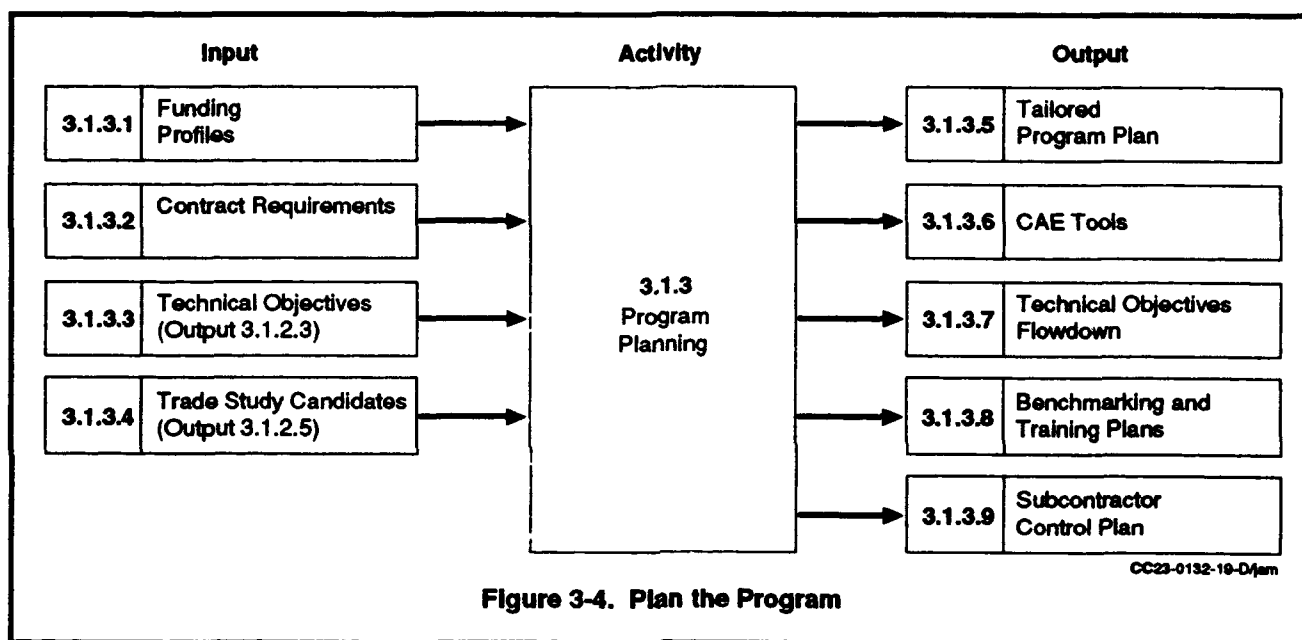
The supplier, in concert with the customer, must identify, for the system being developed, all related research in order to avoid duplication and maximize resources. As the Concept Exploration phase proceeds, additional research necessary to enable developing technology applicable to the system must be identified for inclusion in future plans.

RELATED RESEARCH

3.1.2.5 OUTPUT - TRADE STUDY CANDIDATES

The supplier must identify candidates for trade studies to be performed during the Concept Exploration phase. The Quality Function

Deployment technique can assist in defining these candidates by evaluating the interactions among technical attributes. Trade-off analyses are used to optimize a technical attribute or parameter that interacts with other technical attributes or parameters. For example, radar detection range is a function of power, weight, volume, receiver sensitivity, reliability, and cost. Trade studies are also used to select between alternative technologies or system concepts.



3.1.3 ACTIVITY - PROGRAM PLANNING

Program planning is necessary for the Concept Exploration phase in order to define specific inputs and outputs, the responsibility for these inputs and outputs, the schedule for these inputs and outputs, and the resources to be allocated, all based on customer priorities. As a baseline, planning will consider the Activities, Inputs, and Outputs described in paragraphs 3.1.3 through 3.1.7. If an organization has a set of clear, comprehensive, and integrated process descriptions embracing the intent of paragraphs 3.1.2 through 3.1.7, these should be used in lieu of separately prepared program plans. Specialists in the disciplines of Reliability, Design, Testability and Manufacturing must concur with the content of the program plan.

ALLOCATE THE RESOURCES

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3.1.3.1 INPUT - FUNDING PROFILES

The supplier should have a funding process that is interactive, flexible, and responsive to customer needs and priorities. Funding profiles should be an element of initial requirements reviews to ensure that they are consistent with customer priorities.

**FUNDING
RESPONSIVE TO
CUSTOMER NEEDS**

**3.1.3.2 INPUT - CONTRACT
REQUIREMENTS**

This input consists of a complete description of overall program objectives, schedules, task definitions, and deliverables (reports).

3.1.3.3 INPUT - TECHNICAL OBJECTIVES

Output 3.1.2.3 serves as an input to the Program Planning Activity.

**3.1.3.4 INPUT - TRADE STUDY
CANDIDATES**

Output 3.1.2.5 serves as an input to the Program Planning Activity. Additional Trade Study candidates may be identified based on customer needs and supplier experience. The candidate list should define specific measures of merit being used to evaluate trade study issues or alternative designs. Reliability attributes should always be included as trade study measures of merit.

**3.1.3.5 OUTPUT - TAILORED PROGRAM
PLAN**

The supplier should prepare a program plan for Concept Exploration using the Activities, Inputs, and Outputs of paragraphs 3.1.2 and 3.1.4 through 3.1.7 for guidance. Plans should be tailored based on the complexity and scope of the program. Existing organization-wide process descriptions should be used if they are comprehensive and cover the intent of paragraphs 3.1.2 and 3.1.4 through 3.1.7. Plans must always identify acceptance criteria, responsibility, and schedule for both input and output products.

**3.1.3.6 OUTPUT - COMPUTER AIDED
ENGINEERING (CAE) TOOLS**

The supplier must continuously maintain and update the definition of hardware and software design automation tools and the interoperability of equipment and data bases. These plans would

**CONCURRENT
ENGINEERING**

generally be done on an organization-wide basis and should include plans and provisions for training. Concurrent Engineering demands automation and the capability for the interchange of data. Consideration of customer use/access to data bases should always be part of these plans.

3.1.3.7 OUTPUT - TECHNICAL OBJECTIVES FLOWDOWN

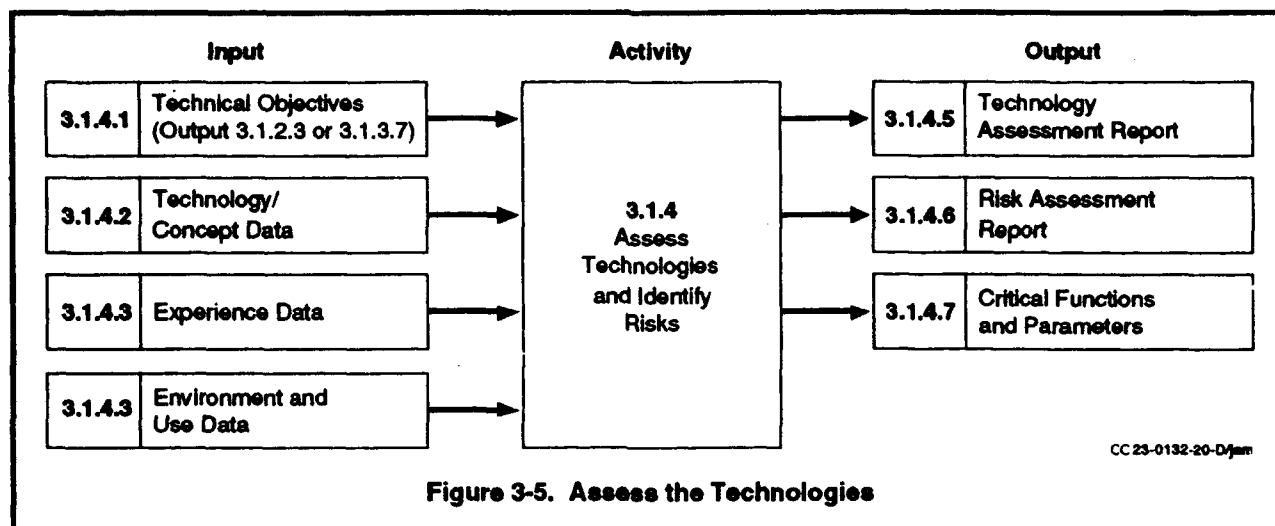
The initial Quality Function Deployment will identify the system level technical attributes and parameters associated with satisfying customer needs, the quantitative objectives for these attributes and parameters, and a quantification of the relative importance of each attribute or parameter based on customer priorities. If required for further analysis or trade studies, these system level attributes and parameters will be decomposed or allocated to lower level parameters and objectives. Traceability to customer needs and quantification of importance based on customer priorities must be maintained.

3.1.3.8 OUTPUT - BENCHMARKING AND TRAINING PLANS

The supplier must develop benchmarking plans to correct weaknesses identified during the Quality Evaluation Activity. These plans should identify the specific corrective actions necessary for improvement that will be beneficial to the conduct of Concept Exploration. An evaluation of the capability of program personnel to implement the Activity, Input, and Output requirements of Concept Exploration must be conducted. Training plans to correct any deficiencies must be prepared. Training plans should also include provisions for ensuring that program personnel fully understand the tasks to be performed and the objectives for reliability attributes.

3.1.3.9 OUTPUT - SUBCONTRACTOR CONTROL PLAN

If required, the supplier must prepare plans that describe the methods used to flow the Activities, Input, and Output tasks of this phase to subcontractors. These plans should define supplier selection criteria and the allocation of technical objectives.



3.1.4 ACTIVITY - ASSESS TECHNOLOGIES AND IDENTIFY RISKS

The supplier must begin the process of developing methods for preventing or eliminating defects in product reliability attributes (life, durability, defect rate, BIT performance). The activity includes identifying initial design, application, and de-rating criteria, environmental sensitivity, critical parameters and functions, parameter variability, projected manufacturing technology, and quantitative performance expectations for reliability attributes.

As an inherent part of this Activity, the supplier must establish the integration of multiple disciplines focused on defect prevention. For example, the definition of BIT requirements and fault tolerance features must be traceable to the definition of critical functions or parameters accomplished by Failure Modes Effects or similar analyses. Similarly, the initial definition of key manufacturing processes should be focused on critical functions or parameters. This activity addresses both defect prevention for new technologies and defect elimination for the existing technology being applied to the system concept.

3.1.4.1 INPUT - TECHNICAL OBJECTIVES

Output 3.1.2.3 or 3.1.3.7, as appropriate, serves as an input to Activity 3.1.4. This input identifies the

DEFECT PREVENTION ACTIVITY

technical attributes and parameters and their baseline quantitative objectives.

3.1.4.2 INPUT - TECHNOLOGY/CONCEPT DATA

The new technology and systems concepts must be completely defined, including identification of functionally and/or physically similar existing technologies or systems. These identifications should define the environmental and use applications of the existing technology or systems. Factors that should be identified for the new technology or systems include definition of system's functions derived from the mission description, environmental constraints or sensitivities, critical attributes, parameters, or functions, variability range of critical parameters, packaging concepts, and projected manufacturing technologies or processes, especially those associated with critical functions or parameters.

3.1.4.3 INPUT - EXPERIENCE DATA

The supplier must assemble all potentially relevant experience data. These data include customer and internal Lessons Learned, user reliability attribute performance data for functionally or physically similar technologies/systems, results from related research, existent design and application guides (e.g., derating, design margins), and current manufacturing process defect rate data. Data concerning lessons learned and the performance of comparable systems should be thoroughly coordinated with the customer.

LESSONS LEARNED

3.1.4.4 INPUT - ENVIRONMENT AND USE DATA

The supplier must derive first order environment and use data from the customer-provided Mission Descriptions. These data should address the primary fault-producing external environments, such as temperature extremes, temperature cycling, vibration, shock, and humidity produced by both expected operating conditions and maintenance conditions. Data should include maximum conditions and an estimate of cumulative lifetime exposures based on expected missions, basing, and maintenance frequency. Functional analyses will be conducted to define operating profiles for the system.

**3.1.4.5 OUTPUT - TECHNOLOGY
ASSESSMENT REPORT**

This report should accomplish two objectives: 1) define, quantitatively, the expected performance levels for the system reliability attributes, and 2) provide an initial definition of design constraints and application guides which will prevent defects. Quantitative performance expectations are to be based on comparisons to user performance levels for functionally or physically comparable current technology or systems. The estimates of quantitative performance for the proposed system are to be supported by specific engineering rationale that include causal analysis of existing performance levels. All critical parameters and/or functions should be identified via Failure Modes Effects or similar analyses. Initial estimates of allowable critical parameter variability should be made. The report will describe defect reduction elements, such as lessons learned, constraints and application guidelines/design margins, definition of environmental stress sensitivities, and required manufacturing technologies or processes applicable to both new and existing technologies proposed for use in the new system.

This is a critical output that should define the following issues:

- Quantitative expectations for system reliability attributes, such as life, durability, BIT performance, and defect rates inclusive of projected manufacturing defects. These estimates should be based on engineering justified changes in the conditions which produced the user experienced performance of comparable equipment.
- Identification of specific defect prevention techniques, such as the incorporation of lessons learned, design rules such as application guides and derating, design for manufacturing principles, and manufacturing process changes.
- Identification of the environmental sensitivities of expected technologies for the purpose of initiating materials characterization testing.

**DEFECT REDUCTION
DESIGN
CONSIDERATIONS**

- Definition of critical functions and parameters in order to provide a basis for BIT requirements and fault tolerance features.
- Definition of the expected variance in critical functions or parameters in order to initiate the process of variability control and the identification of manufacturing processes requiring characterization and control.

Generation of this output provides an excellent opportunity for soliciting customer involvement, particularly in the definition of lessons learned, the performance of comparable equipment, and in the identification of critical functions or parameters.

3.1.4.6 OUTPUT - RISK ASSESSMENT REPORT

RISK REDUCTION

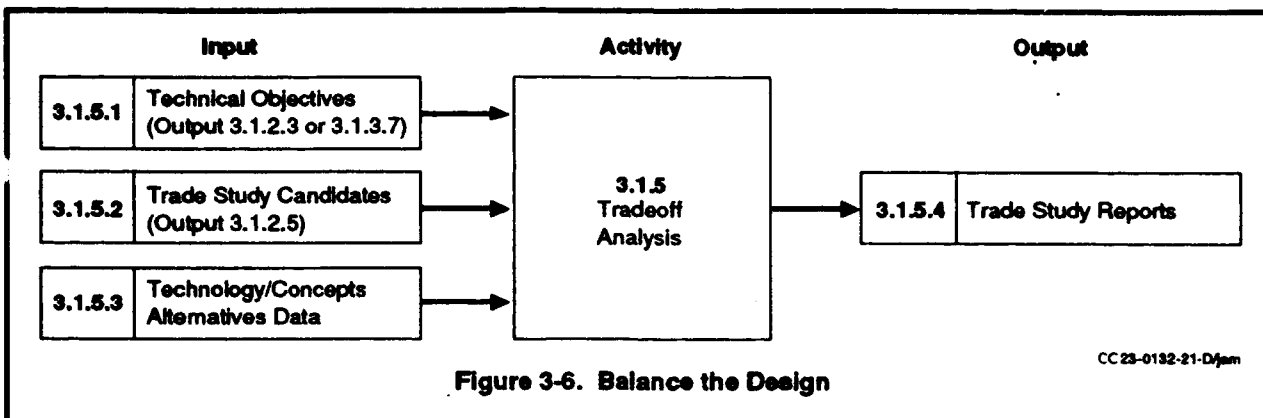
This report should identify areas of uncertainty relative to achieving the technical objectives for reliability attributes and the plans for eliminating those uncertainties. These risk areas include critical parameter variability, environmental stress sensitivities, the absence of design and application criteria, and the lack of definition of manufacturing processes and technology. Estimates of reliability performance that are not justified by substantive engineering rationale should be considered a risk area. Special attention must be paid to the substantiation of reliability attributes (life, durability, design, defect rates, BIT performance, parameter variability, and manufacturing defect rates) for new technologies.

3.1.4.7 OUTPUT - CRITICAL FUNCTIONS AND PARAMETERS

The supplier should create and maintain a listing of all critical system functions and/or parameters. These critical items are identified from functional analyses and Failure Modes Effects or similar analyses. Customer inputs regarding the definition of criticality are required. Fault detection associated with other critical functions or parameters should, itself, be included as a critical function.

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3.1.5 ACTIVITY - TRADE-OFF ANALYSES

Trade-Off analysis is a formal method for making cost-effective decisions during Concept Exploration. The program must have an identified list of trade studies, the measures of merit to be compared for alternative technologies or system concepts, and a weight factor for each measure of merit that is traceable to customer priorities. Trade study candidates are developed during the Interpretation of Customer Need (Activity 3.1.2). One or more of the reliability attributes and measures of merit representing manufacturing technologies must be considered for all trade studies. The supplier must have a well defined Trade-Off process that is linked to the Requirements and Design Review Activity (3.1.7).

BALANCED DESIGNS

3.1.5.1 INPUT - TECHNICAL OBJECTIVES

Output 3.1.2.3 or 3.1.3.7 serves as an input to the Trade-Off Analysis Activity. These are the quantified baseline technical attributes or parameters that satisfy customer needs and include a further quantification that represents customer priorities.

3.1.5.2 INPUT - TRADE STUDY CANDIDATES

Output 3.1.2.5 serves as an Input to the Trade-Off Analysis Activity. The list of candidates may change during the course of the program and should be responsive to changes in customer needs or priorities.

3.1.5.3 INPUT - TECHNOLOGY/CONCEPTS ALTERNATIVES DATA

Accurate information regarding the relationships among technical attributes and parameters (e.g., weight versus reliability attributes) and accurate descriptions of alternative technologies or system concepts is a key to valid Trade-Off conclusions. The claimed relationships among technical attributes and parameters should be validated by experiment or extensive analysis. The data defining alternative technologies or systems concepts should approximate the depth and quality described in paragraph 3.1.4.2, Technology/Concept Data. Weighting factors assigned to the measures of merit used to compare alternatives should be traceable to customer priorities defined during Activity 3.1.2. Specific reliability and manufacturing measures of merit are to be used for all trade studies.

3.1.5.4 OUTPUT - TRADE STUDY REPORTS

These reports provide a complete record of trade-off analysis results. This includes the selected technology or system concept, quantitative values of technical objectives, the trade-study alternatives, methods, and selection criteria. The report should describe how the selection clearly satisfies customer needs and priorities.

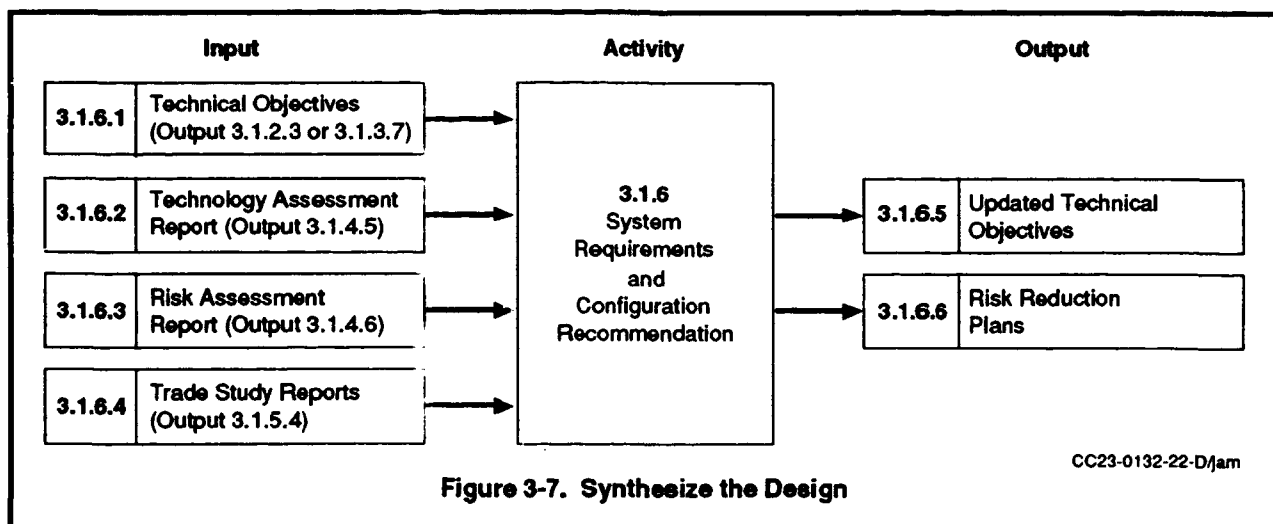


Figure 3-7. Synthesize the Design

3.1.6 ACTIVITY - SYSTEM REQUIREMENTS AND CONFIGURATION RECOMMENDATION

The supplier should prepare a summary report of Concept Exploration phase activities that describes the preferred system concept and its functions,

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quantified objectives for the system's reliability attributes, emerging technologies proposed for incorporation in the system, and risk reduction plans for the riskiest of these technologies.

3.1.6.1 INPUT - TECHNICAL OBJECTIVES

Output 3.1.2.3 or 3.1.3.7 serves as an input to this Activity. These data define initial baseline quantified technical objectives.

3.1.6.2 INPUT - TECHNOLOGY ASSESSMENT REPORT

Output 3.1.4.5 serves as an input to this activity. This input defines the performance expectations for reliability attributes, justified by engineering rationale and supported by design rules.

3.1.6.3 INPUT - RISK ASSESSMENT REPORT

Output 3.1.4.6 serves as an Input to Activity 3.1.6. The data summarizes the risks associated with achieving expected performance levels for the reliability attributes and the plans for the control of these risks.

3.1.6.4 INPUT - TRADE STUDY REPORTS

Output 3.1.5.4 serves as an Input to Activity 3.1.6.

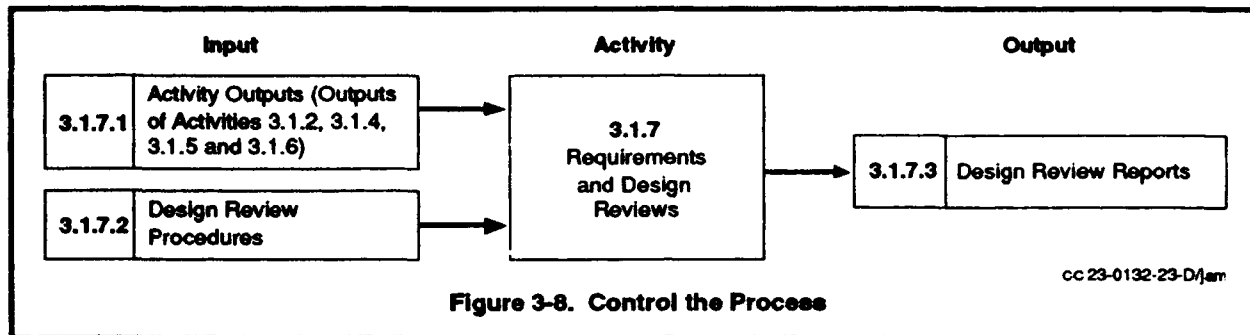
3.1.6.5 OUTPUT - UPDATED TECHNICAL OBJECTIVES

Based on the noted inputs, the supplier must synthesize a revised set of quantitative objectives for the preferred system concept reliability objectives. This output should specify how these objectives satisfy customer needs and identify relevant analyses, trade study reports, and customer reviews which justify the decisions.

3.1.6.6 OUTPUT - RISK REDUCTION PLANS

These plans describe all moderate to high risk technical issues and the recommended analyses and tests required to reduce the risks to low levels. These plans define the measures of merit that will be tracked, the current levels of these measures, and the threshold values that constitute low risk. These plans include the definition of fall back technologies and quantify the impact of implementing the fall back position. All technologies requiring risk reduction plans should include one or more measures of merit

dealing with reliability attributes in those plans. Risk Reduction Plans specifically addressing achievement of customer objectives for reliability attributes may be required based on customer control and audit results. (See paragraph 3.2.)



3.1.7 ACTIVITY - REQUIREMENTS AND DESIGN REVIEWS

This activity must maintain an essential discipline throughout the activities of this phase and ensure that the "voice of the customer" is defined and heeded. The supplier should have a documented design review procedure that ensures consistency and thoroughness. The timing of Requirements and Design Reviews takes place during the Planning Activity (3.1.3). The inputs to the reviewed activities should serve to define entry criteria for reviews with the outputs providing the source of exit criteria.

3.1.7.1 INPUT - ACTIVITY OUTPUTS

The outputs of activities 3.1.2 through 3.1.6 should be subject to the review process. This includes both internal reviews and customer reviews.

3.1.7.2 INPUT - DESIGN REVIEW PROCEDURES

The supplier must have an established and documented procedure for conducting internal review of requirements and design. The procedure covers review frequency, entry and exit criteria, definition of participants, agenda requirements, and closure plans for action items. Reviews should always have an agenda which defines the customer needs to be reviewed and specific review entry and exit criteria. With customer concurrence, these review procedures will serve as the basis for

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customer reviews. Every review must include a definition of applicable customer needs and a demonstration of satisfaction of those needs.

3.1.7.3 OUTPUT - DESIGN REVIEW REPORTS

All design reviews must have results documented, including a definition of actions, responsibility for action closure, criteria for action closure, closure dates, and final disposition of action item.

3.2 CONTROL AND AUDIT

QUANTIFY THE RISK

The control metrics for the Concept Exploration phase process combine the Risk Factor assessment, described in paragraph 2.2, and an evaluation of the quantified reliability objectives contained in Output 3.1.6.5.

The principal benefits of the Risk Factor assessment are as follows:

- Encourages customer/supplier involvement.
- Requires an evaluation of the quality of all significant process activities, inputs, and outputs during this critical early phase of the acquisition process.
- Provides credibility to quantitative estimates of reliability attributes.
- Defines a numerical value representative of the degree to which the entire process is in control. These values are used as thresholds for corrective action.

The Risk Factor assessment uses the process described in paragraph 2.2 with the following changes:

- 1) The Quality Evaluation Activity (paragraph 3.1.1) has been added as an activity requiring a score representing its probability of failure.
- 2) The weight factor for the Technology Assessment Activity has been changed.

- 3) The consequence of failure has been modified to account for mission and safety impacts and cost consequence.

The Risk Factor assessment is conducted in accordance with Figures 3-9 through 3-15 (pages 3-23 through 3-29). Figure 3-10 (and 4-10), which provide the probability of failure criteria for the Quality Evaluation Activity, contain a reference to a "CAP" assessment. This is the Certification and Audit Procedure contained in Volume II of this handbook. The resultant Risk Factor is a score that represents a combination of the likelihood of failure of the reliability process and the consequences of failure.

If the assessment indicates that the risk factor associated with achieving reliability objectives is too high, corrective action should be taken. The recommended actions and the associated Risk Factor scores are as shown in Table 3-1.

RISK REDUCTION

TABLE 3-1 Risk Reduction	
Risk Factor Score	Recommendation
≤ 0.4	None
> 0.4 - ≤ 0.7	Optional Risk Reduction Plan for Reliability
> 0.7	Mandatory Risk Reduction Plan for Reliability

The customer is responsible for the Risk Factor assessment. Ideally, the assessment is done on a continuing basis during the Concept Exploration phase based on customer/supplier interaction. As a minimum the information required for the assessment can be obtained during Design Reviews.

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Probability of Failure				
Parameter	Probability of Failure Caused by:	Weight Factor	Activity	Scoring and Criteria
$P_{(1)}$	Inadequate Quality	0.1	3.1.1	Figure 3-10
$P_{(2)}$	Inadequate Definition and Update of Customer Requirements	0.3	3.1.2 3.1.7	Figure 3-11
$P_{(3)}$	Faulty Planning	0.2	3.1.3	Figure 3-12
$P_{(4)}$	Incomplete or Inadequate Technology Assessment	0.2	3.1.4	Figure 3-13
$P_{(5)}$	Inadequate Trade Studies	0.2	3.1.5	Figure 3-14
$P_{(F)}$	$0.1P_{(1)} + 0.3P_{(2)} + 0.2P_{(3)} + 0.2P_{(4)} + 0.2P_{(5)}$			

Consequence of Failure			
Parameter	Consequence of Failure	Weight Factor	Scoring and Criteria
$C_{(1)}$	Safety or Mission Success Impact	0.5	Figure 3-15
$C_{(2)}$	Cost Impact	0.5	Figure 3-15
$C_{(F)}$	$0.5C_{(1)} + 0.5C_{(2)}$		

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Figure 3-9. Risk Factor: Concept Exploration Phase

$$\text{Risk Factor} = P_{(F)} + C_{(F)} - P_{(F)} \times C_{(F)}$$

Probability of Failure	Criteria for Activity 3.1.1
0.1	Supplier has a consistent, recognized and demonstrated history of high quality and has completed a CAP Assessment or Malcolm Baldrige application with a score above 500.
0.3	Supplier has a recognized commitment to high quality, but quality results are occasionally deficient. Has completed a CAP Assessment or Malcolm Baldrige application with a score above 350.
0.5	Supplier commitment to quality is not completely evident. Has completed a CAP Assessment or Malcolm Baldrige application with a score above 250.
0.7	Supplier has completed a CAP Assessment or Malcolm Baldrige application with a score above 150, but has no specific plans for improvement.
0.9	Contractor has completed a CAP Assessment or Malcolm Baldrige application with a score below 150.

