

**Department of Defense
Reliability and Maintainability Engineering Management
Body of Knowledge**



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**Department of Defense Reliability and Maintainability Engineering Management
Body of Knowledge**

Deputy Assistant Secretary of Defense
Systems Engineering
3030 Defense Pentagon
3C167
Washington, DC 20301-2030

www.acq.osd.mil/se

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INTRODUCTION

PURPOSE AND SCOPE

The purpose of reliability and maintainability (R&M) engineering (maintainability includes built-in-test (BIT)) is to influence system design to increase mission capability and availability, and decrease logistics burden and cost over a system's life cycle. Properly planned, R&M engineering reduces cost and schedule risks by preventing or identifying R&M deficiencies early in development. This early action results in increased acquisition efficiency and higher success rates during operational testing and the development process.

This document presents procedures for Department of Defense (DoD) Program Managers (PM), project engineers, and R&M engineers to use to achieve and control R&M requirements in Major Defense Acquisition Programs (MDAP) and designated special interest programs. The recommendations are derived from the [DoD Instruction \(DoDI\) 5000.02](#), "Operation of the Defense Acquisition System," the basis for DoD acquisition policy and guidance.

These procedures influence the design early and are intended to allow PMs to make sound R&M decisions at critical "in-process" review points and major transitional milestones in the defense acquisition life cycle. The procedures emphasize effective R&M planning, the importance of clearly defined contractual quantitative R&M requirements, and tailored R&M activities.

In addition, the procedures identify R&M activities in each phase of the system life cycle and describe the controls the activities afford. The PM can contractually specify those R&M activities that best fit the particular program to ensure the program achieves the R&M requirements pertinent to each phase of the acquisition life cycle. The R&M activities are applicable for all new-start programs and for programs that have the opportunity to implement these activities preceding each phase of the acquisition life cycle.

The following paragraphs provide an overview of R&M policy and guidance, R&M principles, responsibility for R&M controls, and R&M objectives for each acquisition phase.

POLICY AND GUIDANCE

The R&M policy for DoD materiel is established in the DoDI 5000.02. The responsibility for achieving R&M throughout the life cycle is assigned to the heads of the DoD Components. This responsibility requires PMs for MDAPs to implement a life cycle R&M engineering program.

Related guidance documents include the Reliability, Availability, Maintainability, and Cost (RAM-C) Rationale Report Outline Guidance, and the Systems Engineering Plan (SEP) Outline. The RAM-C Report and the SEP are examples of planning documents that should span the lifecycle of the program and therefore appear as activities during different acquisition phases. Program planning documents should contain appropriate language describing the tailoring of R&M engineering activities based on the program acquisition strategy, equipment type, or design status. These procedures will be updated as needed to reflect changes in referenced documents.

Results of R&M engineering activities are essential for programmatic decision and control functions. The R&M design methods and procedures are not new, but the challenge occurs in the diligent management of these methods and procedures to achieve reliable and maintainable systems. Effective management control of the R&M program, using the policies and guidance set forth by DoD, will ensure timely performance of the necessary activities to achieve the requirements and the development of adequate data to judge the acceptability of R&M achievement at major milestones.

R&M PRINCIPLES

R&M Parameters

Reliability is the probability that an item will perform its intended function for a specified interval under stated conditions. *Maintainability* is a characteristic of design and installation that is expressed as the probability that an item will be retained in or restored to a specified condition within a given period of time, when the maintenance is performed in accordance with prescribed procedures and resources.

R&M parameters are important characteristics used in measuring the operational suitability and effectiveness of DoD weapon systems. R&M parameters also relate to other system parameters, primarily those that characterize the system performance, availability, logistics supportability, and total ownership cost. The R&M parameters and particular levels of performance support other system parameters essential to the success of the mission. For information systems, the availability parameter is the important characteristic when measuring operational suitability and effectiveness. The emphasis is to minimize non-recoverable failures that prevent the system from achieving the required availability.

Maintainability parameters are a characteristic of outage frequency and time to restore to achieve the required availability. Parameters must also consider the maintenance methods and frequencies (time to implement software patches, installation of new releases, etc.). The reliability-maintainability-availability and cost relationship for these particular levels of performance provides a measure of system effectiveness within which considerable trade-off potential usually exists. This potential should be reevaluated at each stage of system development to optimize the balance between reliability, maintainability, availability, and other system performance parameters with respect to technical risks, life cycle cost, acquisition schedule, and operating and maintenance requirements. These requirements have become increasingly important as complexity of system designs increases, dictating the need for integration of system diagnostics monitoring and checkout provisions in the basic design. For MDAPs, the RAM-C Report Outline Guidance describes this relationship and the associated trade-off process.

R&M Activities by Functional Area

Frequently, programs that did not implement an R&M program find during Initial Operational Test and Evaluation (IOT&E) that their weapon systems do not meet the thresholds initially established for the systems. This trend can be halted and reversed if PMs recognize its inevitability in the early phases of materiel acquisition, when a realistic appraisal of R&M