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Figure 3-10. Probability of Failure $P_{(1)}$: Quality Evaluation

Probability of Failure	Criteria for Activities 3.1.2 and 3.1.7
0.1	Customer needs have been identified and prioritized in a systematic manner and translated into product technical objectives. Trade study candidates have been identified. Design reviews have clearly defined exit criteria, customer needs are reviewed and updated, compliance with customer needs are shown. Related research and additional enabling research identified and documented.
0.3	Customer needs have been identified in a systematic manner and translated into product technical objectives. Trade study candidates have been identified. Customer needs reviewed and updated at design reviews. Compliance with customer needs are shown. Related research and additional enabling research identified and documented.
0.5	Customer needs have been identified and translated into product technical objectives. Trade study candidate list is incomplete. Design reviews show compliance with customer needs. Incomplete identification and documentation of related research and additional enabling research.
0.7	Customer needs only partially identified with no clear traceability to product technical objectives. Trade study candidate list is incomplete. Design reviews not thoroughly focused on customer needs. Very limited identification and documentation of related research and additional enabling research.
0.9	Limited customer/supplier interchange. Customer needs not validated with customer, design reviews do not specifically address customer needs. No clear integration of current research or definition of additional enabling research.

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Figure 3-11. Probability of Failure $P_{(2)}$: Customer Needs Interpretation

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Probability of Failure	Criteria for Activity 3.1.3
0.1	Funding profiles are influenced by customer needs and priorities. All contract/technical requirements have been addressed. Phase tasks are tailored to customer priorities. Customer needs clearly transmitted to all personnel. Training needs/plans, benchmarking plan for continuous improvement identified, CAE tools available and data bases integrated. Allocated technical objectives "flowed down" and clearly traceable to customer needs.
0.3	Funding profiles are partially influenced by customer needs and priorities. Contract/technical requirements have been addressed. Customer needs not adequately transmitted to all personnel. Training not specifically addressed. No benchmarking plan. CAE tools list not complete. Allocated technical requirements partially traceable to customer needs.
0.5	Funding profiles not matched to customer needs and priorities. Contract/technical requirements have been addressed. Limited transmittal of customer needs to all personnel. Limited CAE tools defined and data bases are not integrated. Allocated technical requirements not traceable to customer needs.
0.7	Funding inadequate. Contract/technical requirements partially addressed. Very limited transmittal of customer needs to all personnel, very limited CAE tools.
0.9	Funding inadequate. Contract/technical requirements partially addressed. No evidence of transmittal of customer needs to personnel. Extremely limited use of CAE tools.

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Figure 3-12. Probability of Failure $P_{(3)}$: Program Planning

Probability of Failure	Criteria for Activity 3.1.4 To Determine the Total Score, Add Individual Scores and Divide by Six (6)
New Technology Definition	
0.1	New technologies/design concepts are fully described. Positive and negative features and gaps in the knowledge base are defined. Expected operating environment defined and traceable to customer mission description.
0.3	New technologies/design concepts are partially described. Positive and negative features not adequately defined. Gaps in the knowledge base are partially addressed. Expected operating environment defined and traceable to customer mission description.
0.5	New technologies/design concepts are partially described. Some positive features, few negative features defined. Limited definition of gaps in the knowledge base. Expected operating environment does not consider maintenance operations.
0.7	Superficial description of new technologies/design concepts. Negative features not addressed. No description of gaps in the knowledge base. Limited description of expected operating environment.
0.9	New technologies/design concepts proposed without a clear assessment of positive or negative features. No description of gaps in the knowledge base. Limited description of expected operating environment.
Expected Reliability Performance	
0.1	Quantitative performance level estimates based on comparison to current customer experienced levels of performance of existing comparable equipment. Clear engineering rationale is provided for all expected improvements. Initial definition of design/application criteria complete. Lessons learned data available (e.g., derating, environmental sensitivity).
0.3	Quantitative performance level estimates based on comparison to current levels of performance of existing comparable equipment. One or more key performance parameters (e.g., life, fatigue, false alarm rate, etc.) is not identified. Clear engineering rationale is provided for all expected improvements. Initial definition of design/application criteria complete. Lessons learned data is available (e.g., derating, environmental sensitivity).
0.5	Quantitative performance level estimates based on comparison to current levels of performance of existing comparable equipment. Key performance parameters missing and engineering rationale for expected improvements is weak. Initial definition of design/application criteria complete. Lessons learned data is available (e.g., derating, environmental sensitivity).
0.7	Quantitative performance level estimates have limited reference to the performance levels of existing comparable equipment. Engineering rationale for expected improvements is weak. Limited definition of design/application criteria or lessons learned.
0.9	No definition of existing comparable equipment design/application criteria or lessons learned.
Critical Parameters or Functions	
0.1	Failure modes effects analysis or similar analyses have been conducted to identify critical parameters or functions. Fault detection and fault tolerance approaches systematically defined and related to critical parameters or functions. Variability of critical parameters have been estimated.
0.3	Failure modes effects analysis or similar analyses have been conducted to identify critical parameters or functions. Fault detection and fault tolerance approaches systematically defined and related to critical parameters or functions. Variability of critical parameters not estimated.
0.5	Failure modes effects analysis or similar analyses have been conducted to identify critical parameters or functions. Fault detection and fault tolerance approaches partially related to critical parameters or functions and not accomplished concurrently with failure modes effects analysis.
0.7	Failure modes effects analysis or similar analyses have been conducted to identify critical parameters or functions. No evidence of linkage between this analysis and the definition of fault detection and fault tolerance approaches.
0.9	Failure modes effects analysis or similar analyses not conducted or not linked to identifying critical parameters or functions, fault detection or fault tolerance approaches.

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Figure 3-13. Probability of Failure $P_{(4)}$ Technology Assessment

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Probability of Failure	Criteria for Activity 3.1.4
Manufacturing Technology	
0.1	New packaging concepts and manufacturing technologies identified. Sources of variability have been identified.
0.3	New packaging concepts and manufacturing technologies identified. Variability not addressed.
0.5	New packaging concepts and manufacturing technologies only partially addressed.
0.7	New packaging concepts partially addressed. Limited description of manufacturing technologies.
0.9	Slight attention to new packaging concepts or manufacturing technologies.
Risk Reduction Plans	
0.1	All risk areas clearly identified (unproven technologies, packaging concepts, or manufacturing technologies, major differences between customer needs and the justified performance of the equipment). Risk reduction plans include "measures of merit" to be tracked and tests and analyses to be conducted.
0.3	All risk areas clearly identified (unproven technologies, packaging concepts, or manufacturing technologies, major differences between customer needs and the justified performance of the equipment). Risk reduction plans partially defined, missing one or more of the following: "measures of merit" to be tracked and tests or analyses to be conducted.
0.5	Risk areas not clearly identified (unproven technologies, packaging concepts, or manufacturing technologies, major differences between customer needs and the justified performance of the equipment). Risk reduction plans partially defined, missing one or more of the following: "measures of merit" to be tracked. Tests or analyses to be conducted.
0.7	Few risk areas identified (unproven technologies, packaging concepts, or manufacturing technologies, major differences between customer needs and the justified performance of the equipment). Risk reduction plans incomplete.
0.9	No risk reduction plan.
Follow-On Research	
0.1	Areas for further research defined. Process in place for incorporating these in company-wide research programs.
0.3	Areas for further research defined. No specific process for incorporating these in company-wide research programs.
0.5	Areas for further research partially defined. No specific process for incorporating these in company-wide research programs.
0.7	Areas for further research partially identified. No evidence of incorporation in company-wide research programs.
0.9	Limited definition of requirements for further research.

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Figure 3-13 (Continued). Probability of Failure $P_{(4)}$: Technology Assessment

Probability of Failure	Criteria for Activity 3.1.5
0.1	Trade study effort comprehensive. Candidates selected based on conflicts in satisfying customer needs. Alternative technologies/designs evaluated in a manner similar to that done for the baseline. Trade study parameter weights are traceable to priorities identified during customer needs interpretation activity.
0.3	Trade study effort comprehensive. Candidates selection not completely traceable to conflicts in satisfying customer needs. Alternative technologies/designs evaluated in a manner similar to that done for the baseline. Trade study parameter weights are not completely traceable to priorities identified during customer needs interpretation activity.
0.5	Trade study effort limited. Candidate selection not completely justified. Alternative technologies/designs evaluation not as thorough as done for the baseline. Trade study parameter weights are not traceable to priorities identified during customer needs interpretation activity.
0.7	Trade study effort limited. Candidate selection not justified. Limited effort in evaluating alternative technologies/designs. Trade study parameter weights not related to customer priorities.
0.9	Trade study effort very limited. Results not credible.

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Figure 3-14. **Probability of Failure $P_{(s)}$: Tradeoff Analyses**

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Consequences of Failure Score	Criteria for Mission Consequences (C ₍₁₎)
0.1	Equipment is not significant to either mission completion or sortie generation capability.
0.3	Equipment provides moderate enhancement to mission success.
0.5	Equipment is significant to mission success or successive sorties will not be launched if equipment is inoperative.
0.7	Item is mission critical. Failure will always cause a mission abort.
0.9	Item is safety critical.

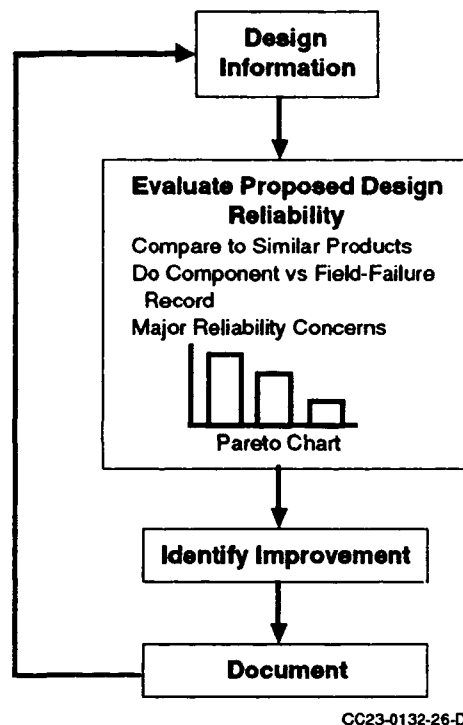
Consequences of Failure Score	Criteria for Cost Consequences (C ₍₂₎)
0.1	Equipment is simple ($\leq 1,000$ parts).
0.3	Equipment is of minor complexity (1,000 – 2,000 parts).
0.5	Equipment is moderately complex (2,000 – 4,000 parts).
0.7	Equipment is significantly complex (4,000 – 6,000 parts).
0.9	Equipment is very complex ($> 6,000$ parts).

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Figure 3-15. Consequence of Failure Criteria

The quantified reliability objectives of Output 3.1.6.5 are the other control metric(s) for the Concept Exploration Phase. As noted in paragraph 3.1.4.5, these projected values for the reliability attributes (life, durability, defect rate and BIT performance) must be based on a causal analysis of customer experience data on similar equipment with accompanying engineering rationale for the expected performance of the proposed system. The general process is illustrated by Figure 3-16.

CUSTOMER BASED RELIABILITY EXPECTATIONS



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Figure 3-16. Reliability Estimates Based on Similar Equipment

The quantification of performance based on comparisons to similar equipment is the preferred approach during the concept exploration phase. It has the following benefits:

- Emphasis on credible solutions to all reliability problems
- Focus on customer use and environments
- Encourages customer involvement

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- Consistent with the level of detail available early in development
- Focuses attention on areas lacking a credible explanation regarding the satisfaction of customer needs

If, by the end of the Concept Exploration phase, less than sixty percent (60%) of the difference between current performance and customer needs is supported by credible engineering rationale, corrective action should be required as part of risk reduction plans.

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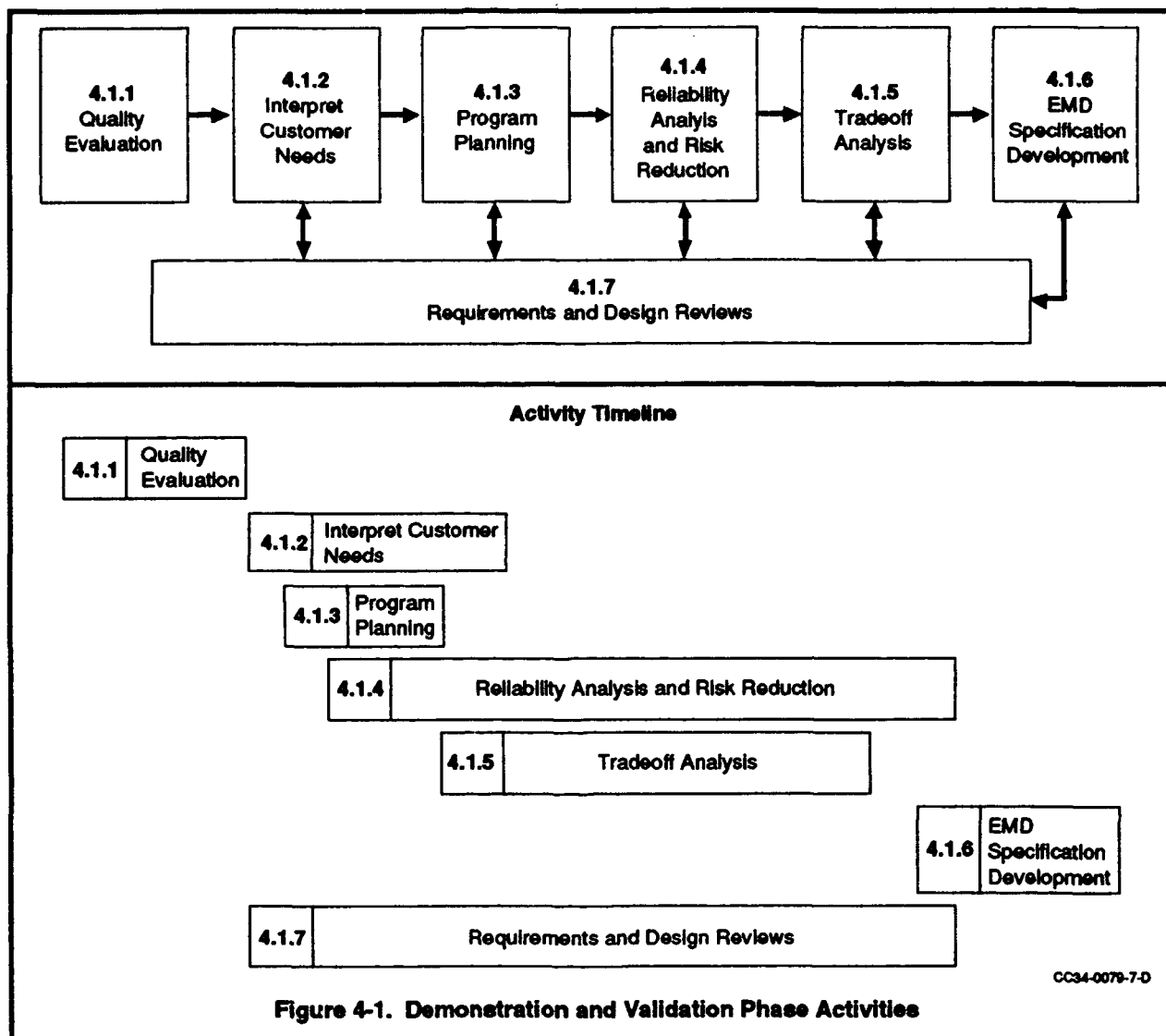


Figure 4-1. Demonstration and Validation Phase Activities

4.0 INTRODUCTION

PROCESS OVERVIEW

This chapter defines the activities that should take place during the Demonstration and Validation Phase to ensure the attainment of product reliability attributes. Figure 4-1 shows the essential reliability activities for the Demonstration and Validation Phase and the general time-phasing of these activities. Activity 4.1.1, Quality Evaluation, is intended to be a pre-contract award activity. Secondly, for maximum benefit and efficiency, much of Activity 4.1.2, Interpret Customer Needs, should take place prior to either the release of Requests for Proposal or contract award. Completion of both Activity 4.1.2 and the remaining activities of the phase takes place within the framework of contracted work. As described for the prior acquisition phases, the Activities of this phase that follow Program Planning are iterative, interact with each other, and the activity outputs should be continuously compared to customer needs. Detail descriptions of the Activities and their Inputs and Outputs are provided in Paragraphs 4.1.1 through 4.1.7. There are several instances of commonality between the tasks of this phase and previous phases. In these cases, reference is made to an appropriate earlier paragraph with any unique description provided in the paragraphs of this chapter.

4.1 SUMMARY OF ACTIVITIES

ACTIVITY SUMMARY

There are two principal objectives for the Demonstration and Validation Phase: 1) risk reduction, and 2) EMD specification development.

Technology issues that have been identified as offering substantial benefits and which have also been rated as moderate to high risk are subject to analysis and test to reduce their risk to low levels for entry into Engineering and Manufacturing Development (EMD). Fallback positions are identified and developed for each technology risk issue for implementation in the event that the risky technology cannot be satisfactorily developed.

The performance requirements for the preferred baseline system concept are refined through analyses, trade studies and risk reduction actions.

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Firm performance and verification requirements are established for inclusion in EMD technical specifications.

These two themes are supported by the reliability process described in paragraphs 4.1.1 through 4.1.7. Validation of reliability attributes (life, durability, defect rates and BIT performance) should be part of each technology risk reduction effort. Achievement of high reliability may, in itself, be considered a risk issue and subject to a specific risk reduction plan during this phase. Additionally, quantitative reliability performance and verification requirements, supported by engineering rationale and actions, are developed for inclusion in EMD performance specifications.

The seven critical activities of this phase are:

- 1) Quality Evaluation
- 2) Interpret Customer Needs
- 3) Program Planning
- 4) Reliability Analyses and Risk Reduction
- 5) Trade-Off Analyses
- 6) EMD Specification Development
- 7) Requirements and Design Reviews.

Most of the activities are common to those defined for the Concept Exploration Phase. The significant differences are primarily based on the level of system detail involved during Demonstration and Validation as compared to Concept Exploration.

The Quality Evaluation is used to establish a quantified baseline for continuous improvement. The evaluation is conducted as part of supplier proposal requirements and is part of source selection criteria. If suppliers have previously completed the evaluation as part of the Concept Exploration Phase some improvement in the results should be expected.

Accurate interpretation of customer needs is one of the most critical activities of this phase, as it was during the Concept Exploration Phase. The Demonstration and Validation Phase is lengthy and some customer needs and priorities can change substantially during this phase. During the Demonstration and Validation Phase, customer

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needs, which were translated to system level design requirements during Concept Exploration, are flowed-down to, at least, the subsystem level.

The program planning activity is substantially the same as that done for Concept Exploration. An updated Risk Reduction Plan is an output that is unique to the Demonstration and Validation Phase.

Substantial breadth and depth is included in the Reliability Analysis and Risk Reduction Activity. Environment and Use data are more specifically defined and translated into profiles representing life-time stresses. These are used to both assess quantitative reliability attributes and define materials characterization test requirements. Technology risk reduction testing and analyses are used to substantiate the reliability expectations of the proposed new technologies. The definition of critical functions and parameters are expanded to lower levels of detail and results are used for variability control analyses. Proposed manufacturing technologies and manufacturing processes are described. Critical processes are identified and the initial steps for process capability determination are taken.

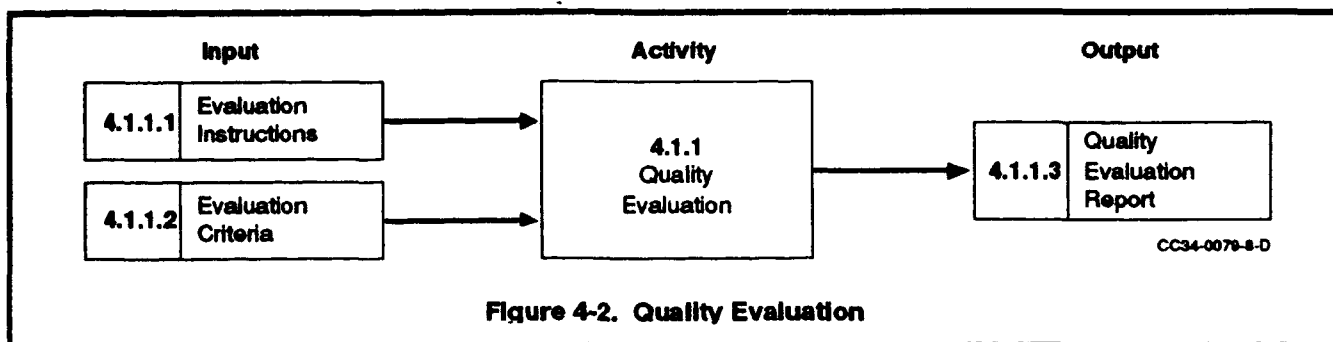
Trade studies continue to be the primary vehicle for defining a balanced design. Trade studies will be much more detailed and numerous than those conducted during the Concept Exploration Phase. The studies will be focussed on identifying a specific system configuration and performance attributes.

The ultimate output of the Demonstration and Validation Phase is a set of technical specifications and related documentation for EMD. These will define both performance and verification requirements for both the system and, in general, critical subsystems. Related documentation includes statements of work, supplier requirements, supplier selection criteria and EMD risk reduction plans.

Requirements and Design reviews bring discipline and a focus on customer needs to the Demonstration and Validation reliability process. These reviews, which include both internal and external customer reviews are a primary vehicle for continuing the

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identification of customer needs and the priorities of those needs.



4.1.1 ACTIVITY - QUALITY EVALUATION

This pre-contract award Activity establishes a quantitative baseline for continuous improvement. In response to customer instructions, the supplier conducts an internal review of company-wide use at quality practices. This evaluation uses criteria derived from Malcolm Baldrige Award criteria. Recommended criteria are provided in Volume II of this guide.

EVALUATE THE WHOLE ORGANIZATION

This activity and its Inputs and Outputs are basically the same as defined in paragraph 3.1.1 for Concept Exploration. In the conduct of this activity it is expected that each major functional division (e.g., Manufacturing, Engineering, etc.) within an organization will assess their activities in light of the criteria contained in Volume II of this guide. At the organization level the inputs from the functional level are to be aggregated and compiled into a single report for submittal to the customer.

This Activity should be applied to all major contracts and subcontracts. The Activity can be integrated with enterprise wide actions such as supplier certification programs. Once the activity has been completed the results should be universally applicable to multiple contracts.

4.1.1.1 INPUT - EVALUATION INSTRUCTIONS

The customer includes in his request for proposal a complete set of instructions for conducting the quality evaluation. These include directions in

Executive Summaries, detail instructions in the Instructions to Offerors (Evaluation Criteria, Reporting Requirements), and the relationship of the evaluation to source selection award factors. An example of instructions is provided following paragraph 3.1.1.3. Report format requirements for a Malcolm Baldrige Award Application are recommended.

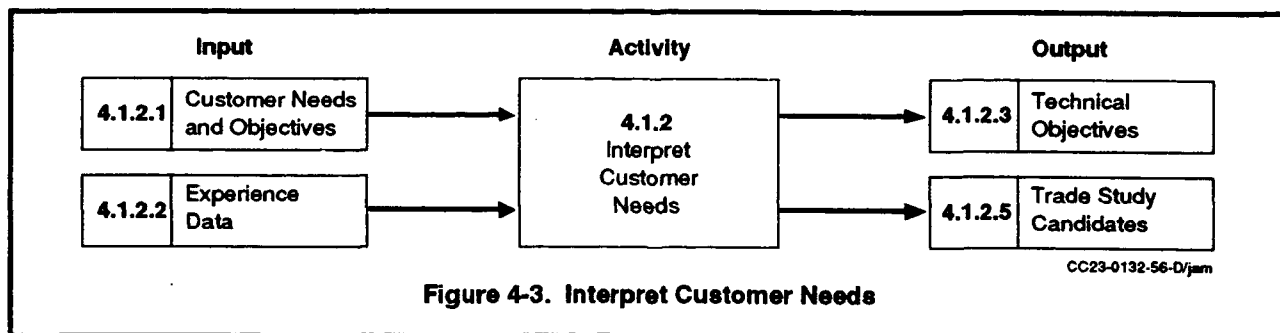
4.1.1.2 INPUT - EVALUATION CRITERIA

The customer supplies the criteria to be used for the quality evaluation. Volume II of this guide provides a set of recommended criteria patterned after the Malcolm Baldrige Award criteria.

4.1.1.3 OUTPUT - QUALITY EVALUATION REPORT

The supplier provides a quality evaluation report in accordance with customer reporting requirements. This report is to be used by both the customer and the supplier. The customer will score the results and use this in source selection. The supplier should similarly score his results and use this evaluation to define weaknesses and plan the required improvements.

If the results of a quality evaluation have been previously reported, for example as a part of the Concept Exploration Phase, and more than a year has elapsed since the evaluation, a customer should expect to see improvement relative to the score of the previous report. Both the absolute score and improvement should be considered in the application of results to source selection.



4.1.2 ACTIVITY - INTERPRET CUSTOMER NEEDS

FLOWDOWN CUSTOMER NEEDS

A systematic, comprehensive process for defining customer needs, the priorities associated with these needs, and the translation of these needs into quantified technical objectives must be implemented for this phase. Quality Function Deployment is the recommended tool for implementing this Activity. This is one of the most critical activities of this phase. Customer contact and inputs should have taken place prior to contract award as part of pre-RFP release discussions. At a minimum, this Activity must take place as one of the first activities of the Demonstration and Validation Phase. Customer needs documented in contract technical material should always be supplemented and validated via direct contact. Customers must encourage and support these contacts.

The translation of customer needs into system level technical requirements should have taken place during the Concept Exploration Phase. If not, it must be accomplished during this phase. Additionally, the flowdown of requirements, via a QFD, to at least the subsystem level must take place during the Demonstration and Validation Phase. The flowdown should continue to the level of indenture required for the conduct of trade studies and other Demonstration and Validation Phase analyses.

4.1.2.1 INPUT - CUSTOMER NEEDS AND OBJECTIVES

Customer needs and objectives should be explicitly defined in the contract technical documentation, such as Statements of Work and preliminary specifications. However, all contract documentation must be reviewed for descriptions of customer needs. Additionally, the supplier must plan for early, direct, and frequent customer contact to validate and refine the documented needs. These contacts must focus on a multidisciplinary definition of customer needs.

4.1.2.2 INPUT - EXPERIENCE DATA

The supplier must ensure that customer documented needs are subject to review by experts in all areas so that all needs are identified and properly translated into technical objectives and flowed down. The supplier must also ensure that customer

needs and technical objectives, defined during the prior acquisition phase is available for application to the Demonstration and Validation contract. The experience data base should include a thorough and documented understanding of both good and bad customer experience with current products as a preferred method for aiding in the identification of needs.

4.1.2.3 OUTPUT - TECHNICAL OBJECTIVES

The supplier must provide a definition of specific technical attributes and parameters that will satisfy all customer needs. Quality Function Deployment is the recommended method for defining and documenting these technical objectives. This definition includes quantitative objectives for each of the attributes and parameters. The customer needs must be given weighting factors which represent priority levels. These factors will be used to define the relative importance of each of the technical attributes and parameters. It is critical that the interaction between reliability technical attributes and the other technical attributes be identified for the purpose of identifying trade study candidates.

The technical objectives should be flowed down by QFD procedures to the subsystem and lower levels of indenture. The flowdown must maintain traceability to customer needs and, more importantly, the customer's priorities for these needs. In order to retain focus on an integrated set of reliability requirements, it is recommended that all the product reliability attributes be grouped together during the QFD development. These attributes include service life, durability, defect rates, and BIT performance requirements (e.g., False Alarm rate, Fault Detection Probability, Could Not Duplicate (CND) rate, etc.).

IDENTIFY ALL RELIABILITY ATTRIBUTES

Early in the Demonstration and Validation Phase these quantified attributes and parameters should be treated as objectives rather than requirements. As a subset of this output, the supplier must identify, list, and update all related research that supports the system development. This list includes any research not otherwise a part of risk reduction plans in order to avoid duplication and maximize resources. As the Demonstration and Validation Phase proceeds,

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additional research applicable to the system must be identified for inclusion in future plans.

4.1.2.4 OUTPUT - TRADE STUDY CANDIDATES

The supplier must identify candidates for trade studies to be performed during the Demonstration and Validation Phase. The Quality Function Deployment techniques can assist in defining these candidates by evaluating the interactions among technical attributes. Trade-off analyses are used to optimize a technical attribute or parameter that interacts with other technical attributes or parameters. For example, radar detection range is a function of power, weight, volume, receiver sensitivity, reliability, and cost. Trade studies are also used to select between alternative technologies or system concepts.

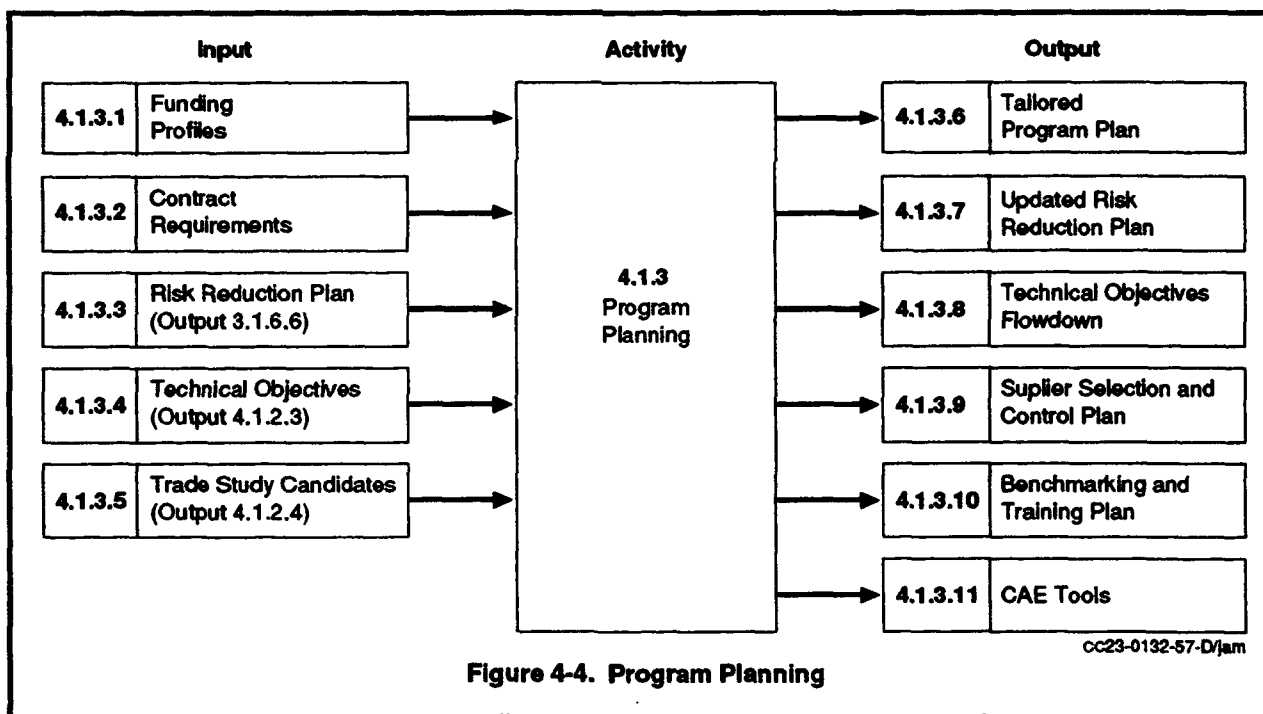


Figure 4-4. Program Planning

4.1.3 ACTIVITY - PROGRAM PLANNING

The Program Planning Activity description is the same as for the Concept Exploration Phase (paragraph 3.1.3) with appropriate changes in the reference paragraph numbers. Demonstration and Validation Phase planning considers one additional

input, Risk Reduction Plan, and generates one additional output, an Updated Risk Reduction Plan. The planning is also more detailed than that done for Concept Exploration as a result of the greater depth of technical detail and the longer program duration.

4.1.3.1 INPUT - FUNDING PROFILE

The description of this Input is the same as provided in paragraph 3.1.3.1.

4.1.3.2 INPUT - CONTRACT REQUIREMENTS

The description of this Input is the same as that provided in paragraph 3.1.3.2.

4.1.3.3 INPUT - RISK REDUCTION PLANS

Output 3.1.6.6 serves as an Input to the Program Planning Activity. Risk Reduction Plans are mandatory for the Demonstration and Validation Phase. They should be prepared as part of the Concept Exploration Phase.

4.1.3.4 INPUT - TECHNICAL OBJECTIVES

Output 4.1.2.3 serves as an input to the Program Planning Activity.

4.1.3.5 INPUT - TRADE STUDY CANDIDATES

Output 4.1.2.4 serves as an input to the Program Planning Activity. Additional trade study candidates may have been developed as a result of risk reduction plans, customer requests, or supplier experience. The candidate list should define the specific measures of merit being used to evaluate trade study alternatives. Any weighting factors applied to the trade study measures of merit should be shown in the candidate list and should be traceable to customer priorities. Reliability attributes and/or parameters should be considered for all trade studies as measures of merit.

4.1.3.6 OUTPUT - TAILORED PROGRAM PLAN

The description for this Output is the same as provided in paragraph 3.1.3.5 with appropriate changes made to the paragraphs referenced therein. The tailored program plan should include inputs from relevant functional disciplines, e.g. Reliability, Design Engineering, Diagnostics Design,

PLAN FOR RISK REDUCTION

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Manufacturing, Engineering Technologies (e.g. Structural Dynamics, Thermodynamics, etc.), and Logistics.

4.1.3.7 OUTPUT - UPDATED RISK REDUCTION PLAN

The baseline Risk Reduction Plan should be reviewed and modified based on changes in customer needs, risk assessment results (identification of technology risk levels), proposed technologies, and resource constraints. Specific attention should be paid to including new manufacturing technologies as risk reduction candidates. The basic attributes of the Risk Reduction Plans remain as described in paragraph 3.1.6.6.

A principle subsection of the Updated Risk Reduction Plan should describe a summary test plan with requirements for Failure Reporting Analyses and Corrective Action System (FRACAS). All testing conducted during the Demonstration and Validation Phase should be considered risk reduction testing. The test plan summary should describe how test results can be used to validate the reliability attributes of the risky technology, define environmental stress properties/sensitivities, and identify variability associated with the critical parameters of the tested items. The FRACAS plan should describe test objectives, failure criteria, the responsibility for root causal analyses and correction, and the process for ensuring that these lessons learned are translated into design rules, application guides, or derating criteria.

4.1.3.8 OUTPUT - TECHNICAL OBJECTIVES FLOWDOWN

The description of this output is the same as provided in paragraph 3.1.3.7. The flowdown/allocation of reliability technical objectives needs to be done to the level of detail at which the Demonstration and Validation analyses and trade studies will be conducted. Allocations should also be established for any subcontract effort.

4.1.3.9 OUTPUT - SUPPLIER SELECTION AND CONTROL PLAN

The description of this output is the same as provided in paragraph 3.1.3.9 with the following

additions:

- 1) The reliability and quality criteria used for supplier selection should be identified.
- 2) Criteria for defining screening testing that would be applied to delivered supplier equipment.

4.1.3.10 OUTPUT - BENCHMARKING AND TRAINING PLAN

The description of this output is the same as provided in paragraph 3.1.3.8. Some potential candidates for Benchmarking are:

- Design for Manufacturing
- Design for Testability
- Trade Study Processes
- Risk Analyses
- Design for Reliability
- Design Automation

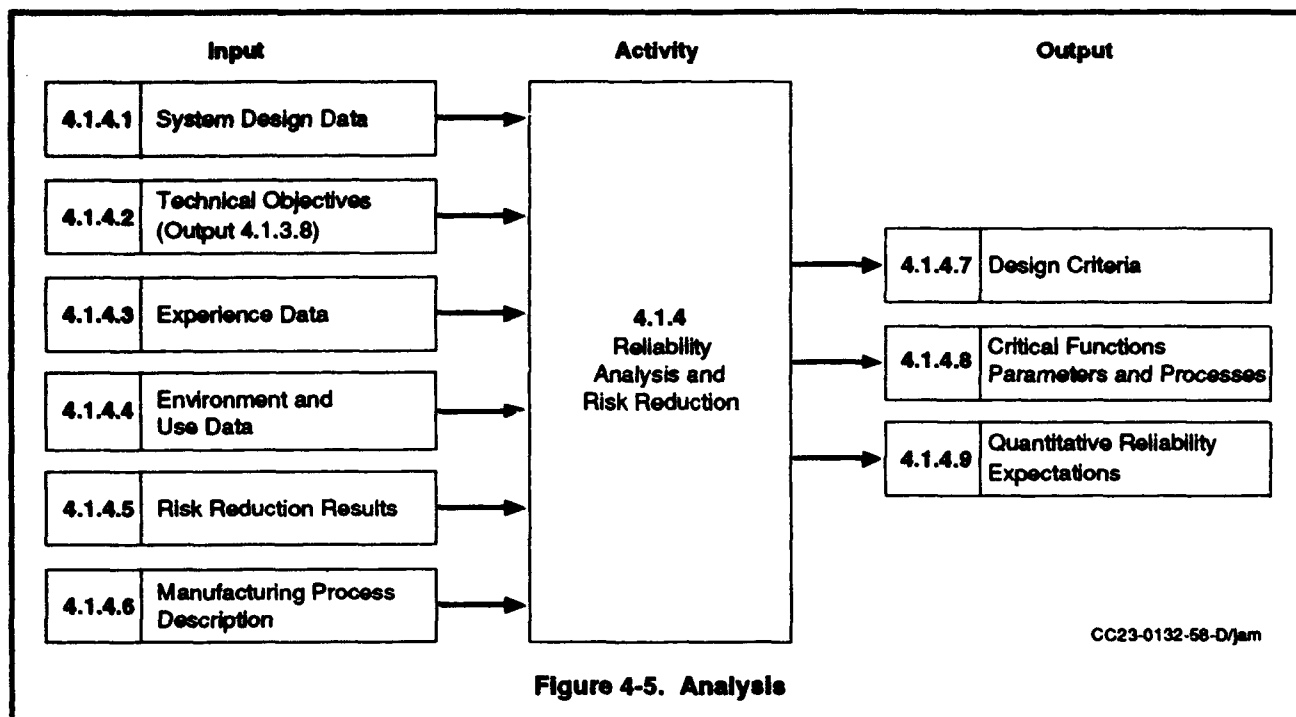
Emphasis on benchmarking as an effective process improvement tool must begin early in the acquisition cycle.

4.1.3.11 OUTPUT - CAE TOOLS

The description of this output is the same as provided in paragraph 3.1.3.6.

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4.1.4 ACTIVITY - RELIABILITY ANALYSIS AND RISK REDUCTION

This is the central Activity of the Demonstration and Validation reliability process. The Activity is continually iterated throughout the phase as detail information is developed through analysis, test, and trade-off analyses. There are two basic elements of this Activity:

- 1) Development of design and manufacturing criteria and application rules that will prevent defects in both the new and existing technologies proposed for systems use.
- 2) Estimation of quantitative reliability parameters, based on the above, for inclusion in EMD technical specifications.

The key implementation issue for a supplier is the integration and coordination of the efforts of multiple functional specialties which affect defect prevention and elimination. The descriptions of inputs and outputs for this Activity could be used to establish checklists directed at achieving the required coordination.

4.1.4.1 INPUT - SYSTEM DESIGN DATA

These data provide a complete engineering description of the proposed system design. It should include the following:

COMPLETE DESIGN DATA

- Functional analysis results, functional block diagrams, and schematics of both the electrical and mechanical design (e.g. packaging, cooling) of the system/equipment. The functional analyses should show time phased functions for all operational use including routine checkout and maintenance.
- Description of new technology (parts, materials, assemblies) including known/suspected environmental sensitivity, critical parameters with expected variability, status of development testing, reference to risk reduction plans, and packaging concepts.
- Description of existing technology being applied to the system.
- Description of comparable current technology and systems/equipment that can be used as a basis for quantitative reliability estimates applicable to the new system. The data is to include a definition of operating and maintenance environments and functional operation.

4.1.4.2 INPUT - TECHNICAL OBJECTIVES

Output 4.1.3.8 serves as an input to this analysis activity. These are the baseline set of quantitative reliability expectations.

4.1.4.3 INPUT - EXPERIENCE DATA

These data include the following:

- Existing de-rating, application, design rules, lessons learned (internal and customer), design for manufacturing rules, customer use reliability data for the systems or equipments identified in Input 4.1.4.1 and manufacturing defect data for current manufacturing processes.
- Data from related research for the proposed new technologies and recommended application/de-rating guides.

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DEMONSTRATION AND VALIDATION PHASE

This input provides an opportunity for significant supplier/ customer interaction during the development of user experience data on current, comparable systems or technology.

4.1.4.4 INPUT - ENVIRONMENT AND USE DATA

The supplier is responsible for defining all local environmental conditions and resultant stresses/stress cycles. The data must be traceable to the customer provided mission description (or similar document). Relevant information includes basing location and operating mission profiles. Internally generated stresses should be derived from the functional analyses of Input 4.1.4.1. Stresses generated as a result of maintenance, storage, handling, transportation and manufacture must also be derived. The data should show expected maximum stress conditions and life cycle stress profiles, showing amplitude and frequency, based on the distribution of basing locations and types/duration of missions and other operation/use. Analyses should focus on primary fault producing stresses such as vibration, loads, shock, temperature and temperature cycling, humidity, and handling stresses.

4.1.4.5 INPUT - RISK REDUCTION RESULTS

The supplier is responsible for ensuring that the results of risk reduction tests and analyses are used to develop the design and manufacturing guides necessary to prevent defects in new or risky technology. Tests may include materials and parts properties characterization defining responses to stress and stress cycling, the identification of parts and materials critical parameter variability and likely control factors. Analysis results may include failure rate, testability attributes, and fatigue analyses.

4.1.4.6 INPUT - MANUFACTURING PROCESS DESCRIPTION

The supplier should develop initial step by step descriptions of the projected manufacturing processes. These should focus on new processes required for new parts/materials/packaging technologies and any new manufacturing technology intended as an improvement to existing manufacturing processes. These descriptions

EARLY MANUFACTURING EVALUATION

should identify any known constraints placed on system electrical or mechanical design or unique stresses imposed on the system elements. The inputs should address the definition of capability indices for both existing and new manufacturing processes and identify any risk reduction analysis or tests.

4.1.4.7 OUTPUT - DESIGN CRITERIA REPORT

The supplier is responsible for generating a comprehensive report(s) describing the design and manufacturing criteria essential to preventing product defects. This report should form the basis for the development of design and manufacturing guides and specifications. The report also provides engineering justification for the quantitative estimates of Output 4.1.4.9. The topics covered by the report should address:

- Fatigue and durability design requirements
- Environmental stress protection
- Electrical, mechanical, and thermal design rules
- Parts and materials applications guides
- BIT and Diagnostics design guides
- Lessons Learned
- Parts and materials selection criteria
- Design for manufacturing rules

The above criteria should pay specific attention to new technologies. The material is developed from existing criteria, risk reduction tests and analyses, and other Demonstration and Validation stress and fatigue analyses.

4.1.4.8 OUTPUT - CRITICAL FUNCTIONS, PARAMETERS, AND PROCESSES

This output product represents the initial steps of a worst case/variability control program. During Demonstration and Validation all critical functions should be identified by a combination of Failure Modes Effects Criticality Analysis (or similar analyses), engineering judgement and experience. The criticality of these functions should be coordinated with the customer who is the final arbiter of criticality. The criticality of functions should then be flowed-down through the system to identify critical subsystems and assemblies. The design of the BIT and diagnostic system should be driven, or

IDENTIFY CRITICAL ITEMS

CHAPTER 4

DEMONSTRATION AND VALIDATION PHASE

at least prioritized, by this criticality analysis, as should the design of fault tolerance features. Additional critical parameters can be identified for new technologies by the results of risk reduction tests and analyses and should include critical mechanical functions such as thermal control. Once critical parameters have been identified, the results are compared to the manufacturing process description (Input 4.1.4.6) to define critical manufacturing processes that are potential candidates for both variability reduction techniques and statistical process control. Critical manufacturing process steps such as soldering operations should be identified based on experience and judgement regarding their overall impact on product reliability.

Once the critical parameters have been identified their variability should be established through test or analysis. CAE tools and/or circuit simulation tools can be used to evaluate these variances against performance specification limits. This analysis has significant benefits in the design of properly operating BIT and diagnostic functions.

4.1.4.9 OUTPUT - QUANTITATIVE RELIABILITY EXPECTATIONS

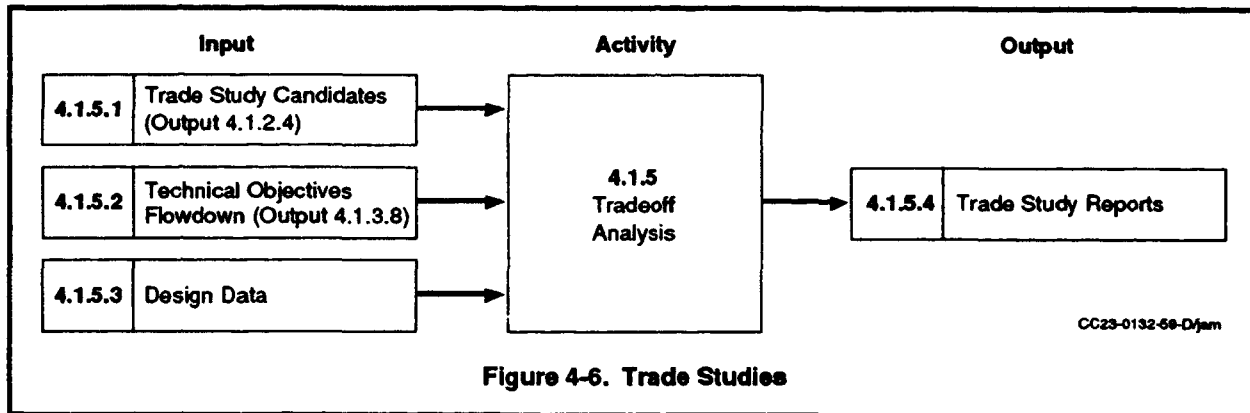
Quantitative reliability expectations are to be estimated based on comparisons to the user experienced performance of current similar systems or equipment. The reliability parameters of interest are: service life, defect rate (e.g. Mean Time Between Maintenance, to include all defects such as fatigue, wearout, catastrophic failure, degraded performance, alleged overstress and faulty BIT performance), Mission Success Probability, and BIT performance. Causal analyses should be done on the current performance data to establish rationale for those levels of performance. Current performance data provided by Input 4.1.4.3 should include manufacturing defect data from which conclusions regarding its impact on field performance can be drawn. Inputs 4.1.4.1 and 4.1.4.4 provide the data required for evaluating differences in environments and use. Combining these factors with data representing new technology characteristics derived from risk reduction activities and the defect prevention actions described in Outputs 4.1.4.7 and 4.1.4.8 should permit an

CUSTOMER BASED RELIABILITY ESTIMATES

assessment of reliability based on solid engineering analyses.

Initial life estimates for known fatigue or wearout mechanisms, particularly lead or solder joint failure, should be made using maximum derived stress cycling applied at worst case locations.

Analyses of the proper performance of BIT systems should be done using circuit simulation analyses.



4.1.5 ACTIVITY - TRADE OFF ANALYSIS

The description of this Activity is the same as provided in paragraph 3.1.5. Key elements are: the existence of a well-defined trade off procedure, the traceability of weighting factors for measures of merit to customer priorities identified in paragraph 4.1.2, and the inclusion of reliability and manufacturing parameters in all trade studies.

4.1.5.1 INPUT - TRADE STUDY CANDIDATES

Output 4.1.2.4 serves as an input to the Activity. This input is a summary description of each of the trade studies to be conducted during the Demonstration and Validation phase. The summary includes the trade study issue, definition of alternatives, parameters to be considered in reaching a conclusion and responsibilities for conducting the study.

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DEMONSTRATION AND VALIDATION PHASE

4.1.5.2 INPUT - TECHNICAL OBJECTIVES FLOWDOWN

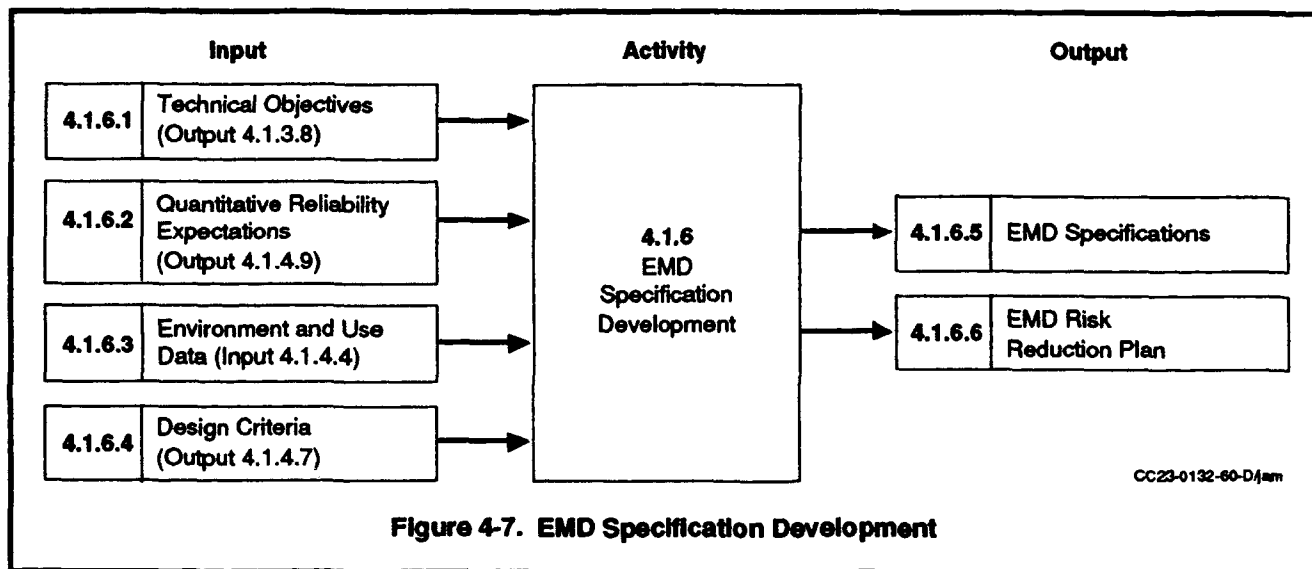
Output 4.1.3.8 defines the baseline quantitative reliability objections that satisfy customer needs and serves as an Input to the Trade-Off Activity.

4.1.5.3 INPUT - DESIGN DATA

The description of this input is the same as contained in paragraph 3.1.5.3 with the referenced paragraphs changed from 3.1.4.2 and 3.1.2 to 4.1.4.4 and 4.1.2.

4.1.5.4 OUTPUT - TRADE STUDY REPORTS

The description of this output is the same as contained in paragraph 3.1.5.4. The supplier trade study procedure should identify the specific mechanisms for ensuring that changes resulting from trade studies are formally implemented and information regarding these changes is disseminated throughout the program.



4.1.6 ACTIVITY - EMD SPECIFICATION DEVELOPMENT

Creation of EMD technical specifications is one of the primary objectives of the Demonstration and Validation Phase activities. These will contain requirements for the following issues:

- 1) Quantative reliability requirements (life, success probabilities, fault rate, and BIT performance)

DEFINE THE REQUIREMENTS

- 2) Design criteria and parts selection, standardization requirements
- 3) Variability requirements
- 4) Test and verification requirements

All of the above, with the exception of Test and Verification requirements, should be developed from the Input and Output products of the previous Activities.

This Activity also includes the development of Statements of Work and Data Item descriptions. Specifications, Statements of Work, Data Item requirements, and supplier selection criteria should also be developed for major subcontracted items. These will continue a flowdown of the requirements developed for the principal customer.

4.1.6.1 INPUT - TECHNICAL OBJECTIVES FLOWDOWN

Output 4.1.3.8 serves as an input to this Activity. These represent the baseline quantitative reliability objectives that are traceable to the satisfaction of customer needs.

4.1.6.2 INPUT - QUANTITATIVE RELIABILITY EXPECTATIONS

Output 4.1.4.9 serves as an input to this Activity. These reliability estimates are the results of Activity 4.1.4 (Reliability Analysis) and 4.1.5 (Trade-Off Analysis). These results must be compared to the baseline objectives to define EMD specification requirements. The baseline values should be changed, subject to customer approval, when it is demonstrated that a properly balanced design results in a reduction of certain reliability objectives. The comparison of baseline values to estimates is otherwise used to establish the level of risk associated with meeting customer needs and provide a basis for EMD risk reduction plans.

4.1.6.3 INPUT - ENVIRONMENT AND USE DATA

Input 4.1.4.4 also serves as an input to this Activity. These data serve to establish design-to requirements and the conditions under which EMD verification

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DEMONSTRATION AND VALIDATION PHASE

testing should take place.

4.1.6.4 INPUT - DESIGN CRITERIA

Output 4.1.4.7 serves as an input to this Activity. Parts selection, derating, design margins for the EMD specifications are determined from this output. This output (4.1.4.7) also provides a source for developing task requirements for statements of work.

4.1.6.5 OUTPUT - EMD SPECIFICATIONS

This output represents the entire range of technical requirements products: customer specifications and statements of work, supplier specifications and statements of work, and supplier selection criteria. The QFD used to translate customer needs into technical objectives and the subsequent flowdown QFD's should serve as the basis for identifying specification performance issues. A comparison of baseline quantitative objectives with estimates derived from Demonstration and Validation analyses and Trade-Off analyses provides the data required to define EMD specification quantitative values. The design criteria input should be used to define specification requirements for design margins while design-to and test environments are determined using the environment and use data input. These data should be structured to describe a life use profile (frequency and amplitude of stress over the life cycle of the product) for application to EMD Reliability development and verification requirements.

EMD verification and testing includes analytical verification, development tests, verification tests, and Environmental Stress Screening and Acceptance tests. Current literature contains sufficient information to develop the appropriate test detail for all testing. The essential element of development and verification tests is that they be conducted under the customer use environment. These may be accelerated using recognized environmental acceleration factors.

Testing must include the validation of life and fatigue characteristics. These can be done with mockups or representative samples.

Development testing includes any required material characterization test that defines behavior under stress cycling or extremes, electrical performance including BIT performance, critical parameter variability definition and manufacturing process characterization.

Statement of Work task development is also part of this output. These tasks include a description of EMD analytical requirements and can be developed using the EMD process description contained in Chapter 5 herein.

Specifications and Statements of Work for major EMD subcontracted equipment should also be part of the output described herein. QFD evaluation can be used to flowdown technical requirements to the appropriate level. Task requirements for Statements of Work are replications of the tasks required of the prime contractor, tailored to the details and importance of the subcontracted equipment.

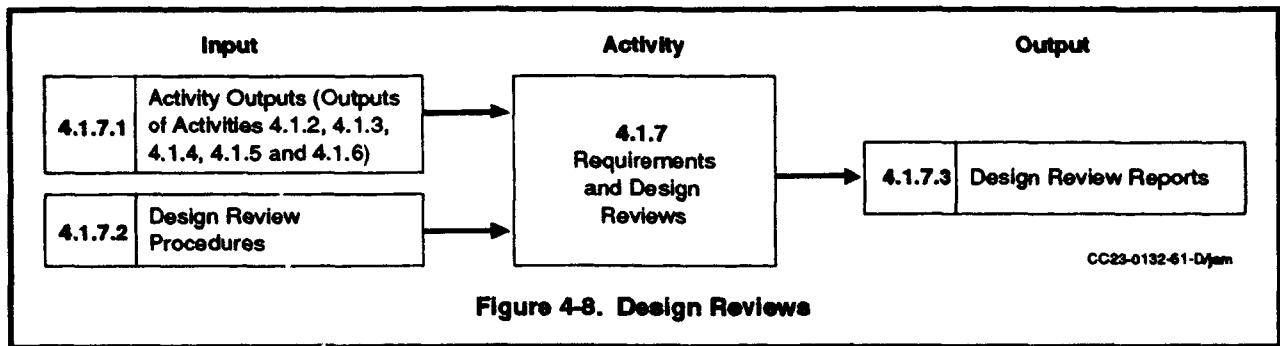
4.1.6.6 OUTPUT - EMD RISK REDUCTION PLAN

Reliability risk reduction plans are necessary for any Demonstration and Validation Phase risks that have not been satisfactorily reduced to a low level, any additional risks uncovered during Demonstration and Validation, or as determined by the Control and Audit requirements of paragraph 4.2. These plans should include the criteria for identifying risks, the risks that have been identified for EMD closure, the measures of merit to be tracked to verify risk closure, the analyses and tests required, and the recommended fall back positions. Inputs 4.1.6.2 and 4.1.6.4 are primary sources for identifying risk reduction candidates.

CONTINUE RISK REDUCTION

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4.1.7 ACTIVITY - REQUIREMENTS AND DESIGN REVIEWS

The description of this Activity is the same as provided in paragraph 3.1.7. Design reviews should always be focused on specific customer reliability need as identified and translated into technical objectives by Activity 4.1.2 and the status of the design in satisfying those needs. The Risk Factor assessment figures contained in paragraph 4.2 can be used to establish checklists for requirements and design review topic material.

4.1.7.1 INPUT - ACTIVITY OUTPUTS

All outputs of Activities 4.1.2, 4.1.3, 4.1.4, 4.1.5, and 4.1.6 are the issues for both internal and customer reviews. Certain outputs such as those from the Program Planning and EMD Specification Activities (4.1.3 and 4.1.6) are subject to a limited number of reviews at the start and near the end of the Demonstration and Validation Phase. The output of Activity 4.1.2 serves as the benchmark against which the outputs of Activities 4.1.4 and 4.1.5 are measured. The outputs of Activities 4.1.4 and 4.1.5 provide the technical material that is subject to continuous review during the Demonstration and Validation Phase.

4.1.7.2 INPUT - DESIGN REVIEW PROCEDURES

The description of this input is the same as provided in paragraph 3.1.7.2.

4.1.7.3 OUTPUT - DESIGN REVIEW REPORTS

The description of this output is the same as provided in paragraph 3.1.7.3. These reports are the

vehicles for documenting changes in customer requirements.

4.2 CONTROL AND AUDIT

CONTROL THE PROCESS

During the Demonstration and Validation Phase of the acquisition cycle, as in all other phases, teaming of multiple disciplines is essential in developing a product that will satisfy reliability needs of the customer. It is during this phase that the design concept is developed into viable product specifications. Heavy emphasis is placed on developing the design to meet all reliability requirements. As the design takes shape, numerous tools and techniques are used in a process that has high probability of producing a product that is very reliable. Initial reliability predictions are based on customer use data and lessons learned and updated as the product takes shape.

To ensure that processes that will increase product reliability exist and that these processes are applied, a continuation of the Risk Factor assessment described in Chapters 2 and 3 is applied.

During the Dem/Val Phase the contractor must have the following controls in place:

- An effective system that translates all the customer's expectations and requirements into product design and performance requirements and provides for continuous review of the satisfaction of customer needs.
- A risk management system for the evaluation and elimination of technical and reliability risk.
- The necessary processes to ensure that the design is assessed for product reliability/durability.
- A process that addresses issues that will ensure a robust design and manufacturing approach.
- A system that will provide effective process controls for identifying key product and process characteristics.

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DEMONSTRATION AND VALIDATION PHASE

- A defined baseline for continuous improvement and processes for achieving it.

The evaluation of the reliability process is based on assessing these control indicators and the degree to which they are implemented into the contractor's way of doing business. Figure 4-9 (page 4-26) summarizes the assessment of the Demonstration and Validation Phase; Figures 4-10 through 4-15 (pages 4-26 through 4-32) describe the criteria for evaluating each process element and the consequences of failure of the process.

The risk factor evaluation is a customer responsibility. The evaluations should use a multidiscipline team and can be conducted as part of design reviews. A Demonstration and Validation Phase is typically three to four years in length. As a result, the risk factor evaluation should be iterated several times throughout the phase. A recommended schedule for these evaluations is: initial evaluation at six months after contract award, semiannual thereafter with a final assessment six months prior to completion of the contract.

If the assessment indicates that the risk factor associated with achieving reliability objectives is too high, corrective action should be taken. The recommended actions and the associated Risk Factor scores are as shown in Table 4-1.

RISK REDUCTION

TABLE 4-1 Risk Reduction	
Risk Factor Score	Recommendation
≤ 0.25	None
$> 0.25 - \leq 0.4$	Optional Risk Reduction Plan for Reliability
> 0.4	Mandatory Risk Reduction Plan for Reliability

The quantified reliability objectives described in paragraph 4.1.4.9 are the second control metric required for the Demonstration and Validation Phase.

Probability of Failure					Consequence of Failure			
Parameter	Probability of Failure Caused by:	Weight Factor	Activity	Scoring and Criteria	Parameter	Consequence of Failure	Weight Factor	Scoring and Criteria
$P_{(1)}$	Inadequate Quality	0.1	4.1.1	Figure 4-10	$C_{(1)}$	Safety or Mission Success Impact	0.5	Figure 4-15
$P_{(2)}$	Inadequate Definition and Update of Customer Requirements	0.2	4.1.2 4.1.7	Figure 4-11	$C_{(2)}$	Cost Impact	0.5	Figure 4-15
$P_{(3)}$	Faulty Planning	0.2	4.1.3	Figure 4-12	$C_{(F)}$	$0.5C_{(1)} + 0.5C_{(2)}$		
$P_{(4)}$	Incomplete or Inadequate Reliability Analysis	0.3	4.1.4	Figure 4-13				
$P_{(5)}$	Inadequate Trade Studies	0.2	3.1.5	Figure 4-14				
$P_{(F)}$	$0.1P_{(1)} + 0.2P_{(2)} + 0.2P_{(3)} + 0.3P_{(4)} + 0.2P_{(5)}$							

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Figure 4-9. Risk Factor: Demonstration and Validation

$$\text{Risk Factor} = P_{(F)} + C_{(F)} - P_{(F)} \times C_{(F)}$$

Probability of Failure	Criteria for Activity 4.1.1
0.1	Supplier has a consistent, recognized and demonstrated history of high quality and has completed a CAP Assessment or Malcolm Baldrige application with a score above 500. If applicable, the supplier has shown improvement over prior quality assessments.
0.3	Supplier has a recognized commitment to high quality, but quality results are occasionally deficient. Has completed a CAP Assessment or Malcolm Baldrige application with a score above 350. If applicable, the supplier has shown improvement over prior quality assessments.
0.5	Supplier commitment to quality is not completely evident. Has completed a CAP Assessment or Malcolm Baldrige application with a score above 250. If applicable, the supplier has shown improvement over prior quality assessments.
0.7	Supplier has completed a CAP Assessment or Malcolm Baldrige application with a score above 150, but has no specific plans for improvement. If applicable, the supplier has shown improvement over prior quality assessments.
0.9	Supplier has completed a CAP Assessment or Malcolm Baldrige application with a score below 150.

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Figure 4-10. Probability of Failure $P_{(1)}$: Quality Evaluation

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Probability of Failure	Criteria for Activities 4.1.2 and 4.1.7
0.1	Customer needs have been identified and prioritized in a systematic manner, translated into product technical objectives, and flowed-down to subsystems levels. Trade study candidates have been identified. Design reviews have clearly defined exit criteria, customer needs are reviewed and updated, compliance with customer needs are shown. Related research and additional enabling research identified and documented.
0.3	Customer needs have been identified in a systematic manner, translated into product technical objectives, and flowed-down to subsystems levels. Trade study candidates have been identified. Customer needs reviewed and updated at design reviews. Compliance with customer needs are shown. Related research and additional enabling research identified and documented.
0.5	Customer needs have been identified and translated into product technical objectives, and flowed-down to subsystems levels. Trade study candidate list is incomplete. Design reviews show compliance with customer needs. Incomplete identification and documentation of related research and additional enabling research.
0.7	Customer needs only partially identified with no clear traceability to product technical objectives. Trade study candidate list is incomplete. Design reviews not thoroughly focused on customer needs. Very limited identification and documentation of related research and additional enabling research.
0.9	Limited customer/supplier interchange. Customer needs not validated with customer, design reviews do not specifically address customer needs. No clear integration of current research or definition of additional enabling research.

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Figure 4-11. Probability of Failure $P_{(2)}$: Customer Needs Interpretation

Probability of Failure	Criteria for Activity 4.1.3
0.1	Funding profiles are influenced by customer needs and priorities. All contract/technical requirements have been addressed. Risk reduction plans include reliability measures of merit. Phase tasks are tailored to customer priorities. Customer needs clearly transmitted to all personnel. Training needs/plans, benchmarking plan for continuous improvement identified, CAE tools available and data bases integrated. Allocated technical objectives "flowed down" and clearly traceable to customer needs.
0.3	Funding profiles are partially influenced by customer needs and priorities. Contract/technical requirements have been addressed. Risk reduction plans include reliability measures of merit. Customer needs not adequately transmitted to all personnel. Training not specifically addressed. No benchmarking plan. CAE tools list not complete. Allocated technical requirements partially traceable to customer needs.
0.5	Funding profiles not matched to customer needs and priorities. Contract/technical requirements have been addressed. Risk reduction plans include reliability measures of merit. Limited transmittal of customer needs to all personnel. Limited CAE tools defined and data bases are not integrated. Allocated technical requirements not traceable to customer needs.
0.7	Funding inadequate. Contract/technical requirements partially addressed. Very limited transmittal of customer needs to all personnel, very limited CAE tools.
0.9	Funding inadequate. Contract/technical requirements partially addressed. No evidence of transmittal of customer needs to personnel. Extremely limited use of CAE tools.

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Figure 4-12. Probability of Failure R₃ : Program Planning

CHAPTER 4 DEMONSTRATION AND VALIDATION PHASE

Probability of Failure	Criteria for Activity 4.1.4 To Determine Total Score, Sum Individual Scores and Divide by Four (4)
Expected Reliability Performance and Design Criteria	
0.1	Quantitative performance level estimates based on comparison to current customer experienced levels of performance of existing comparable equipment. Clear engineering rationale is provided for all expected improvements. Initial definition of design/application criteria complete. Lessons learned data is available (e.g., derating, environmental sensitivity). Expected operating environment including maintenance has been defined and traceable to customer mission description.
0.3	Quantitative performance level estimates based on comparison to current levels of performance of existing comparable equipment. One or more key performance parameters (e.g., life, fatigue, false alarm rate, etc.) is not identified. Clear engineering rationale is provided for all expected improvements. Initial definition of design/application criteria complete. Lessons learned data is available (e.g., derating, environmental sensitivity). Expected operating environment including maintenance has been defined and traceable to customer mission description.
0.5	Quantitative performance level estimates based on comparison to current levels of performance of existing comparable equipment. Key performance parameters missing and engineering rationale for expected improvements is weak. Initial definition of design/application criteria complete. Lessons learned data is available (e.g., derating, environmental sensitivity). Expected operating environment including maintenance has been defined and traceable to customer mission description.
0.7	Quantitative performance level estimates have limited reference to the performance levels of existing comparable equipment. Engineering rationale for expected improvements is weak. Limited definition of design/application criteria or lessons learned. Environment and use data not traceable to the mission description.
0.9	No definition of existing comparable equipment design/application criteria or lessons learned. Environment and use data not traceable to the mission description.
Critical Parameters or Functions	
0.1	Failure modes effects analysis or similar analyses have been conducted to identify critical parameters or functions. Fault detection and fault tolerance approaches systematically defined and related to critical parameters or functions. Variability of critical parameters have been estimated.
0.3	Failure modes effects analysis or similar analyses have been conducted to identify critical parameters or functions. Fault detection and fault tolerance approaches systematically defined and related to critical parameters or functions. Variability of critical parameters not estimated.
0.5	Failure modes effects analysis or similar analyses have been conducted to identify critical parameters or functions. Fault detection and fault tolerance approaches partially related to critical parameters or functions and not accomplished concurrently with failure modes effects analysis.
0.7	Failure modes effects analysis or similar analyses have been conducted to identify critical parameters or functions. No evidence of linkage between this analysis and the definition of fault detection and fault tolerance approaches.
0.9	Failure modes effects analysis or similar analyses not conducted or not linked to identifying critical parameters or functions, fault detection or fault tolerance approaches.

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Figure 4-13. Probability of Failure $P_{(4)}$: Reliability Analysis

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Probability of Failure	Criteria for Activity 4.1.4
Manufacturing Technology	
0.1	New manufacturing technologies and packaging concepts identified. Sources of variability have been identified.
0.3	New manufacturing technologies and packaging concepts identified. Variability not addressed.
0.5	New manufacturing technologies and packaging concepts only partially addressed.
0.7	New packaging concepts partially addressed. Limited description of manufacturing technologies.
0.9	Slight attention to new packaging concepts or manufacturing technologies.
Risk Reduction	
0.1	All risk areas clearly identified (unproven technologies, packaging concepts, or manufacturing technologies, major differences between customer needs and the justified performance of the equipment). Risk reduction includes reliability "measures of merit" to be tracked and tests and analyses conducted to establish reliability design rules.
0.3	All risk areas clearly identified (unproven technologies, packaging concepts, or manufacturing technologies, major differences between customer needs and the justified performance of the equipment). Risk reduction plans partially defined, missing one or more of the following: reliability "measures of merit" to be tracked and tests or analyses conducted to establish reliability design rules.
0.5	Risk areas not clearly identified (unproven technologies, packaging concepts, or manufacturing technologies, major differences between customer needs and the justified performance of the equipment). Risk reduction plans partially defined, missing one or more of the following: reliability "measures of merit" to be tracked and tests or analyses to be conducted to establish reliability design rules.
0.7	Few risk areas identified (unproven technologies, packaging concepts, or manufacturing technologies, major differences between customer needs and the justified performance of the equipment). Risk reduction plans incomplete.
0.9	No risk reduction plan.

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Figure 4-13 (Continued). Probability of Failure $P_{(4)}$: Reliability Analysis

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Probability of Failure	Criteria for Activity 4.1.5
0.1	Trade study effort comprehensive. Candidates selected based on conflicts in satisfying customer needs. Alternative technologies/designs evaluated in a manner similar to that done for the baseline. Trade study parameter weights are traceable to priorities identified during customer needs interpretation activity.
0.3	Trade study effort comprehensive. Candidates selection not completely traceable to conflicts in satisfying customer needs. Alternative technologies/designs evaluated in a manner similar to that done for the baseline. Trade study parameter weights are not completely traceable to priorities identified during customer needs interpretation activity.
0.5	Trade study effort limited. Candidate selection not completely justified. Alternative technologies/designs evaluation not as thorough as done for the baseline. Trade study parameter weights are not traceable to priorities identified during customer needs interpretation activity.
0.7	Trade study effort limited. Candidate selection not justified. Limited effort in evaluating alternative technologies/designs. Trade study parameter weights not related to customer priorities.
0.9	Trade study effort very limited. Results not credible.

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Figure 4-14. Probability of Failure $P_{(F)}$; Tradeoff Analyses

Consequences of Failure Score	Criteria for Mission Consequences (C₍₁₎)
0.1	Equipment is not significant to either mission completion or sortie generation capability.
0.3	Equipment provides moderate enhancement to mission success.
0.5	Equipment is significant to mission success or successive sorties will not be launched if equipment is inoperative.
0.7	Item is mission critical. Failure will always cause a mission abort.
0.9	Item is safety critical.

Consequences of Failure Score	Criteria for Cost Consequences (C₍₂₎)
0.1	Equipment is simple ($\leq 1,000$ parts).
0.3	Equipment is of minor complexity (1,000 – 2,000 parts).
0.5	Equipment is moderately complex (2,000 – 4,000 parts).
0.7	Equipment is significantly complex (4,000 – 6,000 parts).
0.9	Equipment is very complex ($> 6,000$ parts).

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Figure 4-15. Consequence of Failure Criteria

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These estimates must be based on a causal analysis of customer experience data on similar equipment with accompanying engineering rationale for the expected performance of the proposed system.

This method is clearly suitable for the level of detail available during the Demonstration and Validation Phase. The technique, if properly implemented, forces a focus on the customer's experience and environment and preferably is accomplished with customer involvement.

The process of identifying comparable existing equipment and establishing similarities/dissimilarities utilizes several of the Activities/Inputs/Outputs that are noted as critical in the risk factor evaluation. The following issues should be clearly identified for both the proposed and existing equipments:

- Technology Employed
- Complexity
- Packaging Techniques
- Design Margins
- Environments and Use

Customer use data must be the basis for establishing the performance of the existing equipment. The data must include measures of performance for all sources of faults (wearout, damage, "failures," BIT performance). The fundamental concern during the early stages of development must be problem identification and solution.

The final step in the process is the identification of design and technology rationale for improvements in current levels of reliability performance. If, by the end of the Demonstration and Validation Phase, less than seventy-five percent (75%) of the difference between current performance and customer needs is supported by credible engineering rationale, corrective action should be required as part of risk reduction plans.

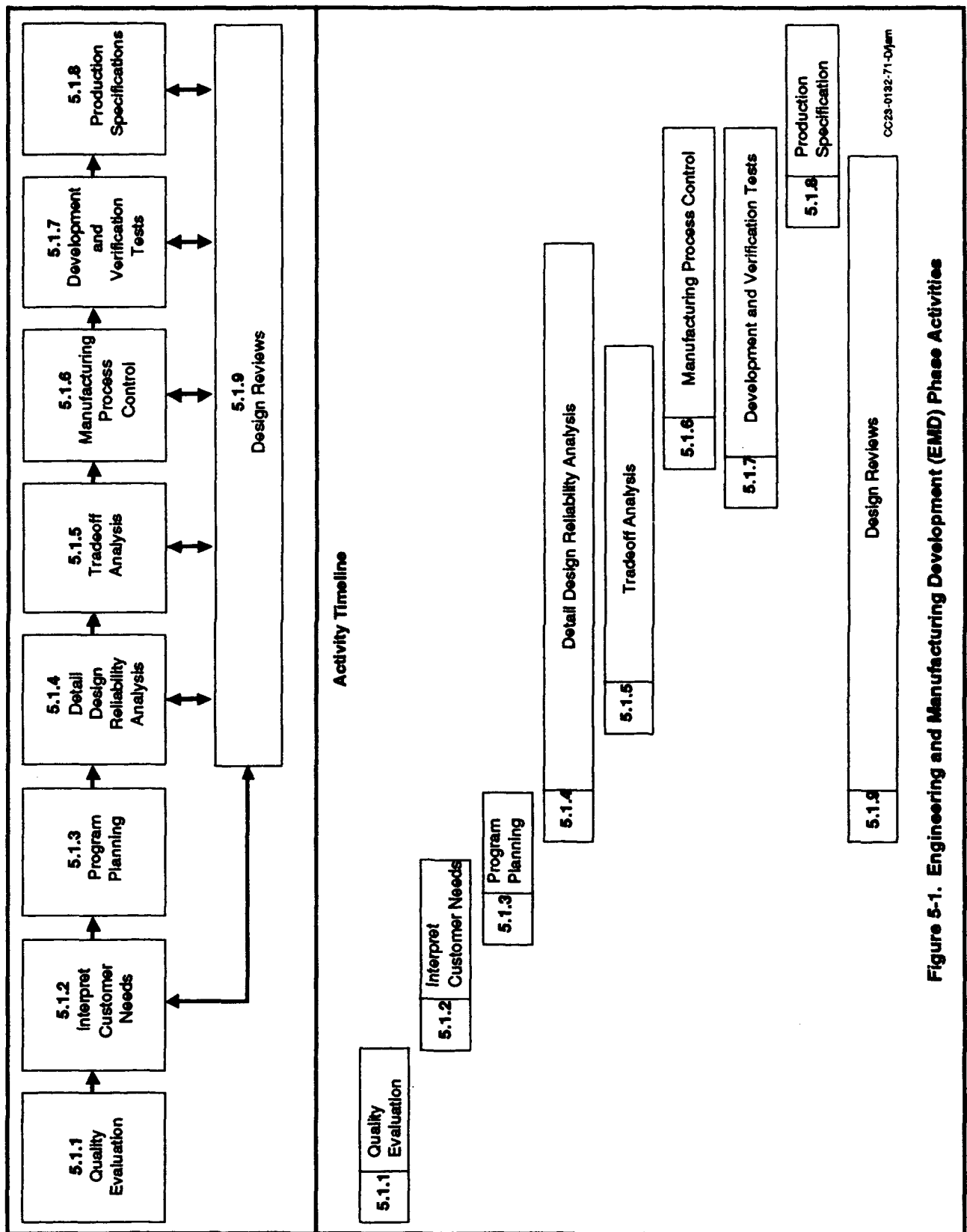


Figure 5-1. Engineering and Manufacturing Development (EMD) Phase Activities

5.0 INTRODUCTION

This chapter defines the activities that should take place during the Engineering and Manufacturing Development (EMD) phase. Figure 5-1 shows the essential activities of this phase and the general time phasing of these activities. Activity 5.1.1, Quality Evaluation, is a continuation of the enterprise-wide quality assessment initiated during the Concept Exploration phase. Activity 5.1.2, Interpretation of Customer Needs, is the application of Quality Function Deployment to systematically flowdown the customer's specification reliability requirements to the lowest levels of design and manufacturing. The balance of activities, 5.1.3 through 5.1.9, define detail design, manufacturing, and test activity focused on the requirements for defect elimination tasks. Specific descriptions of the phase activities and their inputs and outputs are contained in paragraphs 5.1.1 through 5.1.9. In the instances where any of these elements are common to previously described elements, reference is made to the appropriate paragraphs. Paragraph 5.2 defines the appropriate metrics required to provide the customer with assurance that the reliability process is in control.

DETAIL DESIGN AND MANUFACTURING

5.1 SUMMARY OF ACTIVITIES

There are three primary objectives of the EMD phase: 1) detail design implementation of specification requirements, 2) development of the manufacturing processes required to produce the product, and 3) verification, by both analyses and test, that the design and manufacturing processes comply with customer requirements.

THREE EMD OBJECTIVES

The reliability process described in paragraphs 5.1.1 through 5.1.9 support these objectives. Analytical verification of the capability of the detail design to achieve all reliability requirements is accomplished as described in paragraph 5.1.4. The identification of critical items is continued to parameters of the piece part level, and the corresponding manufacturing processes affecting these critical parameters are identified. The capability indices for the critical manufacturing processes are determined for the purpose of eliminating defects and controlling the

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manufacturing process. Development tests are conducted on risky design and manufacturing elements for the purpose of validating and refining analytical results and completing the characterization of materials and parts. Verification tests are conducted to confirm that the design and manufacturing processes are capable of satisfying all specification requirements.

There are seven essential reliability activities during the EMD phase. These are:

RELIABILITY PROCESS ACTIVITIES

- 1) Quality Evaluation
- 2) Interpretation of Customer Needs
- 3) Program Planning
- 4) Detail Design Reliability Analysis
- 5) Trade-Off Analyses
- 6) Manufacturing Process Control
- 7) Development and Verification Tests
- 8) Development of Production Specifications
- 9) Design Reviews

Several of these activities and their inputs and outputs share common attributes with similar items that should have taken place in both the Concept Exploration and Demonstration and Validation phases. The significant difference in the EMD versions of these activities' inputs and outputs is the level of detail required for the EMD phase.

The Quality Evaluation should represent a continuation of the drive to quantify the commitment of the entire enterprise to total quality. If these evaluations have been completed in prior acquisition phases, significant improvement should be seen by the EMD phase. In instances where this is an initial evaluation, the results should be used to establish a basis for specific improvements.

The interpretation of customer needs activity is also a continuation of the process begun during the Pre-Concept Exploration Phase. Firm specifications are available, and Quality Function Deployment techniques are used to confirm the customer priorities associated with reliability requirements and to flow the requirements to the lowest levels of design and manufacturing process detail.

Program planning uses activities, inputs, and outputs described in paragraphs 5.1.4 through 5.1.9 to define a tailored program plan. The plan is adjusted to reflect the technologies employed, the severity of the customer's environment, risk areas, and the customer's priorities attached to reliability issues. The planning activity also must develop test plans, supplier selection, and control plans, and continue the process of continuous improvement through benchmarking and training plans.

Activity 5.1.4, Detail Design Reliability Analysis, is one of the central defect prevention activities of the EMD phase. This activity uses detail design data, design rules, and an expanded definition of imposed stresses to create predictions of reliability, a description of the consequences of part parameter variability, a definition of critical parts characteristics and related manufacturing processes, and a set of design for manufacturing guidelines. Inputs from development testing are used to refine the analytical results.

Trade-off analyses continue to be used to balance the design. These analyses should focus on simplifying both the design and the manufacturing processes.

The Manufacturing Process Control activity is a second major activity directed at defect prevention. Its purpose is to define the capability indices of the manufacturing process and identify process control factors and the levels for these factors associated with minimum variance. The analysis is driven by the definition of critical parts and parameters and an experience data base that describes the current capabilities of the manufacturing process.

Development and Verification testing remains an important part of the EMD reliability process. Both development and verification testing rely heavily on aggressive and comprehensive failure reporting analyses and corrective action system. Testing must be conducted using expected customer environments representing realistic imposed stresses. All reliability attributes must be verified, including life, durability, BIT performance, and defect rates. Included in this activity is the development of appropriate Environmental Stress

STRESS ANALYSIS

MANUFACTURING PROCESS CONTROL

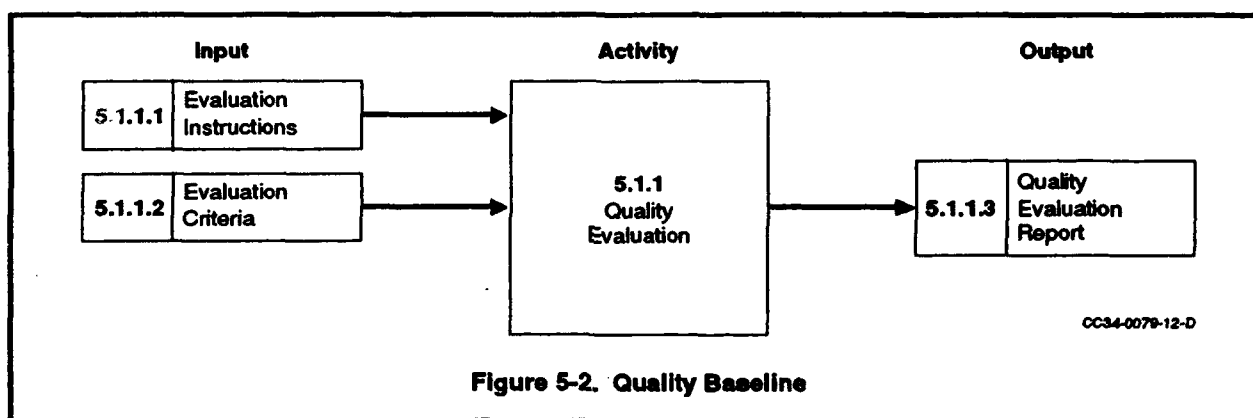
TESTING

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Screening (ESS) programs for production equipment.

Production specifications are developed in activity 5.1.8. These combine the results of the analytical activities 5.1.4 and 5.1.6 with the test results of activity 5.1.7 to create production performance specifications and their related manufacturing specifications.

Design Reviews (Activity 5.1.9) continue to serve as the vehicles for applying discipline and a focus on customer requirements to the reliability process. Design reviews must have well defined entry and exit criteria and include a definition of applicable customer requirements.



5.1.1 ACTIVITY - QUALITY EVALUATION

This pre-contract award activity is substantially the same as defined in paragraphs 3.1.1 and 4.1.1. This evaluation quantitatively measures the supplier's company-wide commitment to quality. If these evaluations have been previously conducted, substantial improvements in a supplier's score should be expected and demanded. In addition, suppliers should be expected to demonstrate that similar evaluations are conducted for subcontractors and suppliers with results used in source selection.

COMMITMENT TO QUALITY

In the conduct of this activity, it is expected that each major functional division (e.g., Manufacturing, Engineering, etc.) within an organization will assess their activities in light of the criteria contained in

Volume II of this guide. At the organization level, the inputs from the functional level are to be aggregated and compiled into a single report for submittal to the customer.

5.1.1.1 INPUT - EVALUATION INSTRUCTIONS

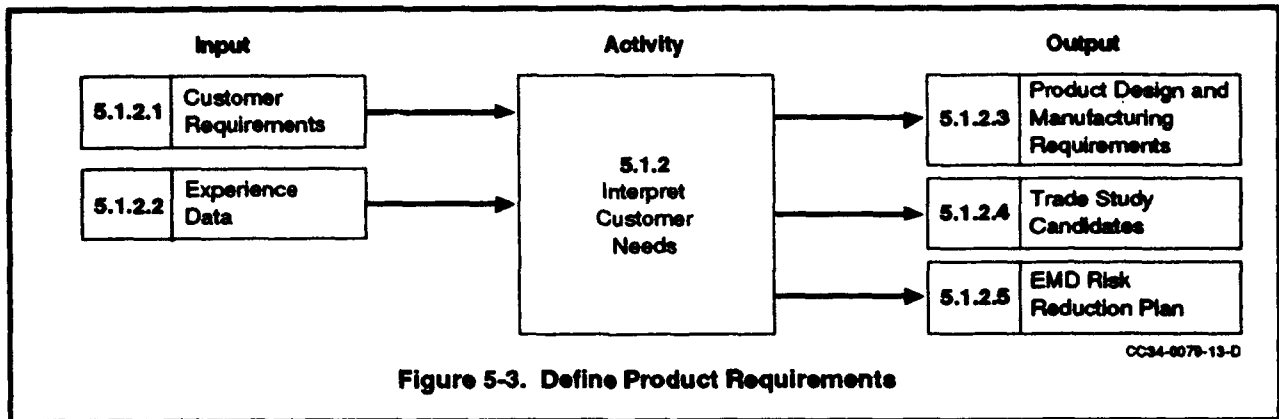
The customer includes in his request for proposal a complete set of instructions for conducting the quality evaluation. These include directions in Executive Summaries, detail instructions in the Instructions to Offerors (Evaluation Criteria, Reporting Requirements), and the relationship of the evaluation to source selection award factors. An example of instructions is provided following paragraph 3.1.1.3. Report format requirements for a Malcolm Baldrige Award Application are recommended.

5.1.1.2 INPUT - EVALUATION CRITERIA

The customer supplies the criteria to be used for the quality evaluation. Volume II of this guide provides a set of recommended criteria patterned after the Malcolm Baldrige Award Criteria. Suggested scoring is also provided.

5.1.1.3 OUTPUT - QUALITY EVALUATION REPORT

The supplier provides a quality evaluation report in accordance with customer reporting requirements. This report is to be used by both the customer and the supplier. The customer will score the results and use this in source selection. The supplier should similarly score his results and use this evaluation to define weaknesses and plan the required improvements.



5.1.2 ACTIVITY - INTERPRET CUSTOMER NEEDS

During the EMD phase, firm performance and verification specifications are available. However, a systematic and comprehensive evaluation of customer needs and priorities is still a mandatory activity, with Quality Function Deployment QFD as the recommended tool. Customer requirements and priorities must be translated into product technical requirements and flowed down to the component and manufacturing process level using QFD techniques. Direct interchange between customer and supplier are required for the proper implementation of this activity. There will be several iterations of the QFD as the requirements flow from the system to subsystem to assembly to lower levels of design and manufacturing detail.

REQUIREMENTS FLOWDOWN

5.1.2.1 INPUT - CUSTOMER REQUIREMENTS

Customer needs and objectives should be explicitly defined in the contract technical documentation, such as Statements of Work and specifications. However, all contract documentation must be reviewed for descriptions of customer requirements. Additionally, the supplier must plan for early, direct, and frequent customer contact to validate and refine the documented needs. These contacts must focus on a multidisciplinary definition of customer needs.

CUSTOMER CONTACT

5.1.2.2 INPUT - EXPERIENCE DATA

The supplier must ensure that customer documented requirements are subject to review by experts in all

areas so that all requirements are identified, with correct priorities, properly translated into design and manufacturing requirements, and flowed down. The supplier must also ensure that QFDs completed during the prior acquisition phase are available for application to the EMD contract. The experience data base should include a thorough and documented understanding of good and bad customer experience with current products as a preferred method for aiding in the identification of requirements.

5.1.2.3 OUTPUT - PRODUCT DESIGN AND MANUFACTURING REQUIREMENTS

The supplier must provide a definition of specific technical attributes and parameters that will satisfy all customer requirements. This definition includes quantitative values for each of the attributes and parameters. The customer needs must be given weighting factors which represent their priority levels. These factors will be used to define the relative importance of each of the technical attributes and parameters. It is critical that the interaction between reliability technical attributes and the other technical attributes be identified for the purpose of identifying trade study candidates.

The technical requirements should be flowed down by QFD procedures to the component and manufacturing process level of indenture. This flowdown will usually require several iterations during the EMD phase. The flowdown must maintain traceability to customer requirements and, more importantly, the customer's priorities for these requirements. In order to retain focus on an integrated set of reliability requirements, it is recommended that all the product reliability attributes be grouped together during the QFD development. These attributes include service life, durability, defect rates, and BIT performance requirements (e.g., False Alarm rate, Fault Detection Probability, Could Not Duplicate (CND) rate, etc.).

COMPREHENSIVE RELIABILITY REQUIREMENTS

5.1.2.4 OUTPUT - TRADE STUDY CANDIDATES

The supplier must identify candidates for trade studies to be performed during the EMD Phase. The Quality Function Deployment techniques can assist in defining these candidates by evaluating the

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interactions among technical attributes. Trade-off analyses are used to optimize a technical attribute or parameter that interacts with other technical attributes or parameters. For example, radar detection range is a function of power, weight, volume, receiver sensitivity, reliability, and cost. Trade studies are also used to select between alternative design and manufacturing approaches.

5.1.2.5 OUTPUT - EMD RISK REDUCTION PLAN

The baseline reliability risk reduction plan is that prepared for Output 4.1.6.6 at the conclusion of the Demonstration and Validation phase. The risk issues addressed here are those not satisfactorily closed during the Demonstration and Validation phase or those that are determined by the Control and Audit requirements of paragraph 4.2. If a supplier has not participated in the Demonstration and Validation phase, an initial risk reduction plan must be prepared. The plan must include the criteria for selection of risk issues. The output of the QFD should be used to establish a list of technical requirements rank-ordered based on customer priorities. This list then serves as a baseline for establishing priorities for the risk issues. The risk reduction plan must describe the criteria used to select the risk issues. Criteria can consider elements such as new technology parts and materials, prior negative reliability history, life limited items, parts and materials which are uncharacterized relative to the expected use environments or manufacturing technologies whose capability indices are low or have not been established. The plan must also describe the analyses and tests required to establish either defect prevention design margins or manufacturing process controls. This includes the identification of measures of merit that will be tracked and thresholds that identify success. Finally, the plan must identify fall back positions that will be implemented if risks cannot be resolved and the milestones at which those decisions will be made.

**CONTINUOUS RISK
REDUCTION**

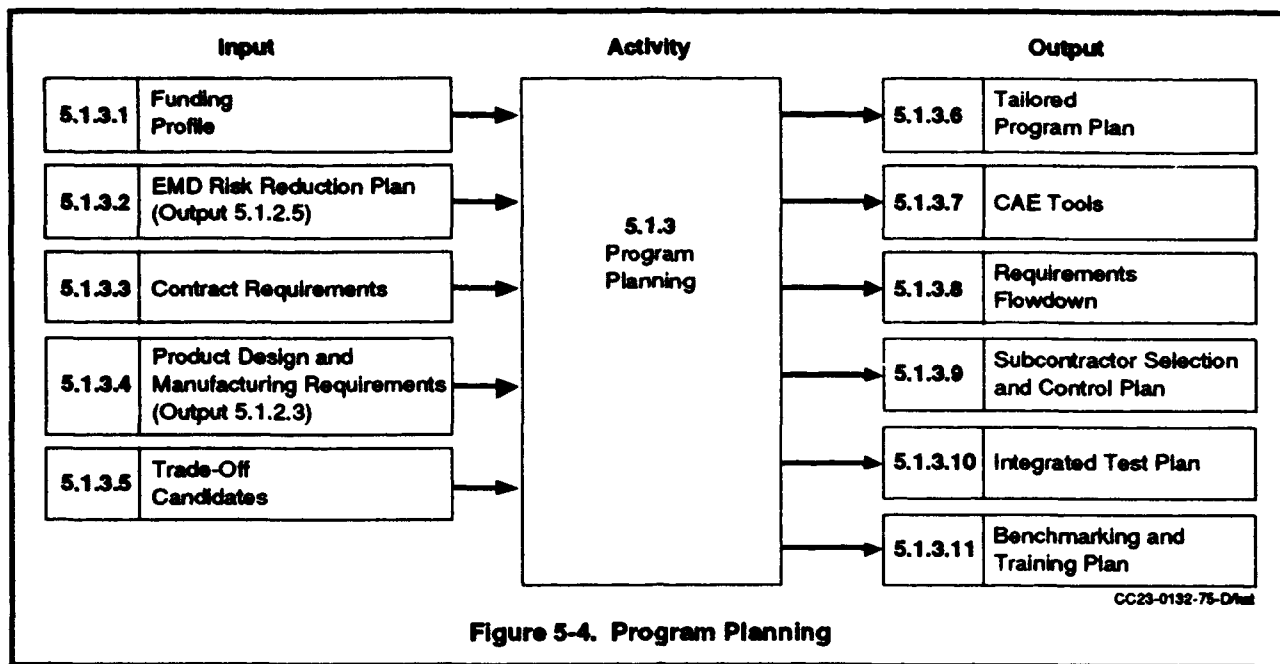


Figure 5-4. Program Planning

5.1.3 ACTIVITY - PROGRAM PLANNING

Much of this activity is substantially the same as described in paragraphs 3.1.3 and 4.1.3. The inputs and outputs of the remaining phase activities (5.1.4 through 5.1.9) serve to identify the baseline tasks to be accomplished during the EMD phase. The tailoring is driven by the inputs to this activity which include customer priorities, trade-off candidates, EMD risk reduction plans, and contract requirements. The resultant plans must identify specific responsibilities for inputs and outputs, schedules for these tasks, and data required. The plan should be coauthored by all the functional specialties with principal involvement in defect prevention activities (Figure 1-19).

MULTIDISCIPLINE PLANNING

5.1.3.1 INPUT - FUNDING PROFILES

The allocation of funds must be interactive, flexible, and demonstrably shown to be related to the customer priorities identified as a result of Activity 5.1.2. The description of this input is otherwise the same as provided in paragraphs 3.1.3.1 and 4.1.3.1.

5.1.3.2 INPUT - EMD RISK REDUCTION PLAN

Output 5.1.2.5 serves as an input to the Planning Activity. This input establishes the reliability risk reduction analyses and test tasks including parts and materials environmental characterization test requirements.

5.1.3.3 INPUT - CONTRACT REQUIREMENTS

The description of this input is the same as provided in paragraph 3.1.3.2

5.1.3.4 INPUT - PRODUCT DESIGN AND MANUFACTURING REQUIREMENTS

Output 5.1.2.3 serves as an input to the Planning Activity. Quantified and prioritized reliability requirements establish the focus and direction for program planning outputs.

5.1.3.5 INPUT - TRADE STUDY CANDIDATES

DEFINE THE TRADE-OFF

Output 5.1.2.4 serves as an input to the Program Planning Activity. Additional trade study candidates may have been developed as a result of risk reduction plans, customer requests, or supplier experience. The candidate list should define the specific measures of merit being used to evaluate trade study alternatives. Any weighting factors applied to the trade study measures of merit should be shown in the candidate list and should be traceable to customer priorities. Reliability attributes and/or parameters should be considered for all trade studies as measures of merit.

5.1.3.6 OUTPUT - TAILORED PROGRAM PLAN

The supplier should prepare a program plan for the EMD phase using the activities, inputs, and outputs of paragraph 5.1.4 through 5.1.9 as the baseline for the tasks to be performed. Plans must be tailored based on the complexity of the equipment, the expected customer use environment, and contract requirements. The task descriptions may use organization-wide process descriptions if they are comprehensive and cover the intent of the activities, inputs, and outputs described in paragraphs 5.1.4 through 5.1.9. Plans must identify task acceptance (completion) criteria, responsibility for all tasks, and

schedules for both task input and output products.

5.1.3.7 OUTPUT - CAE TOOLS

The description of this output is the same as provided in paragraphs 3.1.3.6 and 4.1.3.11.

5.1.3.8 OUTPUT - REQUIREMENTS FLOWDOWN

If not accomplished as part of Activity 5.1.2, the quantitative and qualitative (e.g., fault tolerance) requirements identified in Output 5.1.2.3 must be allocated to all necessary levels of indenture and to all procured assemblies. The allocation process must retain the definition of customer priorities among reliability requirements and between reliability requirements and other design and manufacturing requirements. The allocation process must account for the historical user experience with like and similar equipment.

5.1.3.9 OUTPUT - SUBCONTRACTOR SELECTION AND CONTROL PLAN

This plan describes the supplier and subcontractor actions needed to ensure that all EMD phase requirements are assigned to suppliers and subcontractors. This plan includes a definition of supplier or subcontractor selection criteria including the application of the Quality Evaluation activity of paragraph 5.1.1. This task may be accomplished as part of any existing enterprise-wide supplier certification program. The plan should specifically address the selection and control of high quality parts and materials with a focus on determining the process control exercised by parts and materials suppliers. The plan should also describe the procedures for ensuring the timely conduct of a Quality Function Deployment between the contractor and his suppliers or subcontractors.

CONTROL SUPPLIERS

5.1.3.10 OUTPUT - INTEGRATED TEST PLAN

This output is a comprehensive definition of all reliability related development and verification testing and the failure reporting analyses and corrective action system that will be employed during these tests. The purpose of the test plan is to ensure that all reliability attributes are validated, that testing is not duplicated, that the test schedule and resources are adequate, and that test faults are

PERFORMANCE VERIFICATION

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corrected by design or manufacturing process changes. The testing that must be defined includes:

- Risk reduction tests, such as parts and materials properties characterization tests, parameter variability determination, subassembly performance tests, and manufacturing process development tests.
- Performance verification testing at environmental extremes.
- Life and durability verification testing.
- Reliability growth or verification testing.
- Built-In-Test development and verification test.
- Environmental Stress Screening (ESS) and equipment acceptance tests.

Each test from the above categories must be identified, scheduled, and have the following issues addressed:

- Definition of test objectives and the measurable criteria for success.
- Test sample requirements.
- Environmental and operating conditions.
- Test duration and test facilities required.
- Responsibility for detail test procedures and reporting.
- Failure reporting analysis and corrective action requirements, including responsibility for all elements of this process and the corrective action close-out status tracking system.

Several key issues must be addressed in the test plan. The applied environments must represent customer use environments (thermal, electrical, mechanical) and customer operation including maintenance. Life testing must be long enough and of sufficient severity to verify fatigue resistance and

REALISTIC TESTING

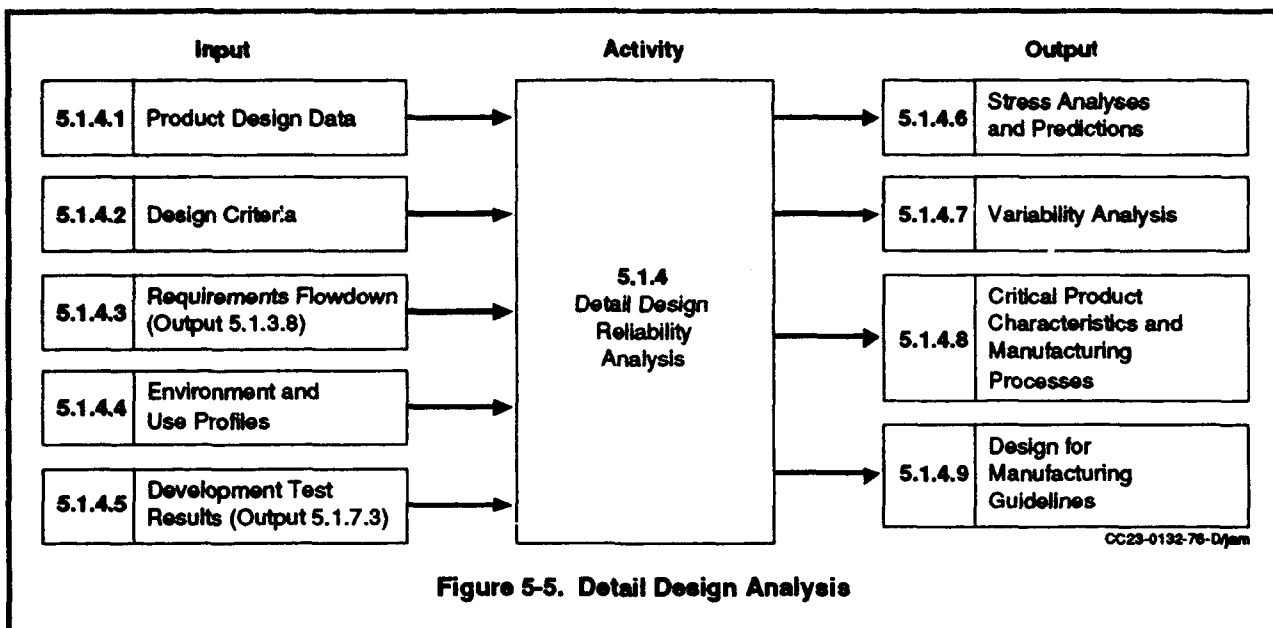
durability. All failures must be subjected to a thorough causal analysis, such that broadly applicable design and manufacturing process changes can be implemented.

5.1.3.11 OUTPUT - BENCHMARKING AND TRAINING PLAN

The benchmarking section of this plan should address any weaknesses in the supplier's reliability processes uncovered by the quality evaluation of paragraph 5.1.1. The plan should address the benchmarking issues described in paragraph 1.1.2 and Figure 1-7. The benchmarking should be directed at improving the reliability processes directly affecting the EMD phase. Candidates for consideration, in addition to those listed in paragraph 4.1.3.10, are:

- Design/Electronic Circuit Simulation Techniques
- Design and Manufacturing Variability Control
- Physics of Failure Analyses.

The training position of the plan must address the capability of program personnel to accomplish the activities, inputs, and outputs defined in paragraphs 5.1.4 through 5.1.9 (e.g., Design for Manufacturing, Variability Control, etc.), and identify training needs and the resources to satisfy those needs. The training plan must also describe the methods for disseminating information relative to reliability requirements to all affected program personnel.



5.1.4 ACTIVITY - DETAIL DESIGN RELIABILITY ANALYSIS

This is one of the key activities of the EMD phase. There are four principal subactivities. The definition of design rules, begun during the Demonstration and Validation phase, is continued and refined based on detail stress analyses and results from development tests. The stress analyses and predictions also yield quantitative estimates of reliability attributes (life and defect rate including BIT and manufacturing defects). Critical product characteristics are defined down to the component and parameter levels. These in turn drive variability control analyses and the identification of critical manufacturing processes. Lastly, design for manufacturing guidelines are defined in order to simplify both the design and the manufacturing process. Much of this activity builds on the results of the Demonstration and Validation Activity, 4.1.4. If the equipment being developed has not been subjected to a formal Demonstration and Validation phase, several of the Inputs and Outputs described in Chapter 4 must be accomplished as part of this phase.

5.1.4.1 INPUT - PRODUCT DESIGN DATA

Complete electrical, mechanical, and thermal engineering design descriptions are required for this

analysis. These data include:

- Function block diagrams, functional descriptions, circuit schematics, circuit board layout drawings, packaging and assembly drawings, parts lists, parts performance data, thermal models, and properties related to dynamic analyses of the equipment.
- Detail parts and material characterization data (response to environmental stress).
- Parts and materials parameters variability data. These data are vital to variability control. The distribution of critical parts and materials parameters must be obtained from suppliers/manufacturers or by test. This issue is also an important topic for inclusion in parts/materials specifications and control plans.
- Parts and Materials quality control parameters, such as defect per million requirements, screening and test requirements, and manufacturing process control elements.
- Manufacturing and Assembly drawings and the initial description of all manufacturing process steps.

If the equipment has not been subject to a Demonstration and Validation phase, the data described in the last item of paragraph 4.1.4.1 is also applicable.

5.1.4.2 INPUT - DESIGN CRITERIA

This input represents a continuing refinement of the data described in paragraph 4.1.4.7, Design Criteria Report. These data are a comprehensive set of design rules including parts and materials application guides, lessons learned, derating requirements, thermal design guides, BIT/testability design guides, and manufacturing and assembly design rules. Special attention should be paid to any new or untried technologies and components having a poor record of reliability performance.

DEFECT PREVENTION

5.1.4.3 INPUT - REQUIREMENTS FLOWDOWN

Output 5.1.3.8 serves as an input to this activity. These data are the customer quantitative reliability requirements.

5.1.4.4 INPUT - ENVIRONMENT AND USE PROFILES

This input is a refinement of the data described in paragraph 4.1.4.4. The supplier is responsible for defining local life cycle stress profiles that result from external environments, including power and cooling conditions, and equipment operation during all use including all forms of maintenance. The data must show both maximum expected stress levels and durations and total life cycle exposure profiles based on service life, basing locations, and types/durations of missions and other operations/use. All damaging environments should be defined in the manner described above.

5.1.4.5 INPUT - DEVELOPMENT TEST RESULTS

Development tests include risk reduction tests, such as parts and materials characterization tests and element/subassembly performance verification tests. These tests are identified in paragraphs 5.1.2.5 and 5.1.3.10. All development testing should include data from which conclusions regarding reliability can be drawn. A key element in development test results is a comprehensive failure reporting analyses and corrective action system.

TEST RESULTS

5.1.4.6 OUTPUT - STRESS ANALYSIS AND PREDICTIONS

This output represents a complete evaluation of imposed stresses and the capability of the design to withstand these stresses. The analysis consists of the following elements:

- Electrical stress margins, including performance under transient conditions.
- Mechanical stress margins to include vibration, g-loading, and thermal stresses. Analyses should include solder joint fatigue and other deterioration mechanisms.

PHYSICS OF FAILURE ANALYSIS

- Testability analyses proving the accuracy of BIT design.
- Quantitative estimates of maintenance frequency to include both unscheduled maintenance resulting from all causes and any proposed scheduled maintenance. These predictions must exceed customer requirements and be based on compliance with the design criteria of paragraph 5.1.4.2. At times MIL-HDBK-217 predictions may not be complete and may require supplements such as physics of failure and fatigue analysis. Prediction results should also be compared to customer experience with similar equipment and differences justified by the stress analyses cited above, the design criteria defined in paragraph 5.1.4.2, or the results of the development test defined in paragraph 5.1.4.5. Predictions should be iterated throughout the EMD phase. Improvements over initial estimates must be shown and must be based on design simplification, increased stress margins (exclusive of improved cooling), or changes in the implementation of the BIT design.

5.1.4.7 OUTPUT - VARIABILITY ANALYSIS

In addition to estimates of maintenance frequency, a comprehensive variability analysis and control program should be implemented for both the design and manufacturing processes. The program should be based on the outputs of paragraph 5.1.4.8 which defines critical product characteristics and the corresponding critical manufacturing processes. Parametric and geometric variability should be established from test data and should be included as a parts and materials control requirement. The objective of the variability analyses should be the demonstration that the nominal values of critical parameters are six sigma from specification limits. The variability analyses, including worst case evaluations should be used to verify the margins and sensitivity of the equipment BIT design. Variability should also be included in stress and fatigue analyses to ensure the adequacy and accuracy of these analyses. The variability analyses should make maximum use of Computer Aided Engineering (CAE) tools and computer

CONTROL VARIANCE

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simulation to evaluate the consequences of parts and materials variability. This output should define the tools that will be employed and the specific methodology, inputs, and assumptions necessary for the operation of these tools.

5.1.4.8 OUTPUT - CRITICAL PRODUCT CHARACTERISTICS AND MANUFACTURING PROCESSES

CRITICAL ITEMS

This output is the primary driving force behind three key issues: 1) variability control, BIT design, and fault tolerance design. There are three sources for the definition of critical product characteristics: 1) the QFD interpretation of customer requirements, 2) Failure Modes Effects and Criticality Analyses, and 3) engineering experience. Critical functions and critical signals are initially identified and, as the design is detailed, critical assemblies, parts, and parameters of the design are identified by the three methods described above. These evaluations must take place as the design is being developed.

The design of BIT functions, fault tolerance features, and the identification of critical items for variability control must be shown to be traceable to the analyses defined by this output. These results must also be used to identify the manufacturing processes affecting the critical product characteristics in order to establish priorities for the control of manufacturing processes. Customer inputs are necessary to properly define all critical product characteristics.

5.1.4.9 OUTPUT - DESIGN FOR MANUFACTURING GUIDELINES

A central element is the achievement of both quantitative reliability requirements and control of variability in an explicit set of design for manufacturing guidelines. These should emphasize simplicity, commonality, and the use of standardized manufacturing processes. These guides must also define any special handling or processing constraints.

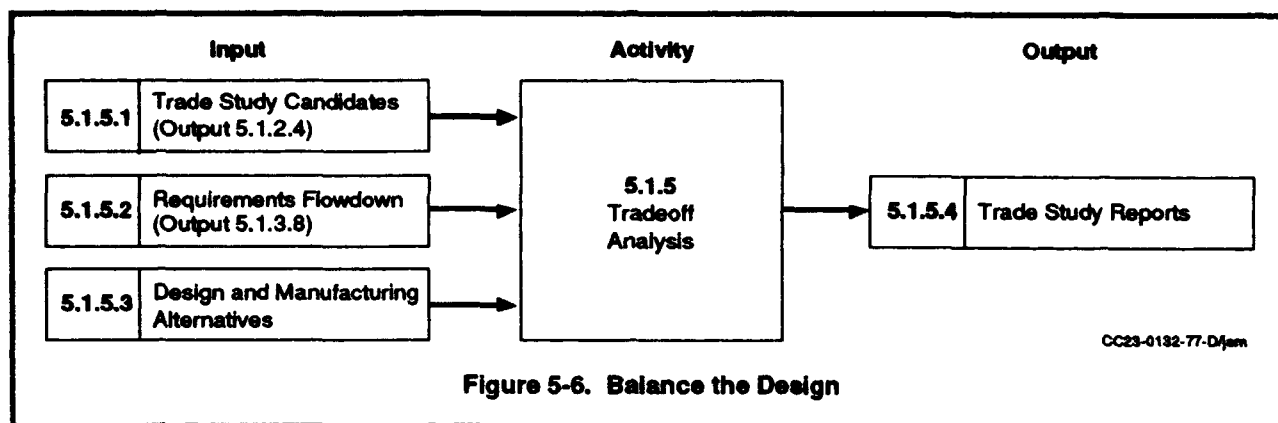


Figure 5-6. Balance the Design

5.1.5 ACTIVITY - TRADE-OFF ANALYSIS

This activity is substantially the same as defined in paragraphs 3.1.5 and 4.1.5. If equipment has not been the subject of concept exploration or demonstration and validation phases, the initial trade-off analyses must be directed at the selection of technologies to be employed and the refinement of system level parameters. The remainder of the trade-off analyses are directed at balancing detail design implementation issues with emphasis on the selection of specific parts, materials, and manufacturing processes.

5.1.5.1 INPUT TRADE STUDY CANDIDATES

Output 5.1.2.4 serves as an input to the trade study activity. This input is a comprehensive list of the trade studies to be conducted, the objectives of these trades, the parameters to be evaluated, and the responsibilities for the conduct of these analyses.

5.1.5.2 INPUT - REQUIREMENTS FLOWDOWN

Output 5.1.3.8 serves as an input to the trade-off analysis activity. This output defines the quantitative customer reliability requirements that must be met.

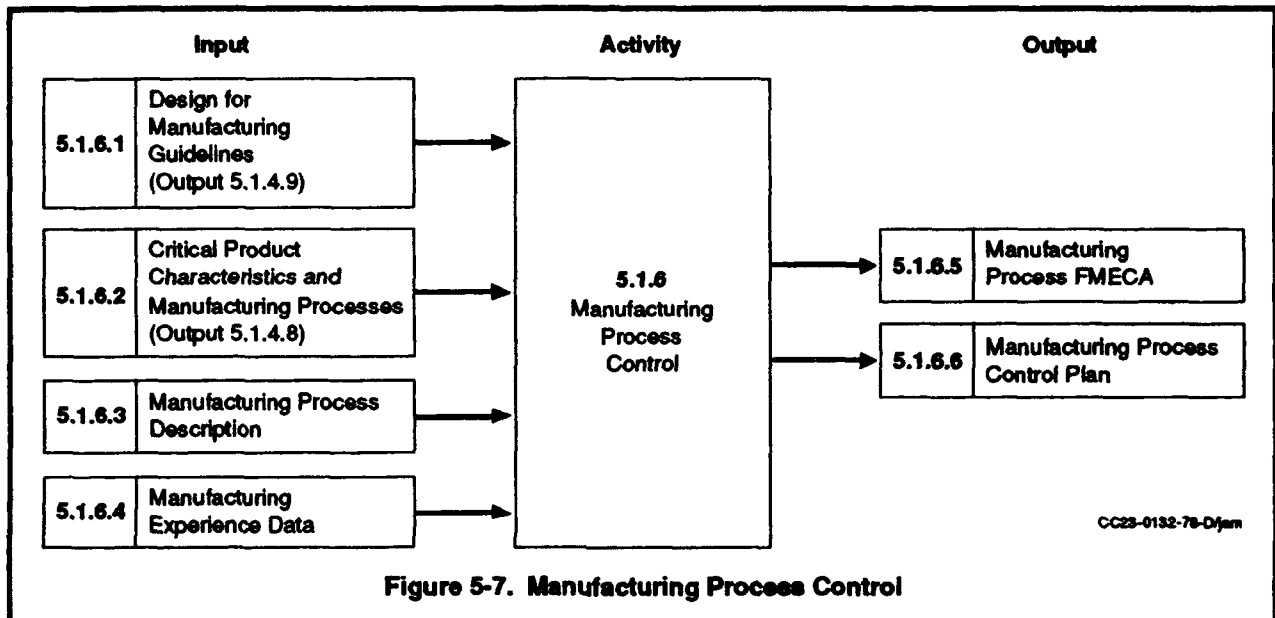
5.1.5.3 INPUT - DESIGN AND MANUFACTURING ALTERNATIVES

Each alternative design implementation or manufacturing process for each trade-off analysis should be described as defined in paragraph

5.1.4.1.

5.1.5.4 OUTPUT - TRADE STUDY REPORTS

The description of this output is the same as contained in paragraphs 4.1.5.4 and 3.1.5.4. Trade study results are subject to customer review and approval.



5.1.6 ACTIVITY - MANUFACTURING PROCESS CONTROL

This activity defines the requirements necessary for the control of the manufacturing process and the prevention of defects introduced by manufacturing. This is also the second element of variability control. Design activity focuses on the relationship between parameter variance and allowable tolerances; this activity defines the steps necessary to achieve the required variance limits. The activity includes the flow-through of requirements to parts and materials suppliers. The outputs of this activity define manufacturing process capability indices, the factors which control the manufacturing process results, and the control limits imposed on these variables.

CONTROL THE MANUFACTURING PROCESS

**5.1.6.1 INPUT - DESIGN FOR
MANUFACTURING GUIDELINES**

Output 5.1.4.9 serves as an input to this activity. These guidelines must be iteratively developed with design engineering and must reflect the capabilities and limitations of the manufacturing process.

**5.1.6.2 INPUT - CRITICAL PRODUCT
CHARACTERISTICS AND MANUFACTURING
PROCESSES**

Output 5.1.4.8 serves as an input to this activity. The control of manufacturing processes must be clearly linked to, and priorities established by, the definition of critical product characteristics.

**5.1.6.3 INPUT - MANUFACTURING
PROCESS DESCRIPTION**

This input is a complete description of the manufacturing process and the capability index associated with each step in the process. These descriptions must be provided for those processes, including suppliers processes, which affect critical product characteristics. This input should highlight process steps for which the capability index has not been defined.

**5.1.6.4 INPUT - MANUFACTURING
EXPERIENCE DATA**

This input is the manufacturing process equivalent to the design input described in paragraph 5.1.4.2. The data includes defect rates for existing manufacturing process steps, corrective actions to be implemented as part of the EMD phase, lessons learned for inclusion in design for manufacturing guidelines, and process control variables and control limits for existing manufacturing process steps.

**5.1.6.5 OUTPUT - MANUFACTURING
PROCESS FMECA**

A failure modes effects and criticality analysis should be conducted on the equipment required to implement the most important manufacturing processing steps. These analyses, or similar analyses, represent a continuing progression in the identification of critical elements. These analyses can be used to ensure the reliability of manufacturing equipment, define fault indication and monitoring requirements, and provide the basis for

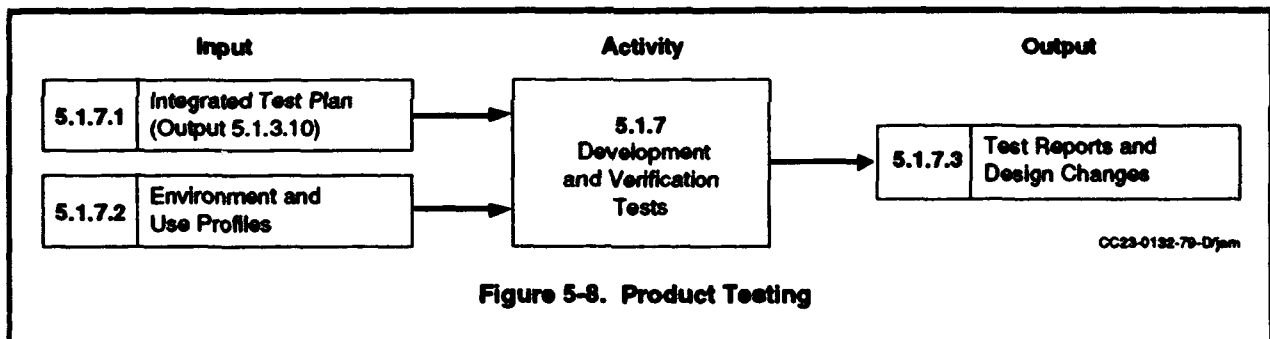
**MANUFACTURING
EQUIPMENT
CRITICALITY**

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maintenance practices and manufacturing workaround plans.

5.1.6.6 OUTPUT - MANUFACTURING PROCESS CONTROL PLAN

This plan applies to all critical manufacturing processes. It defines the capability indices for these processes, the control variables for these processes and their limits, and the description of process control elements including Statistical Process Control (SPC) implementation requirements. The plan should define the methods, tests, and analyses that will be implemented for manufacturing process steps that are not completely characterized. The plan should also define the criteria and capability for conducting Design of Experiments for the purpose of reducing process variability. This plan should include flow through requirements to ensure the control of purchased parts and materials.



5.1.7 ACTIVITY - DEVELOPMENT AND VERIFICATION TESTS

This activity includes the complete spectrum of tests required to develop and verify product performance requirements. All testing should be expected to yield data required for defect prevention or elimination.

5.1.7.1 INPUT - INTEGRATED TEST PLAN

Output 5.1.3.10 serves as an input to this activity. This input defines all tests, test conditions, test objectives, and failure reporting analyses and corrective action system (FRACAS) requirements. Testing should include performance under expected environmental extremes, life testing for fatigue and wearout mechanisms using representative models of

COMPREHENSIVE TESTING

the operational equipment, long term mission environment tests to validate requirements, such as Mean Time Between Maintenance, and all parts, materials, and subassembly development tests. A comprehensive FRACAS that results in design and manufacturing process changes is an essential element of the test plan.

5.1.7.2 INPUT - ENVIRONMENT AND USE PROFILES

Input 5.1.4.4 also serves as an input to this activity. All testing, especially life and long term performance testing, should be conducted under conditions derived from, and traceable to, customer use.

5.1.7.3 OUTPUT - TEST REPORTS AND DESIGN CHANGES

All test results and all corrective actions resulting from these tests should be reported for customer approval. The key to this output is the definition of the procedures for ensuring that changes are incorporated in the equipment design or manufacturing processes and the criteria for verifying the effectiveness of these changes.

This output also defines the stress screening that will be applied to production equipment. This includes both subassembly and system level screening. The stress levels and duration of these tests should be based on the results of development test and long term performance tests. A sufficient body of knowledge exists in the literature to fully and adequately define these tests.

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ENGINEERING AND MANUFACTURING DEVELOPMENT PHASE

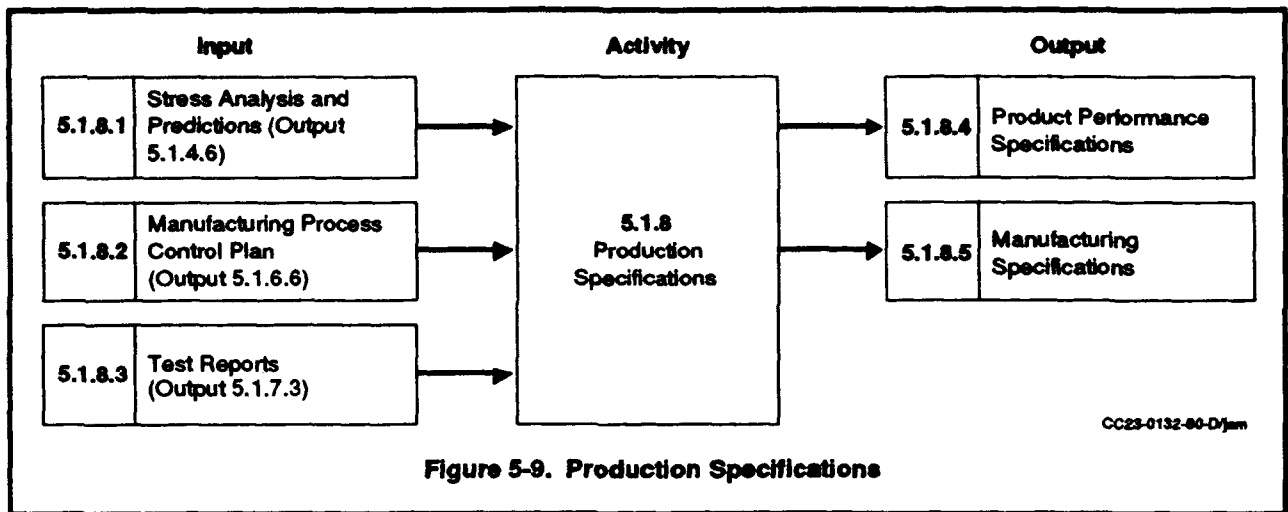


Figure 5-9. Production Specifications

5.1.8 ACTIVITY - PRODUCTION SPECIFICATIONS

Production specifications that include both product performance and verification and manufacturing requirements are developed by this activity. This activity includes the development of specifications for procured subassemblies and equipment.

5.1.8.1 INPUT - STRESS ANALYSES AND PREDICTIONS

Output 5.1.4.6 serves as an input to this activity. Quantitative reliability requirements for all production specifications are developed using this output. This output also provides the data necessary for the development of production specification derating and design margin requirements.

5.1.8.2 INPUT - MANUFACTURING PROCESS CONTROL PLAN

Output 5.1.6.6 serves as an input to this activity. This output provides the baseline for creating manufacturing process specifications, identifying information, such as SPC control variables and control limits, and in-process inspection requirements.

5.1.8.3 INPUT - TEST REPORTS

Output 5.1.7.3 serves as an input to the production specification activity. This output defines the

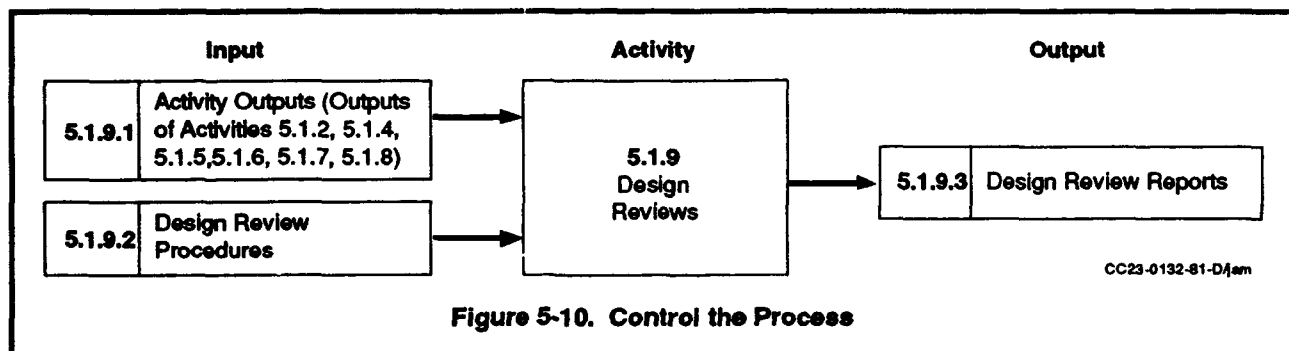
baseline production verification and screening test requirements for subassemblies and systems.

5.1.8.4 OUTPUT - PRODUCT PERFORMANCE SPECIFICATIONS

This output is the complete set of DoD customer specifications and all specifications for procured hardware. The specifications contain all quantitative and qualitative reliability requirements. These requirements include such parameters as service life, Mean Time Between Maintenance (scheduled and unscheduled) and BIT false alarm rates. The specifications include such qualitative requirements as environmental descriptions, design margins, and parameter variability limits. All test and performance verification requirements must be defined in the production specifications.

5.1.8.5 OUTPUT - MANUFACTURING SPECIFICATIONS

This output is the specification of the manufacturing process. all process steps are identified and process specifications defined. These include definition of control variables, limits for those variables, measurement techniques, and the definition of SPC requirements. These manufacturing specifications should also identify all inspection, test, reporting, and corrective action procedures applied to the manufacturing process.



5.1.9 ACTIVITY - DESIGN REVIEWS

This activity is substantially the same as that defined in paragraphs 3.1.7 and 4.1.7. Reviews are the method for bringing discipline to the reliability process and maintaining a focus on customer requirements. All reviews should have clearly

AUDIT THE DESIGN

CHAPTER 5 ENGINEERING AND MANUFACTURING DEVELOPMENT PHASE

defined entry and exist criteria, an explicit definition of applicable customer requirements, and a description of how these requirements are being satisfied. The review process should also have a description of responsibilities for closure of action items and implementation of corrective action and changes.

5.1.9.1 INPUT - ACTIVITY OUTPUTS

The outputs of Activities 5.1.2, 5.1.4, 5.1.5, 5.1.6, 5.1.7, and 5.1.8 define all the reliability issues that should be subject to internal and customer review. Selected critical inputs (e.g., Environment and Use Description) to these activities are also proper issues for design reviews.

5.1.9.2 INPUT - DESIGN REVIEW PROCEDURES

The description of this input is the same as provided in paragraphs 3.1.7.2 and 4.1.7.2

5.1.9.3 OUTPUT - DESIGN REVIEW REPORT

The description of this output is the same as provided in paragraph 3.1.7.3

5.2 CONTROL AND AUDIT

There are three primary control and audit metrics applicable during the EMD phase. Failure to achieve the indicated levels for these metrics should result in requirements for a corrective action plan.

5.2.1 DETAIL QUANTITATIVE RELIABILITY PREDICTIONS

A detailed prediction of expected reliability performance is one of three control factors applicable during the EMD phase. The current practice of using MIL-HDBK-217 for detailed predictions may not be complete and may require supplements such as a physics of failure approach, including assessments/predictions of known wearout and fatigue mechanisms, estimates of the malperformance of the equipment's self-diagnosis functions, and adjustments based on demonstrated results (customer use experience, part manufacturer test data).

The credibility of the prediction is contingent on the quality of several key issues that must be evaluated in concert with a prediction:

- Scope and quality of "Lessons Learned"
- Design for Manufacturing guidelines (Design simplification)
- Environmental and Use data traceable to the Mission Description (Stresses)
- Quality of Design margins/guidelines/derating/application guidance
- Characterization and control of Manufacturing processes
- Materials characterization data (Fatigue/Overstress/Corrosion resistance)
- Parts control

Guidance regarding techniques appropriate to the estimation of life for some dominant fatigue and wearout mechanisms are contained in Report RL-TR-91-155, "Computer Aided Assessment of Reliability Using Finite Element Methods" and RL-TR-91-251, "Reliability Assessment of Water Scale Integration Using Finite Element Analysis." Sufficient data exists to address additional issues, such as connector durability, corrosion, and electromigration. Estimates of wearout and fatigue life should be initially applied to worst case conditions to determine the need for more extensive analyses.

Use of detail predictions as a control parameter requires that corrective action be implemented if the parameter falls below established criteria. These criteria are as follows:

- **Prediction values must exceed customer requirements by a minimum of twenty percent (20%).**
- **Predictions will be iterated several times during the EMD phase. Final values shall reflect a twenty percent (20%) improvement over initial values. The improvement shall be traceable to either design simplification or reductions in electrical or mechanical stress levels.**

5.2.2 DESIGN VARIABILITY CONTROL

Detailed quantitative reliability predictions basically address the issue of stress-induced failures. The robustness of the design and its resistance to parameter variation is another major part of eliminating defects.

The basic design approach is to keep the variation under control such that the average result is separated from the specification limit by six standard deviation units. This separation should include the effects of shifts and drifts in the mean. A shift in the mean of 1.5 sigma accounts for typical shifts and drifts. This concept and a definition of capability indices is shown in Figure 5-11 as a measure of control.

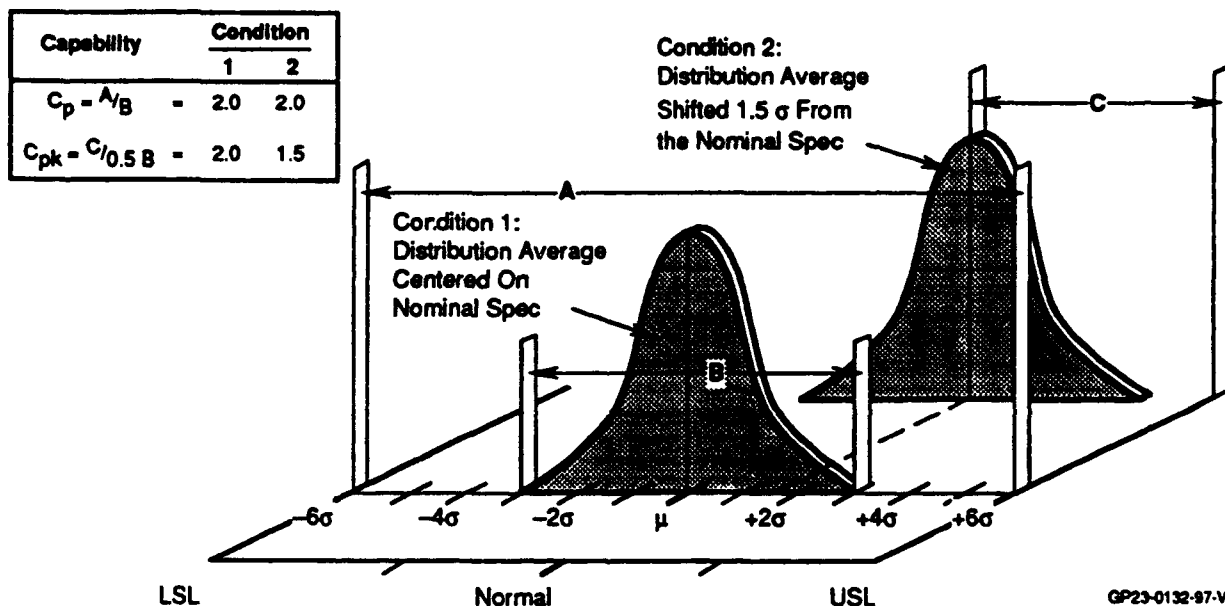


Figure 5-11. Concepts Underlying C_p and C_{pk}

The concepts identified herein can be applied to virtually any critical product characteristic. For control purposes during the EMD phase, the goal for each critical parameter is six sigma ($C_p = 2.0$) with a threshold for corrective action being four sigma ($C_p = 1.33$).

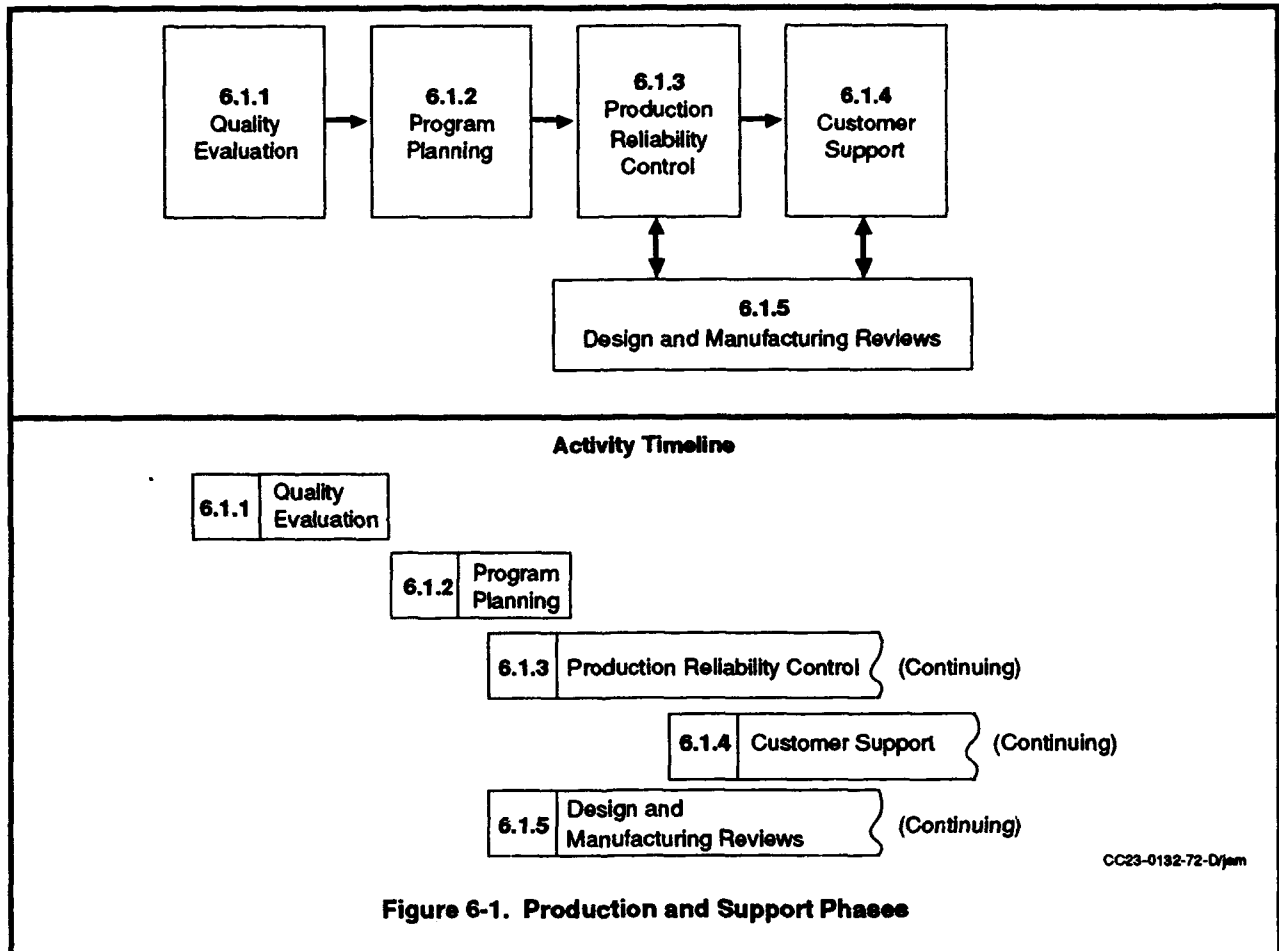
5.2.3 MANUFACTURING VARIABILITY CONTROL

Manufacturing is the final element contributing to defects and must be "scored" and controlled in a fashion almost identical to that described in paragraph 5.2.2.

The overall ability of a manufacturing process to consistently produce a high-quality end item is highly dependent on the capability of the individual steps that comprise that process. In turn, the capability of any given process step is determined by the degree of capability related to, and the subsequent control of, the underlying factors.

The control criteria for manufacturing control is similar to that defined in paragraph 5.2.2. However, control of the manufacturing process clearly extends into both the Production and Support phases. The ultimate goal for each critical manufacturing process step is a capability index, C_p , of 2.0. The EMD threshold for corrective action is an index, C_p , of 1.33.

CHAPTER 6
PRODUCTION AND OPERATIONAL SUPPORT PHASES



6.0 INTRODUCTION

This chapter defines the activities that should take place during the Production and Operational Support acquisition phases. Figure 6-1 shows the essential activities of this phase and the general time phasing of these activities. Activity 6.1.1, quality evaluation, is a continuation of the continuous improvement process started in the Concept-Exploration phase. It should also be an important element of both subcontractor control and supplier selection. Activity 6.1.2 is the program planning for both internal engineering and manufacturing operations and customer support for fielded systems. Activities 6.1.3 and 6.1.4 are the internally and externally directed actions required for defect detection, elimination, and prevention.

Continuing design and manufacturing reviews, activity 6.1.5, are essential to maintain a focus on both continuous improvement and continuing satisfaction of customer requirements.

Specific descriptions of the phase activities are contained in paragraphs 6.1.1 through 6.1.5. These paragraphs discuss the routine reliability improvement activities of the production and operational support phases. Major changes, upgrades, or improvements are subject to control via the appropriate activities from the previously described phases. The activities are selected based on the development status of the change.

MAJOR CHANGES

6.1 SUMMARY OF ACTIVITIES

The full scale production phase implements the contractor's production plan, as modified, by what was learned in the preproduction phase. Using Statistical Process Control (SPC) to measure the process and product variability at strategic points in the production flow will ensure that reliability is not affected by workmanship, tooling tolerances, equipment calibration, and/or various manufacturing processes. Once the processes are under control, the next most important task is to ensure that all anomalies are properly corrected. This is accomplished through the Failure Reporting Analysis and Corrective Action System (FRACAS) process. The data collected from this system is used

CHAPTER 6

PRODUCTION AND OPERATIONAL SUPPORT PHASES

to establish failure history, cause, and corrective action. It provides the detail necessary to establish trends and provide closed loop feedback to the designer on product and process problems that require modification.

Verification test data is collected from production Environmental Stress Screening (ESS) and Production Reliability Acceptance Tests (PRAT) to ensure that parts and materials and manufacturing processes provide what is necessary to produce a product that is consistently reliable.

Once the product is fielded, the focus is on failure reporting, analysis, and corrective action. Failure reporting analysis and corrective action data is carried over from production and combined with actual field performance data to determine if there are unique conditions that must be addressed that did not appear in-house.

It is critical that information pertaining to performance criteria, such as range, accuracy, clarity, speed, reliability, etc., is accurately reported.

Customer/User satisfaction must be primary, and if an anomaly does occur, rapid response is important. Information provided can be used to isolate design deficiencies or unforeseen process problems that don't show up until the product is in the field. This information is then fed back to the contractor to determine the root cause and implement corrective action. Data collected and stored over the operational life of the program can reveal long term conditions. This information may reveal handling or usage conditions that can be compensated for in existing and future designs.

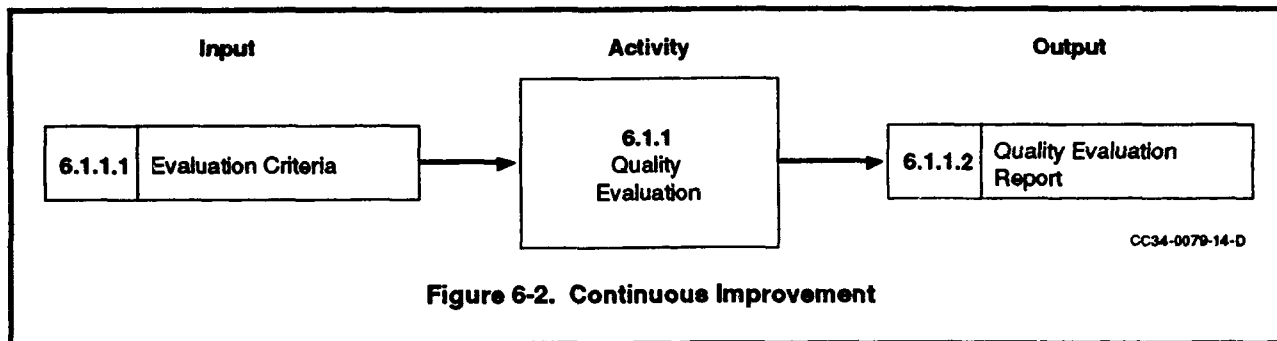
CUSTOMER SATISFACTION

The following program attributes must be in place for the Production and Operational Support phases:

- An effective system that translates all the customer's expectations and requirements into Production and Operational Support requirements.
- An effective system for identifying key product and process characteristics and their impact on reliability/durability.

- An effective system of process controls that addresses process yield and variability and an inhouse feedback system that informs engineering of potential design deficiencies.
- An effective plan that verifies through testing the life and reliability of the product that gives credibility to earlier predictions.
- An effective system of reporting, retrieving, analyzing, and correcting field problems that might have a relationship to product design or manufacturing processes.

With these attributes in place, and with the application of TQM tools, such as Cycle Time Management and SPC, the production phase should have good product yield with exceptional reliability and durability. Operational Support costs will be low when the product is fielded, and customer/user satisfaction will be high.



6.1.1 ACTIVITY - QUALITY EVALUATION

This activity shifts during this phase from a primary use as source selection criteria to an evaluation directed at monitoring and measuring continuous improvement. However, it can and should still be used for source selection for competitive procurement and second sourcing. The quality evaluation should also be embedded in a supplier certification program directed at identifying a selection of preferred suppliers. The quality evaluation should also be used as a measurement tool for continuous improvement, with results requested periodically and reviewed as part of supplier monitoring and control.

CHAPTER 6

PRODUCTION AND OPERATIONAL SUPPORT PHASES

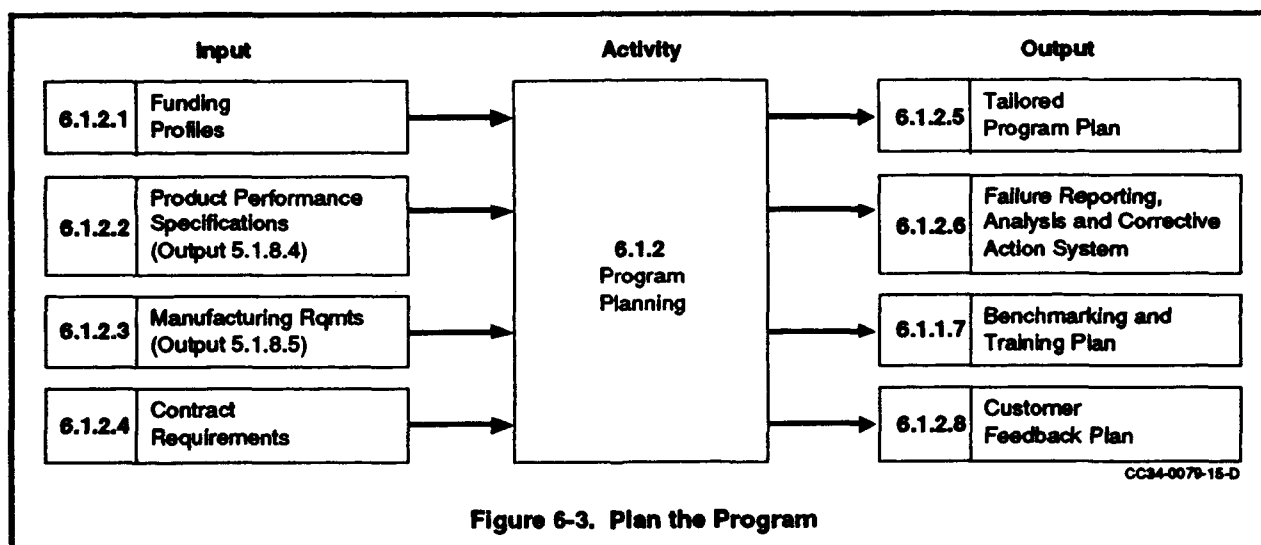
6.1.1.1 INPUT - EVALUATION CRITERIA

The evaluation criteria defined in Volume II of this handbook is the recommended benchmark for continuing quality evaluation. These criteria should be included in production contracts with instructions for periodic evaluations.

6.1.1.2 OUTPUT - QUALITY EVALUATION REPORT

The supplier provides a quality evaluation report in accordance with customer reporting requirements. The Malcolm Baldrige report format is a recommended source for reporting requirements. These reports should be prepared and evaluated on an annual or biannual basis with a focus on problem areas and corrective actions.

ASSESSMENT REPORTS



6.1.2 ACTIVITY - PROGRAM PLANNING

This activity is reduced in comparison to the planning required for prior acquisition phases. The planning for the production and operational support phases should emphasize the continuing reduction in variability of manufacturing processes, failure reporting, analyses and corrective action systems, supplier control, and the development of customer use feedback systems. The plans must clearly identify the relationships between reliability engineering, manufacturing, quality assurance, design engineering, and logistic support

FOCUS OF ACTIVITIES

organizations.

6.1.2.1 INPUT - FUNDING PROFILES

The description of this input is the same as contained in paragraphs 3.1.3.1, 4.1.3.1, and 5.1.3.1.

6.1.2.2 INPUT - PRODUCT PERFORMANCE SPECIFICATIONS

The output described in paragraph 5.1.8.4 serves as an input to the planning activity. These specifications completely describe all performance and verification requirements.

6.1.2.3 INPUT - MANUFACTURING REQUIREMENTS

The output described in paragraph 5.1.6.5 serves as an input to the planning activity. This input includes all manufacturing process specifications, the status of capability indices (C_p) for the design and manufacturing processes, and SPC criteria.

6.1.2.4 INPUT - CONTRACT REQUIREMENTS

The description of this input is the same as provided in paragraph 3.1.3.2.

6.1.2.5 OUTPUT - TAILORED PROGRAM PLAN

The program plan should use the inputs and outputs of Activities 6.1.1, 6.1.3, 6.1.4, and 6.1.5, as the baseline for defining the specific tasks for the production and operational support phases. The plan should concentrate on the topics described in paragraph 6.1.2.

6.1.2.6 OUTPUT - FAILURE REPORTING ANALYSIS AND CORRECTIVE ACTION SYSTEM (FRACAS)

The supplier must have a comprehensive FRACAS that addresses all defects discovered in both the manufacturing and test processes. The system should clearly identify the requirements and responsibility for reporting, analyzing, correcting, and tracking the status of all defects. There are two keys to the effectiveness of FRACAS systems: 1) it should be a single system that records and corrects defects from all sources from receipt of parts and materials through finished product, and 2) there must

ELIMINATE DEFECTS

CHAPTER 6

PRODUCTION AND OPERATIONAL SUPPORT PHASES

be evidence of continuous management oversight and insistence on the root cause analysis and correction of all defects.

6.1.2.7 OUTPUT - BENCHMARKING AND TRAINING PLAN

Benchmarking plans should be built around two issues: 1) weaknesses uncovered during the quality evaluation activity of paragraph 6.1.1, and 2) the issues of continuing variability reduction, failure elimination, and supplier control. The plans should identify the process and company being benchmarked, the data collection method, responsibility for the effort, and schedules for completing the benchmarking. Suggested topics for benchmarking include:

- Failure Reporting, Analyses, and Corrective Action Systems
- Customer Feedback Systems
- Manufacturing Cycle Time
- Supplier Control
- Statistical Process Control
- Variability Reduction

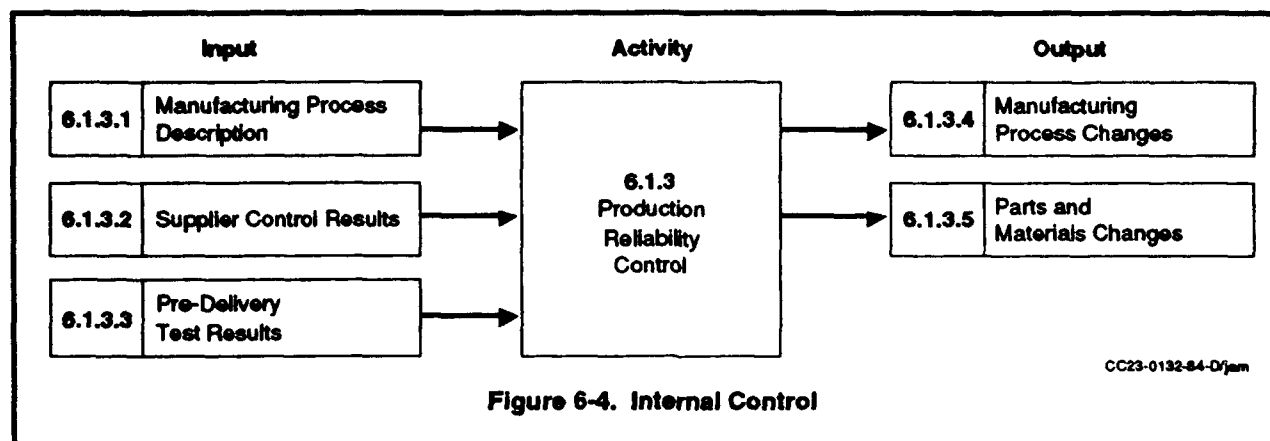
The training plan should address the capability of program personnel to accomplish the phase activities, inputs and outputs, and the training resources employed to correct deficiencies. The training plan should also address the topic of the dissemination of reliability requirements throughout all program areas.

6.1.2.8 OUTPUT - CUSTOMER FEEDBACK PLAN

Customer feedback is a critical element during the Production and Operational Support phases. The supplier should develop a plan for obtaining information from their customer and the end use of the equipment. The plan should identify all use environments, the type of data generated, and procedures for the disposition and repair of failed items. Having identified these issues, the plan should describe the methods employed to collect all relevant information, the responsibility for acting on the information, and the status/tracking techniques to be applied to ensure problem resolution. The plan should address both the customer's data and the mechanics for transmitting this information to

CUSTOMER SATISFACTION

suppliers and subcontractors for their action and problem closeout.



6.1.3 ACTIVITY - PRODUCTION RELIABILITY CONTROL

This activity is a central activity of the Production and Operational Support phases. Data from internal manufacturing processes, supplier processing and test, and all pre-delivery testing is evaluated. Based on these analyses, changes to manufacturing processes, parts, and materials are implemented. The key to the success of this activity is the comprehensiveness of the data sources.

IN-PROCESS TESTING

6.1.3.1 INPUT - MANUFACTURING PROCESS DESCRIPTION

This is a comprehensive definition of the manufacturing process. The data includes a description of every manufacturing process step, the capability index associated with that step, the identification of inspection and test steps, and the data reflecting the number of defects and parameter variability detected at each of the test and inspection steps. This latter data should be represented in the FRACAS data base. Within the description of the manufacturing process steps, those affecting critical product characteristics should be identified and highlighted.

MANUFACTURING RESULTS

CHAPTER 6
PRODUCTION AND OPERATIONAL SUPPORT PHASES

6.1.3.2 INPUT - SUPPLIER CONTROL RESULTS

Data from suppliers of critical parts and materials should maintain the data indicated in paragraph 6.1.3.1 and provide variability data for critical parts and materials parameters. This input also includes parts and materials defect/failure data and status reports for problem closeout.

6.1.3.3 INPUT - PRE-DELIVERY TEST RESULTS

Pre-delivery testing includes all post-manufacturing assembly testing, including Environmental Stress Screening at all levels of assembly, acceptance testing, and any operation or testing prior to use by the ultimate customer. These data become part of the defect data base subject to reporting, analyses, corrective action, and problem closure status tracking. During this testing, there should be no acceptable levels of defect nor any defects which are not subject to corrective action requirements. All testing should be identified in either performance or manufacturing specifications.

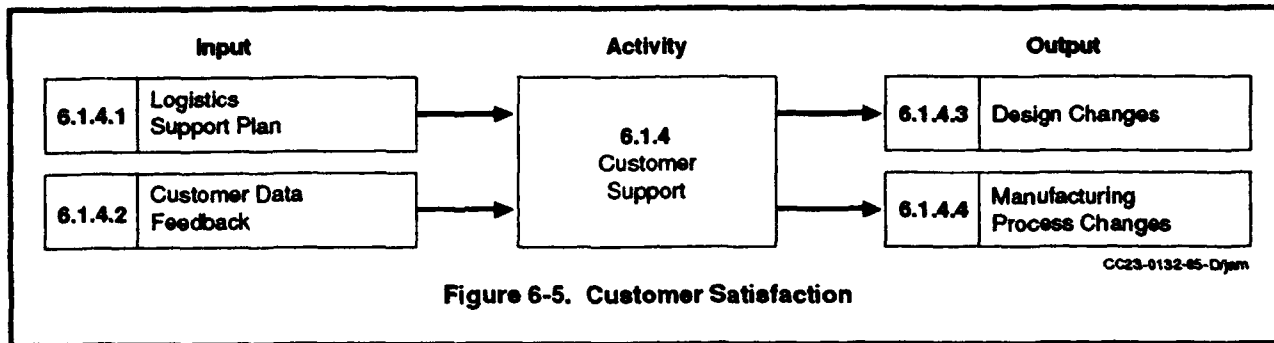
6.1.3.4 OUTPUT - MANUFACTURING PROCESS CHANGES

Test results from all phases of testing should be combined and used to validate the achievement of six sigma levels in both design and manufacturing processes. The capability index of the manufacturing processes, starting with critical processes, should be demonstrated to be at least 2.0 (six sigma). Planned corrective actions, such as variability reduction testing, SPC, and process simplification, should be defined for processes not achieving necessary levels of reliability.

6.1.3.5 OUTPUT - PARTS AND MATERIALS CHANGES

Test data from all phases of testing, including tests conducted by parts and materials suppliers, should be combined to demonstrate the achievement of six sigma quality levels by parts and materials supplier manufacturing processes. In addition, test data should be accumulated on critical parameters to validate that variability relative to required tolerances are equal to six sigma. Plans for corrective action should be developed for parts and materials not complying with these requirements.

Within the constraints of configuration management, the design should be continuously reviewed for simplification and the incorporation of improved technology parts and materials.



6.1.4 ACTIVITY - CUSTOMER SUPPORT

Satisfaction of the ultimate using customer is the goal of this activity. Provisions should be in place that ensure that all levels of suppliers are made aware of the performance of their products in the hands of the end user. Satisfaction should be measured both by conformance to performance specification requirements and by direct customer contact.

6.1.4.1 INPUT - LOGISTIC SUPPORT PLAN

The support environment and the stresses resulting from that environment have been identified as design requirements from the earliest acquisition phases. This input represents data describing troubleshooting and repair practices and environments at all levels of maintenance, support and test equipment at all levels of maintenance, storage handling and transportation conditions, and maintenance training. The data also includes details regarding procedures for warranties and return of failed assets to suppliers for repair.

6.1.4.2 INPUT - CUSTOMER DATA FEEDBACK

All sources of performance data should be identified and employed to measure customer satisfaction. This data includes standard DoD maintenance data, depot repair reports, direct customer contact, and reports from contractor field service personnel. This data should be collected and evaluated in a centralized and systematic fashion.

PRODUCT PERFORMANCE

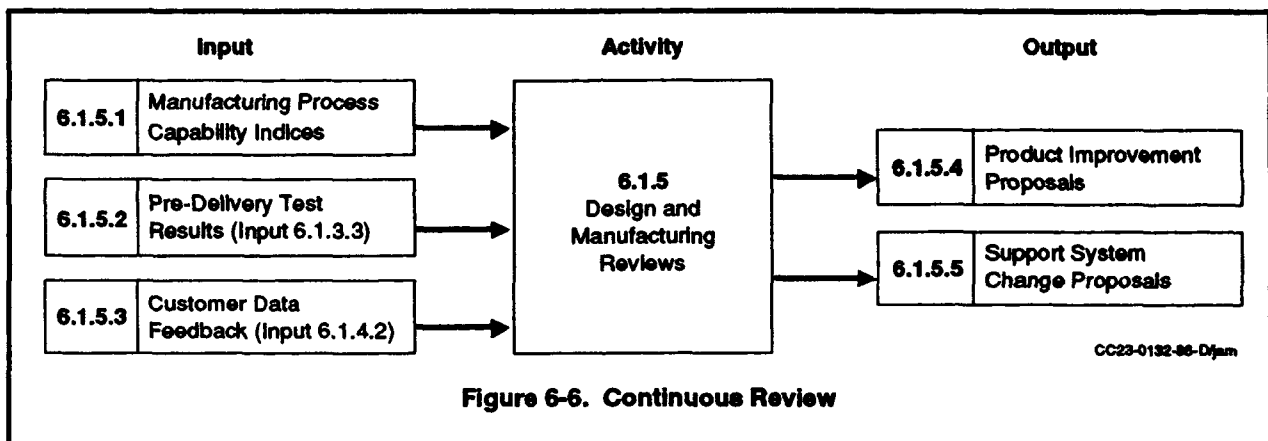
FIELD DATA

6.1.4.3 OUTPUT - DESIGN CHANGES

Data analyses should be a continuous supplier process to measure quantitative reliability performance levels, identify problem areas, and validate assumptions regarding customer environments and use. The supplier should have a process in place that ensures the widest possible distribution of these analytic results along with criteria for initiating design changes to correct problems.

6.1.4.4 OUTPUT - MANUFACTURING PROCESS CHANGES

The description of this output is substantially the same as output 6.1.4.3 except that the output product is manufacturing process changes.



6.1.5 ACTIVITY - DESIGN AND MANUFACTURING REVIEWS

The supplier should have, in place, a process for ensuring the continuous review of the results of activities 6.1.1, 6.1.3, and 6.1.4. The review process includes both internal and customer reviews. All reviews should have clearly defined entry and exit criteria, an explicit definition of applicable customer requirements, and a demonstration that these requirements are being met. The review process is an integral part of outputs 6.1.3.4, 6.1.3.5, 6.1.4.3, and 6.1.4.4.

REVIEW THE RESULTS

**6.1.5.1 INPUT - MANUFACTURING
PROCESS CAPABILITY INDICES**

This input defines the variability of key manufacturing processes in terms of process capability indices (C_p or C_{pk}) or defects per million opportunities.

**6.1.5.2 INPUT - PRE-DELIVERY TEST
RESULTS**

Input 6.1.3.3 also serves as an input to the review activity.

**6.1.5.3 INPUT - CUSTOMER DATA
FEEDBACK**

Input 6.1.4.2 also serves as an input to the review activity.

**6.1.5.4 OUTPUT - PRODUCT
IMPROVEMENT PROPOSALS**

One of the principal outputs of the review process are recommendations for product improvements. These are product changes that require customer approval or those requiring any contractual or configuration changes.

**6.1.5.5 OUTPUT - SUPPORT SYSTEM
CHANGE PROPOSALS**

These outputs represent changes in the customer's support activities and require customer approval.

6.2 CONTROL AND AUDIT

METRICS

The two control metrics for this phase are the six sigma manufacturing capability metrics described in paragraph 5.2, and product performance specification reliability values which should be achieved in the user's environment. This is supplemented by demonstration of equipment/ system level performance at, or above, customer requirements during pre-delivery testing. The recommended methodology for tracking the achievement of customer requirements, based on pre-delivery testing, is described in paragraph 2.8, pages 83 through 88, of Report RL-TR-91-300, Volume 1 (of 2), "Evaluation of Quantitative Environmental Stress Screening (ESS) Methods." The only stipulation regarding this procedure is that

CHAPTER 6
PRODUCTION AND OPERATIONAL SUPPORT PHASES

all defects and equipment malperformance, including design errors and malperformance of self-diagnostics, be included as part of the data base.

[illegible]

7-1

7.0 INTRODUCTION

This example demonstrates how the reliability process can be used to enhance the reliability of products. It by no means covers all the areas of the reliability process, but instead covers some important areas in a concrete manner as a general demonstration of the use of the process. The overall product in this example is a radar system, with most of the example concentrating on an identified critical item, a linear hybrid. Even though this example centers on a linear hybrid, the process can be used on all products and at all levels of indenture. Samples of the use of Quality Function Deployment (QFD) are integrated into the example. These show how QFD is used to interpret customer needs and flow the resulting technical requirements to the lowest levels of design and manufacturing.

7.1 PRECONCEPT EXPLORATION PHASE ACTIVITIES

Before the formal request for proposal (RFP) was released, Ajax Company met with the customer to discuss their needs and expectations for the future Radar system and to work with the customer in defining requirements and explaining contractor capability. The translation of customer needs into requirements was performed using QFD. Figure 7-1 shows an example of a partial QFD. The customer's operational needs are translated into system level technical objectives. These objectives are related to customer needs and priorities and "scored" to define the relative importance of the objectives. At this early stage in the acquisition cycle, the QFD technical objectives (labeled in the Figure as Design Requirements) can be used as criteria for selecting emerging technologies that may satisfy these objectives. The Ajax Company had used this approach on other contracts and found it most beneficial. In the past, the customer passed down requirements that were beyond Ajax's capability or did not directly translate into meeting total customer requirements. By discussing the expectations and needs of the customer before the RFP was released, Ajax was able to inform the customer of Ajax's technical capability and options, and work with them to develop requirements that would directly translate into satisfying their needs and expectations.

QUALITY FUNCTION DEPLOYMENT

CHAPTER 7
APPLYING THE PROCESS

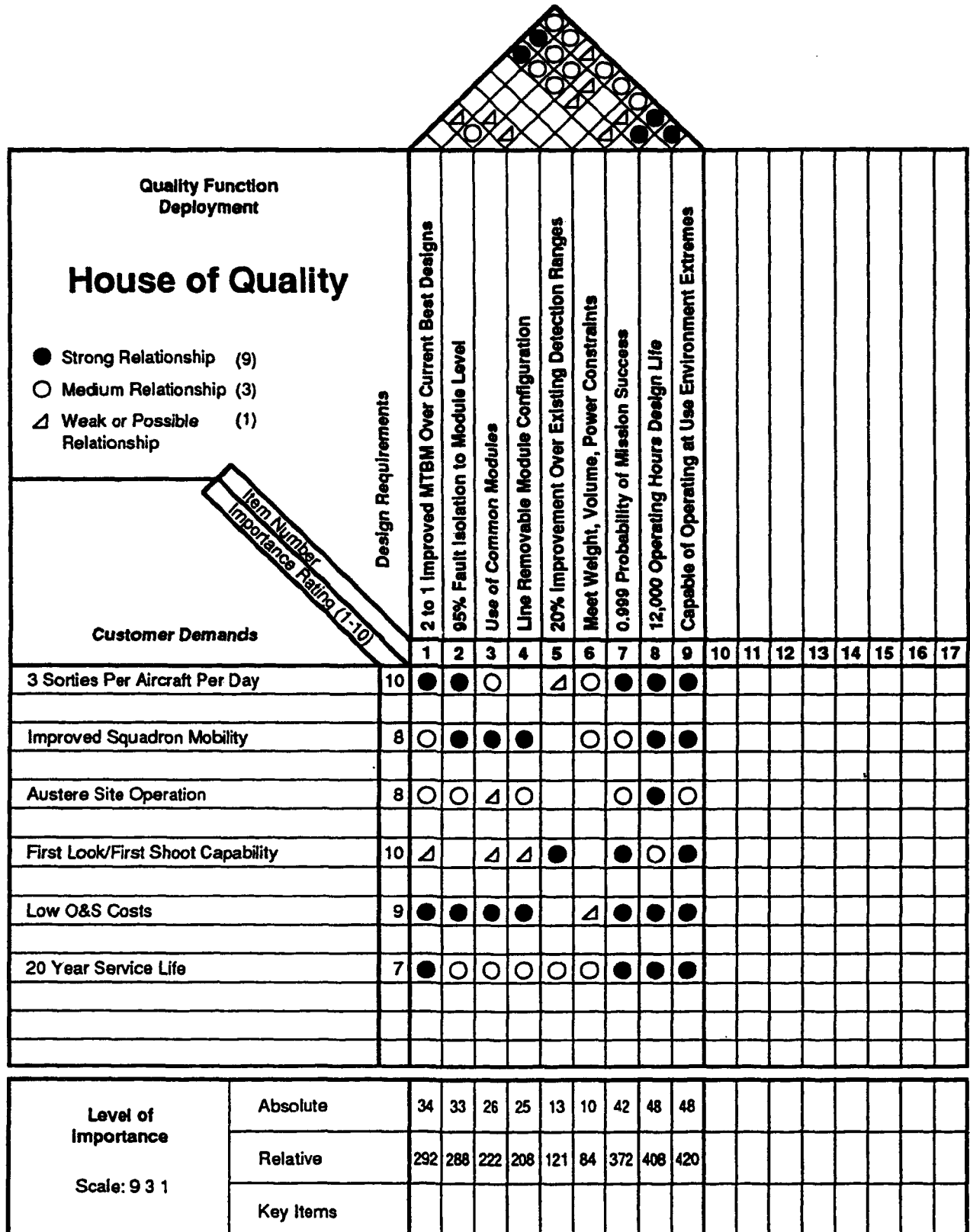


Figure 7-2. Concept Exploration Phase Quality Function Deployment

Upon completing the requirements development, Ajax concluded that they had the capability to meet the needs and expectations of the customer. Ajax was currently building three radar systems: an APG 50, 51M, and 52M Radar. The 51M and 52M radar both utilized slightly different design concepts compared to the APG 50. However, the 51M and 52M radars utilized a Radar Receiver Processor (RRP) module that the designer felt was optimal for the upgrade of the APG 50. Ajax's plan was to redesign the receiver module in the APG 50 Radar using the receiver (RRP) module from the 51M or 52M Radar. However, a Preconcept Risk Analysis found that the receiver module has been the problem module in the factory and in the field. The problem was determined to be the Receiver (RCV) hybrid. The RCV hybrid is the heart and soul of the RRP module.

An alternative approach considered by Ajax Company was to redesign the RRP module using the Super Receiver (SRCV I) hybrid. The SRCV I hybrid was part of a new program funded to design and build cost effective state-of-the-art receiver hybrids using Microwave Monolithic Integrated Circuits (MMIC) GaAs chips and tape automated bonding. A detailed trade-off study was planned for the Concept Phase to investigate the advantages and disadvantages of the redesigned RCV hybrid versus the new technology.

COMPARE TECHNOLOGIES

7.2 CONCEPT EXPLORATION PHASE ACTIVITIES

Upon receiving the RFP, Ajax Company began the formal development of the proposal. The customer requirements stated in the contract were very similar to the requirements that were developed during the preconcept phase. The analysis and deployment of requirements from the preconcept phase were updated using Quality Functional Deployment QFD to establish cost, performance, reliability, producibility, and support requirements, along with identifying customer priorities and requirement interaction. As shown in Figure 7-2, the technical objectives represent system level objectives, but contain additional and more specific attributes than identified during Pre-Concept Exploration phase.

CHAPTER 7

APPLYING THE PROCESS

Their winning proposal included a plan that clearly demonstrated how the customer's needs and expectations would be satisfied. Ajax attributed much of the success to the Preconcept QFD, which established what the customer was looking for and translated these needs into requirements that both parties felt were optimal.

The Concept Phase Reliability Implementation Plan included a general outline of the activities planned through Production. Though many of the details of the plan were not known at the time, the general concepts were well defined. The general areas covered were roles and responsibilities, design guides development, critical item identification, variability control, and verification test. An engineering and manufacturing team collectively established the specific roles and responsibilities for contract activities.

In order to establish a system concept and a firm direction for choice of technology, the designer requested additional historical data to confirm the poor reliability history of the RSV hybrid. The investigation determined that many of the critical parts and processes of the RSV hybrid had been identified and corrected, but in spite of this, the hybrid continued to demonstrate poor reliability performance. Concurrently, he contacted the new technology SRSV I hybrid program to determine what actions had been taken to determine critical parts and processes for the SRCV I hybrid. There had been limited analyses or tests performed to determine the critical materials or processes of these new technologies. The cost of performing these analyses and tests were available from the SRSV I hybrid program manager. The design engineer planned to use these for his Trade-Off Analysis.

SELECT TECHNOLOGIES

The management of Ajax had recently adopted a new philosophy of commonality of designs across programs. This was another consideration for the Trade-Off Analysis. The RSV hybrid was already used on the M50 and M51 program and many of the critical processes of the RSV hybrid were already known. Little was known about the reliability of the SRSV I hybrid and the development costs were high. When these factors were used in the Trade-Off Analysis, it was decided that redesigning the RRP

module using the RSV hybrid was the optimal decision. It was a clear choice based on the data available.

Once the configuration and technology choice was decided, a risk reduction plan was developed to improve the reliability of the identified critical item, the RSV hybrid.

7.3 DEMONSTRATION AND VALIDATION PHASE ACTIVITIES

At the completion of the concept phase, Ajax had identified a critical item, the RCV hybrid and a risk reduction plan. This example will now concentrate on applying the reliability process to the RCV hybrid. Remember, there may be many critical items in a design. This example demonstrates just one of the many ways of applying the reliability design process.

The analysis and deployment of requirements (Quality Functional Deployment) was used to flowdown cost, performance, reliability, producibility, and support requirements--first to the Receiver module, and then to the critical component (Figures 7-3 and 7-4). At the component level, the QFD resulted in very specific technical requirements and actions focused on defining and correcting the technical problems of the RCV hybrid. Important requirements for this example were stress cycle life process yields and defect rate.

During the Concept Exploration phase, the RCV hybrid was chosen as the preferred design option, despite the fact that early critical parts review indicated a poor reliability history. The designer took this information into account in his DEM/VAL Reliability Plan. The reliability engineer, manufacturing engineer, component specialist, and the design engineer jointly developed the following risk reduction plan details:

1. Perform a critical parts and materials review for the hybrid. Look at the historical data in detail. Determine use conditions when the device failed and what was the physical failure mode.

Quality Function Deployment		Receiver Module Requirements																	
House of Quality		Item Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Module Level Design Requirements		Importance Rating (1-10)	Rcvr With RCV Hybrid Must Exceed MTBMA of 2,000 hrs	92% Fault Isolation to Receiver Module Parts	Utilize Common RRP Module Configuration	Receiver Module Must Be Line Replaceable	20% Improvement in Receiver Sensitivity	Meet Weight, Volume, Power Constraints	No Fatigue Failures in Less Than 2,000 hrs	Rcvr Must Be Able to Operate at Spec Envrntl Extremes									
2 to 1 MTBM Improvement Over Current	10	●	△	○	○	○	△	●	●										
Best Designs																			
95% Fault Isolation to Module Level	9		●	○	●		○	○	○										
Use of Common Modules	7	○	○	●	○	●	●	●	○										
Line Removable Module Configuration	9	△	○	○	●	○	△	○	△										
20% Improvement Over Existing	10	○		○		●			○										
Detection Ranges																			
Meet Weight, Volume, Power Rqmts	8			○			●	●	○										
0.999 Probability of Mission Success	10	●	●	●	○	●	●	●	●										
12,000 hr Design Life	8	●	○	●	○		○	●	●										
Capable of Operating at Usage	8	●		●		●	○	●	●										
Environmental Extremes																			

Level of Importance

Scale: 9 3 1

Absolute	43	28	51	30	42	38	60	49											
Relative	384	253	435	267	372	319	513	435											
Key Items																			

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CHAPTER 7

APPLYING THE PROCESS

2. Determine if failure analyses had been performed to determine cause of failure or develop accelerated tests and failure analyses to determine the dominant stress factors and the root cause of the failure.

Upon performing the critical parts and materials review, it was confirmed that the hybrid had demonstrated poor reliability performance, both in-house and in the field, on two different Ajax programs. Reliability data showed that the hybrid failed to meet the minimum standards for critical process yields and the field failure rate was excessive. Review of the data indicated that the failure mode was possibly related to temperature cycling. Because limited failure analysis had been performed on failed hybrids, accelerated tests and failure analyses were conducted to determine the dominant stress factors and the root cause of failure. The results concluded that the cause of failure was related to the mismatch of the thermal coefficient of expansion (TCE) of the semiconductor die attach material and the carrier it was mounted on.

REDUCE RISK

The mechanism of this failure was determined to be fatigue of the epoxy die attach material, which is temperature cycling dependent. The thickness of the epoxy die attach material was also determined to be important for thermal dissipation needs.

The designer went back to the failure modes and effects analysis (FMECA) developed in the earlier part of the Demonstration and Validation Phase to update the analysis to include the new failure information. The break in the thermal path through the epoxy caused the semiconductor die to overheat and fail. The FMECA showed that failure of this chip would result in a single point failure to the hybrid and to the overall system.

The test, analyses, and conclusions were sufficient to show that reliability problems could be resolved during the Engineering and Manufacturing Development phase.

7.4 ENGINEERING AND MANUFACTURING DEVELOPMENT (EMD) PHASE ACTIVITIES

In this example, the transition to EMD was

approximately continuous. The customer had reviewed the Reliability Plan at the conclusion of the Demonstration and Validation phase and requested an update to the Reliability Plan to explain what actions would be taken to address the hybrid reliability issues.

The QFD had been continually updated from the start of the program, so the flowdown of customer expectations and requirements went very smoothly. Figure 7-5 shows the final flowdown of requirements for the RCV hybrid. The updates had been rigorous, and comments at the design review resulted in very few requirement changes. EMD Master Schedules confirmed the value of performing a preliminary critical parts and material review during DEM/VAL. Since the time envelope available for determining critical items and developing a course of action during EMD was very short, it was most beneficial to determine critical issues as early as possible in the design process to allow time for refinement and final optimization.

Upon reviewing the requirement changes from DEM/VAL to EMD and the DEM/VAL design and analysis data, it was determined that additional testing and analysis was required. The EMD planning effort considered all DEM/VAL information and included additional planning, testing, and analysis that was required to ensure the design would meet all program requirements. The Reliability Plan was developed in a concurrent engineering environment using QFD to aid in the prioritization of activities. The design engineer, component specialists, failure analysts, manufacturing engineers, and reliability engineers jointly developed the following hybrid improvement plan:

1. Consult with material specialists and component engineers in choosing potential epoxy suppliers. Choose the epoxies to be evaluated based on the appropriate thermal coefficient of expansion (TCE), other thermal characteristics, historical life and producibility data, and cost.
2. Use thermal modeling techniques to establish a maximum thickness for each epoxy type.

DEFECT PREVENTION

[illegible]

3. Using engineering judgement, historical data, and vendor experience, determine a minimum epoxy die attach thickness as a target value for each epoxy type. Choose three thicknesses within the feasible range.
4. Utilize Design of Experiments (DOE) for performing the following manufacturing process development tests: a) determine the relationship between the amount of epoxy and the epoxy die attach thickness after curing for each epoxy type, including the corresponding values for the application needle height (mils), robot speed (cm/s), and needle diameter (mils), as well as die placement pressure; b) determine process control variables for applying the desired quantity of each epoxy type.
5. Choose five different temperature ranges that are within the application requirement and perform temperature cycling to failure.
6. Use DOE to evaluate the variability of cycles to failures for each epoxy type, based on thickness, temperature range, and epoxy supplier.
7. Determine Key Product Characteristics and Key Control Characteristics.
8. Develop a Statistical Process Control Plan.

Based on previous experience, the material specialist and component engineer were able to choose three potential epoxies, all supplied by different suppliers. The three epoxies were chosen for further studies based on TCE and thermal characteristics, historical life and producibility data, and cost.

Because of early planning, many of the activities stated in the Reliability Plan were performed simultaneously, instead of the chronological order stated above. This procedure optimized the time available for reliability product development. While thermal modeling was being performed to determine the maximum thickness to satisfy thermal dissipation targets, samples were being developed for testing,

CHAPTER 7

APPLYING THE PROCESS

process development, and producibility studies.

Upon completing steps 1 through 7, results were weighted by order of criticality and used to perform a trade-off of reliability, manufacturability, and cost. The trade-off activity resulted in a choice of Epoxy 1. Epoxy 1 was subjected to a reliability verification test. All Epoxy 1 samples passed all the verification tests. The desired epoxy die attach thickness was determined to be $(1 \text{ mil} < X < 1.5 \text{ mil})$. This was identified as a Key Product Characteristic (KPC). The required quantity of Epoxy 1 to satisfy the thickness requirement was determined to be $(2 \text{ gms} < X < 2.3 \text{ gms})$. This was identified as a Key Control Characteristic (KCC), along with a die placement pressure of $(5 \text{ gms} < X < 6 \text{ gms})$.

REFINE THE MANUFACTURING PROCESS

The epoxy die attach thickness is critical. It was determined through analysis that if it varies outside of the determined thickness requirement, a failure will occur. The epoxy quantity and die placement pressure must be controlled around some target value to ensure that variation in the epoxy die attach thickness is maintained or minimized within its stated range. This is accomplished through utilizing Statistical Process Control (SPC). SPC was used to chart the performance of the epoxy weight and die placement pressure over time. This not only indicates when the process is "out of control," but also provides valuable information which can be used to better understand the variability of the process. For example, if the die placement pressure changes over time, then utilizing SPC can determine how often adjustments of the pressure apparatus are necessary to maintain or minimize variability over time.

7.5 PRODUCTION AND OPERATIONAL SUPPORT PHASE ACTIVITIES

Production, Operation, and Support Requirements were firmly established prior to the start of production. The customer had met with Ajax to discuss production requirements, such as process yield targets, statistical process control, failure reporting, analysis and corrective action, and a continuous measurable improvement (CMI) program. The QFD was again updated to include product and process changes that arose after EMD.

Ajax was familiar with many of the success stories of companies utilizing continuous measurable improvement philosophies. Ajax had adopted statistical process control, variability reduction, and a FRACAS system for the M51 and M52 radar production operations. Ajax was currently experiencing the success of variability reduction in improved process yields. The plans from these two programs were used to develop the plans for the current contract. The plans in place during EMD required only minor changes prior to the start of production.

The FRACAS plan used for the M50 and M51 radar were slightly different than what Ajax had used in the past. In the past, Ajax tracked failures at the unit and system level. The new system would include failures occurring at module level test. Ajax had found that many of the problems occurring at unit burn-in could have been detected and corrected during module level build.

DEFECT ELIMINATION

In addition, Ajax developed a field failure tracking system to track the performance of the product in the field. This would start the moment the product left Ajax. The data base used was directly tied to the FRACAS system so part and failure searches could be performed. The number of systems to be tracked were based on a sample of the total population, i.e., the total number of systems built for the customer on this contract. The system documented all faults, identifying cause and corrective action. This information was documented as lessons learned and used to identify areas of improvement for the reliability design process. Ajax decision to use sampling was based on past experience. The data received on past contracts were incomplete. The data was not useful for drawing definite conclusions that could be used to improve the reliability design process. This was attributed to the difficulty involved in recording detailed failure information and maintaining traceability. This was also a function of the large quantity of systems produced and the number of failures. Ajax felt that by choosing a manageable number of samples to track over their life, a failure history record could be developed in which critical process problems could be identified, corrected, and used as lessons learned to improve both the product and process.

8.0 INTRODUCTION

This handbook describes a revised process for assuring the reliability of systems and their hardware elements. However, modern electronic systems contain increasing dependence on computers and their software for system control and execution of functions. Assuring the reliability of software is therefore crucial to the reliability of electronic systems. This assurance can be realized by application of the principles and approaches of this handbook to software development.

8.1 SUMMARY OF ACTIVITIES

KEY SOFTWARE ACTIVITIES

Each of the acquisition phases are described in Chapters two through six in terms of key activities, each having inputs and outputs. These activities are listed as follows:

- (1) Quality Evaluation
- (2) Interpret Customer Needs
- (3) Program Planning
- (4) Technology Assessments and Testing
- (5) Technical Specifications
- (6) Design Reviews

The activity designated above as "Technology Assessments and Testing" is a composite representation of one or more activities within each phase. For example, the EMD phase contains four technology assessments and test activities (5.1.4 through 5.1.7) which are summarized here as "Technology Assessments and Testing." Each of the above six activities is applicable to software reliability.

The Quality Evaluation is an overall assessment of the commitment to defect free hardware. The software analog is continuous process improvement in accordance with the Capability Maturity Model (CMM) developed by the Software Engineering Institute (SEI). This approach provides guidance for maturing and measuring the software development process through five levels of achievement. This process is defined in more detail in paragraph 8.2.

Definition of customer requirements is an activity equally applicable to both hardware and software. Quality Function Deployment, defined as a recommended tool for interpreting customer needs, should be applied to the development of software requirements that are directly traceable to customer needs. This activity corresponds to the System Requirements Analysis/Design and Software Requirements Analyses activities of DOD-STD-2167A.

Program planning is as essential for software as it is for hardware. For example, this activity would be used to develop the Software Development Plan defined in DOD-STD-2167A. Most outputs of this activity, as described in Chapters two through six, are appropriate to software reliability. For instance, these outputs include CAE Tools, Technical Objectives Flowdown and Benchmarking and Training Plans. These three outputs are as appropriate to software as they are to hardware.

SOFTWARE RELIABILITY PLANNING

- CAE Tools - Specific automated software development tools must be defined along with all required hardware and training for the use of these tools.
- Technical Objectives Flowdown - Software requirements, including quantitative reliability requirements, must be allocated to lower levels in the software hierarchy in a manner comparable to the flowdown of hardware requirement. Traceability from lower level requirements back to customer requirements must be maintained.
- Benchmarking and Training Plans - The description of this output for hardware reliability is directly applicable to software reliability. Software benchmarking can be done both within the enterprise and external to the enterprise. Its purpose is to employ dramatically improved processes based on "best practices" used by others. Training plans that focus on deploying "best practices" are key to developing high reliability software. These plans should cover such issues as requirements development, coding practices,

defect reduction techniques, testing methods and software configuration management.

The software equivalent to "Technology Assessment and Testing" consists of activities required to generate detail software specifications, interface documents, coded software, quantitative software defect estimates, software test procedures and testing. The technology issues focus primarily on defect prevention actions including topics such as Lesson Learned.

The technical specifications activity consists of the development of the deliverables spelled out in DOD-STD-2167A. These include Software Requirements Specifications, Interface Requirements Specifications, Software Design Documents, and Software Specifications.

Design Reviews are a critical element of defect prevention programs. Software inspections and walkthroughs are powerful tools for improving the quality and reliability of software. These software reviews should have the same attributes as identified for the Design Review Activity defined in Chapters two through six. Primary among these attributes are issues such as internal consistency, traceability to customer requirements, and documented procedures for conducting both internal and external reviews.

Applying a quality process approach to software reliability assurance uses the methodology defined in Chapters two through six. As applied to software this consists of process development in accordance with the SEI maturity model, development of the products described in DOD-STD-2167A, determination of expected failure rates and testing in accordance with the principles outlined in the 6 December 1991 draft MIL-HDBK-XXX, "Military Handbook, Hardware/Software Reliability Assurance and Control," and the implementation of a comprehensive defect prevention program.

SOFTWARE REVIEWS

8.2 SOFTWARE PROCESS MATURITY

Continuous process improvement is based on many small, evolutionary steps. The SEI Capability Maturity Model (CMM) provides a framework for organizing these evolutionary steps into five maturity levels that lay successive foundations for continuous process improvement. These five maturity levels define scale for measuring the maturity of an organization's software process and for evaluating its software process capability. The levels also help an organization prioritize its improvement efforts.

A maturity level is a well-defined plateau toward achieving a mature software process. Each maturity level provides a layer in the foundation for continuous process improvement. Each level comprises a set of process goals that, when satisfied, stabilize an important component of the software process.

The following characterizations of the five maturity levels highlight the primary process changes made at each level:

Level 1 - The Initial Level

At the Initial Level, the organization typically does not provide a stable environment for developing and maintaining software. When an organization lacks sound management practices, the benefits of good software engineering practices are undermined by ineffective planning and reaction-driven commitment systems.

The software process capability of Level 1 organizations is unpredictable because the software process is constantly changed or modified as the work progresses. Schedules, budgets, functionality, and product quality are generally unpredictable. There are few stable software processes in evidence, and performance can be predicted only by individual rather than organizational capability.

SOFTWARE MATURITY

Level 2 - The Repeatable Level

At the Repeatable Level, policies for managing a software project and procedures to implement those policies are established. Planning and managing new projects is based on experience with similar projects. An objective in achieving Level 2 is to institutionalize effective management processes for software projects, which allows organizations to repeat successful practices developed on earlier projects, although the specific processes implemented by the projects may differ. An effective process can be characterized as practiced, documented, enforced, trained, measured, and able to improve.

Level 2 organizations have installed basic software management controls. Realistic project commitments are based on the results observed on previous projects and on the requirements of the current project. The software managers for a project track software costs, schedules, and functionality, problems in meeting commitments are identified when they arise. Software requirements and the work products developed to satisfy them are baselined, and their integrity is controlled. Software project standards are defined, and the organization ensures they are faithfully followed. The software project works with its subcontractors, if any, to establish a strong customer-supplier relationship.

BASIC CONTROL

Level 3 - The Defined Level

At the Defined Level, the standard process for developing and maintaining software across the organization is documented, including both software engineering and management processes, and these processes are integrated into a coherent whole. This standard process is referred to as the organization's standard software process. Processes established at Level 3 are used (and changed, as appropriate) to help the software managers and technical staff perform more effectively. The organization exploits effective software engineering practices when standardizing its software processes. There is a group that is responsible for the organization's

software process activities. An organization-wide training program is implemented to ensure that the staff and managers have the knowledge and skills required to fulfill their assigned roles.

A well-defined process can be characterized as including readiness criteria, inputs, standards and procedures for performing the work, verification mechanisms (such as peer reviews), outputs, and completion criteria. Because the software process is well defined, management has good insight into technical progress on all projects.

Level 4 - The Managed Level

At the Managed Level, the organization sets quantitative defect goals for both software products and process. Productivity and defect level are measured for important software process activities across all projects as part of an organizational measurement program. An organization-wide software process database is used to collect and analyze the data available from the projects' defined software processes. Software processes are instrumented with well-defined and consistent measurements at Level 4.

These measurements establish the quantitative foundation for evaluating the project's software processes and products.

Projects achieve control over their products and processes by narrowing the variation in their process performance to fall within acceptable quantitative boundaries. Meaningful variations in process performance can be distinguished from random variation (noise), particularly within established product lines. The risks involved in moving up the learning curve of a new application domain are known and carefully managed.

Level 5 - The Optimizing Level

At the Optimizing Level, the entire organization is focused on continuous process improvement. The organization has the means to identify weaknesses and strengthen the process proactively, with the goal

MEASURABLE PROGRESS

DEFECT CONTROL

of preventing the occurrence of defects. Data on the effectiveness of the software process is used to perform cost benefit analyses of new technologies and proposed changes to the organization's software process. Innovations that exploit the best software engineering practices are identified and transferred throughout the organization.

Software project teams in Level 5 organizations analyze defects to determine their causes. Software processes are evaluated to prevent known types of defects from recurring, and lessons learned are disseminated to other projects.

The software process capability of Level 5 organizations can be characterized as continuously improving because Level 5 organizations are continuously striving to improve the range of their process capability, thereby improving the process performance of their projects. Improvement occurs both by incremental advancements in the existing process and by innovations using new technologies and methods.

Each of the maturity levels two through five are characterized by the availability of credible metrics to measure planned versus actual results. These metrics are:

METRICS

Level Two:

- (1) **Software Size** - This metric tracks changes in the size of the software being developed. Size is typically specified by source lines of code.
- (2) **Staffing Profiles** - This tracks the project's ability to maintain planned staffing levels and sufficient staffing for timely completion of the program.
- (3) **Software Units Designed, Tested and Integrated.**
- (4) **Computer Resource Utilization (Throughput, Memory and Communications Channels)**
- (5) **Testing of Deliverables** - This metric composes the actual versus planned system testing results.
- (6) **Code Errors** - This is a measurement of the rate at which software code errors are identified and

CHAPTER 8

SOFTWARE RELIABILITY

resolved.

- (7) **Cumulative Code Defect Plot** - This metric measures -cumulative software discrepancy reports over the life of the project.

Level Three:

This level includes the metrics described for level two plus the following:

- (1) **Design Errors** - This measures the rate of which software errors are identified and resolved during the design phase of the software development process.
- (2) **Development Progress** - This metric monitors progress by combining schedule weighting factors, percent complete estimates and weighted percent complete estimates based on relative difficulty of development.

Level Four:

Level Four metrics contains level three metrics plus the following:

- (1) **Earned Value Index** - This a composite metric that measures work progress in terms of percentage complete, labor hours charged and labor hours estimated.
- (2) **Production Rate** - This metric measures the software size (lines of code) per total labor hour charged.
- (3) **Requirements Traceability** - Measurement of requirements changes during the development cycle.
- (4) **Requirements Coverage** - This is the ratio of the total requirements met to the total number of requirements, plotted over time.
- (5) **Design Specification Change Rates** - This is the measure of changes caused by changed requirements or modified design.

Level Five

There are no new metrics required for this level.

The SEI maturity methodology is expected to be used throughout all acquisition phases with continuous progress towards level five monitored through the appropriate metrics noted above.

8.3 SOFTWARE FAILURE RATES

The fundamental focal points of this handbook is the prevention and/or elimination of failure. Inherent in this focus is the quantification of failure rates. Each of the acquisition phase descriptions contains requirements for the quantification of failure rates both through an allocation process in the early acquisition phases and prediction process in the later acquisition phases. Similar methodologies need to be applied to software.

Software and hardware differ in several respects. Software does not wear out. Once a software failure is corrected it is gone forever; many hardware faults can recur. However, hardware and software reliability are very similar. Both a running program and an operating hardware item can be seen as "black boxes." Every once in a while the black box fails. For software, time brings with it a succession of input states. The more time that goes by, the higher the quantity of, and the more variety of, input states the program encounters. Eventually, because of the presence of defects, an input state will trigger a failure. Thus both hardware and software reliability can be modeled as random processes.

There are two terms relating to software reliability that are used in the following paragraphs. These terms are failure and defect. As used herein, a failure is an observed malfunction of the software, a defect is the deficiency that causes or can cause failure.

A software failure occurs when the program produces output that deviates from what the requirements specify. A failure can be one of conformance, in which the program does not produce the right answer, or one of performance, in which the program does not perform a required function in a timely manner. Performance failures

HARDWARE AND SOFTWARE FAILURES

include crashes, hangs, and software that does not meet its response or throughput time requirements.

Software failures arise from a population of software defects. A software defect is missing, extra, or defective code that has caused or can potentially cause a failure. Every time a defect is traversed during execution, a failure does not necessarily ensue; it depends on the machine state (values of intermediate variables). The extent to which a program contains defects may be expressed in defects per thousand lines of executable source code (KLOC).

These defects can occur during any of the four primary phases of software development; 1) requirements definition, 2) preliminary design, 3) detail design and 4) coding. Defects during these phases are affected by factors such as the frequency of changes to program specification, programmer skill and the volume of program design documentation. Control of these factors is the key to failure prevention.

DEFECT FACTORS

8.3.1 FAILURE RATE ALLOCATION

Allocation of failure rate consists of finding an achievable combination of failure rates that supports achievement of a system's or subsystem's requirements. The failure rates cannot have just any values; values are constrained by a range that is realistically achievable. An acceptable allocation is one in which all rates lie within their achievable ranges and the overall subsystem or system meets or exceeds the requirements. The rates can be chosen arbitrarily but ideally would be chosen based on intuition and on experience with similar and previous-generation items. If the allocated values ensure that the system requirements are met, the allocation is complete and any "excess" can be either allocated to another part of the system, or reserved as a means of mitigating risk.

The failure rate allocation process, at any level in the software hierarchy, should apply a "Six Sigma" approach to software defect reduction since the prevention of defects is the key to the prevention of

SIX SIGMA

failures. The baseline level of defects is based on prior experience. It is recommended that benchmarking be used as a tool to identify the best (i.e. fewest defects) examples of prior software developments. Generally this benchmarking can be applied within an organization. The objective is to identify both the lowest defect software development and the processes used in the development. Having established the "best" baseline, the allocation process must establish improvement targets to be achieved through techniques such as software simplification and check lists based on root cause analysis.

Once the system functionality is partitioned into hardware and software subsystems, the levels of software hierarchy are established through DOD-STD-2167A methodology. The levels of software decomposition, such as computer software components (CSCs) and computer software configuration items (CSCIs), refer to parts of the static program as it is viewed for the purpose of configuration management. When executing, the software subsystem will exhibit a dynamic structure. Allocation should take place at the level at which individual threads of execution (processes" or "tasks") exist. Generally, this level corresponds to the CSCI level. This level is also appropriate for allocation because the interfaces among modules are included.

The allocation techniques identified herein are "Allocation Based on Achievable Failure Rates," "Equal Apportionment", "Proportional Allocation," "Weighted Allocation," "Constrained Allocation," and "Re-allocation."

ALLOCATION TECHNIQUES

The bottom-up allocation method, "Allocation Based on Achievable Failure Rates" requires the ability to estimate CSCI utilization rates. This method provides a set of allocations to each CSCI which accurately reflect the planned usage and the execution time available for achieving reliability growth. If failure rate allocations provided by this method do not support achievement of the system or subsystem requirements it is an indication that there

may be a problem with the specification requirements or one or more higher level allocations.

In "Equal Apportionment," the components of an aggregate are allocated equal rates in such a way that the aggregate meets its reliability goal.

"Proportional Allocation" takes into account the length of time each component is active. the longer a component is active, the more exposure it has to the possibility of failure. The premise of proportional allocation is that higher reliability should be demanded of components that active for a greater share of the time relative to the other components.

In "Weighted Allocation," the rate allocated to a component is based on the criticality of the component and/or feasibility of its meeting a reliability objective. The criticality of the component includes the consequences of the failure to mission success and safety.

In "Constrained Allocation," the allocation is optimized with respect to additional considerations such as cost.

In "Re-allocation," a previous allocation is revised because one or more components could not meet their reliability objectives.

Details concerning these allocations techniques can be found in Rome Laboratory Report RL-TR-92-15, "Reliability Techniques for Combined Hardware and Software Systems," or MIL-HDBK-XXX, Draft Military handbook, "Hardware/Software Reliability Assurance and Control," dated 6 December 1991.

8.3.2 FAILURE RATE PREDICTIONS

Hardware reliability prediction provides a failure rate which, in theory, is the best reliability achievable as the development and manufacturing processes are perfected. Software does not have the same kind of limitation. The reliability of software will generally improve over time as failures are uncovered through testing and are fixed. When software reliability is predicted, that prediction must be related to a point in time.

The technique for software failure rate prediction uses metrics derived from characteristics of the software development process and of the products. They are consistent with the metrics required as part of the SEI Maturity Model approach to continuous improvement. These metrics are as follows:

Metric #1 - is the number of errors in the Software Requirements Specification (SRS).

Metric #2 - is the number of requirements statements in the SRS.

Metric #3 - is the number of pages in the SRS,. Writing style will account for a small, unavoidable, variation in this metric.

Metric #4 - is the effort expended, in man-months, on the requirements analysis phase.

Metric #5 - is the number of changes (corrections and modifications) to the SRS after it has been placed under configuration control.

Metric #6 - is the number of errors in preliminary design documents.

Metric #7 - is the number of Computer Software Components (CSCs) in the software structure.

Metric #8 - is the number of Computer Software Units (CSUs) in the design structure.

Metric #9 - is the number of pages in the Software Design Documents (SDDs).

Metric #10 - is the number of man-months expended for preliminary design.

Metric #11 - is the average number of times a unit is tested by the programmer during CSU testing.

Metric #12 - is the sum of the number of design errors identified after the SDD has been placed under configuration control, the number of design errors identified as the result of internal reviews, and the number of faults found through code reviews and related inspections.

Metric #13 - is the total number of executable lines of source code.

As noted, these process metrics, are consistent with the SEI maturity index metrics described in paragraph 8.3.1. When used in conjunction with experience based formulae, the above data permit the assessment of initial software failure rates at various stages of development. These stages are requirements analysis, preliminary design, detail design, coding, and software module/system testing. The empirical formulae may be found in Section 5 of MIL-HDBK-XXX, Draft Military Handbook:

"Hardware/Software Reliability Assurance and Control," dated 6 December 1991. This draft handbook also contains a procedure for predicting failure rates very early in the development process when only the program size and processor speed may be known.

The flowdown of quantitative failure rate requirements and the prediction of achieved values as detail knowledge becomes available, sets the stage for preventing/eliminating failures through the use of software reviews coupled with root cause analysis.

PREDICTION FORMULAE

8.4 DEFECT PREVENTION TECHNIQUES

To achieve reliable software products, most development processes rely on defect detection and correction through inspections, walkthroughs, and reviews early in the development cycle, and through extensive testing.

Inspections and walkthroughs are peer/customer examinations aimed at assisting the program developers in improving their work by detecting defects. They are the direct analog of the Design Review Activities described in Chapters two through six.

Software inspection is a powerful technique for improving the quality of software development. This objective is achieved by helping the software developer recognize and fix their own errors early in the process and to gather data on defects that can be

used for improving the software development process. Inspections are labor intensive but are very effective for eliminating defects. The inspection process involves a peer review of the developing software with emphasis on error detection and correction. These inspections should be conducted at every point in the development process. In addition to inspecting new product elements, every change should be inspected and re-inspections of an entire element are needed when there is substantial change activity or if inspection/test results indicate unusual problems. Checklists are also important to the success of the inspection, insuring that all details of the process are covered. In all cases, the inspection should take place with a clear set of entry and exit criteria in place.

As defects are identified they are recorded and discussed. Particular attention is paid to previously undetected defects. The developer of the software product is charged with the responsibility for correcting the error. The corrected products must be re-submitted to the inspection team to verify the adequacy of the correction. A complete inspection process will consist of planning, preliminary review, inspection meeting, defect correction and follow-up.

A walkthrough is a less intensive review of a software product than an inspection. They are also less formal and do not generally involve the rework and follow-up required in inspections. Errors found during a walkthrough are, however, documented, usually in the form of a results report.

True defect prevention requires combining causal analysis with inspections/walkthroughs. Defects are analyzed to determine the cause of the error, how to prevent the error and how to remove similar defects that may exist in the rest of the software. This causal analysis should be done by the software development team during the development process. Causal analysis by the developer making the error results in a more accurate determination of the true error cause and more relevant prevention actions.

There are four key elements in a defect prevention process: 1) systematic causal analysis, 2) management support, 3) on-going development team meetings and 4) a database and tools for data collection and tracking of actions.

DEFECT PREVENTION KEYS

The causal analysis should take place once the defects from a software development stage have been discovered and corrected by virtue of inspections and walkthroughs. For each defect the following questions can be posed:

- 1) What is the error category (communication, oversight, education or transcription)
- 2) How was the error introduced or caused
- 3) At what stage was the error created
- 4) How can the error be prevented in the future and how can similar errors be detected and removed from other elements of the program.

Repeated causal analyses reviews should take place during any software development phases during which numerous errors are likely to be detected.

Preventative actions resulting from these causal analysis reviews generally fall into several categories:

- 1) Process improvements
- 2) Tool enhancement
- 3) Education
- 4) Software product changes
- 5) Communications improvements

These preventative actions are reported and saved in a lessons learned file that may include items such as error lists, inspection or walkthrough checklists, coding or performance guidelines, and training improvements.

8.5 CONCLUSIONS

The approach to software defect prevention described in this chapter, parallels the hardware process described in Chapters 2 through 6. A framework for ensuring the implementation of continuous improvement during all acquisition phases is

provided by the SEI Capability Maturity Model. Each acquisition phase requires many of the same activities and outputs for both hardware and software. Quantitative measures of defect levels for software can be allocated and predicted in a manner similar to that applied to hardware. The development of these defect estimates use many of the metrics required by the SEI model. Defect prevention takes place through the continuous application of design reviews and the implementation of a systematic causal analysis process.

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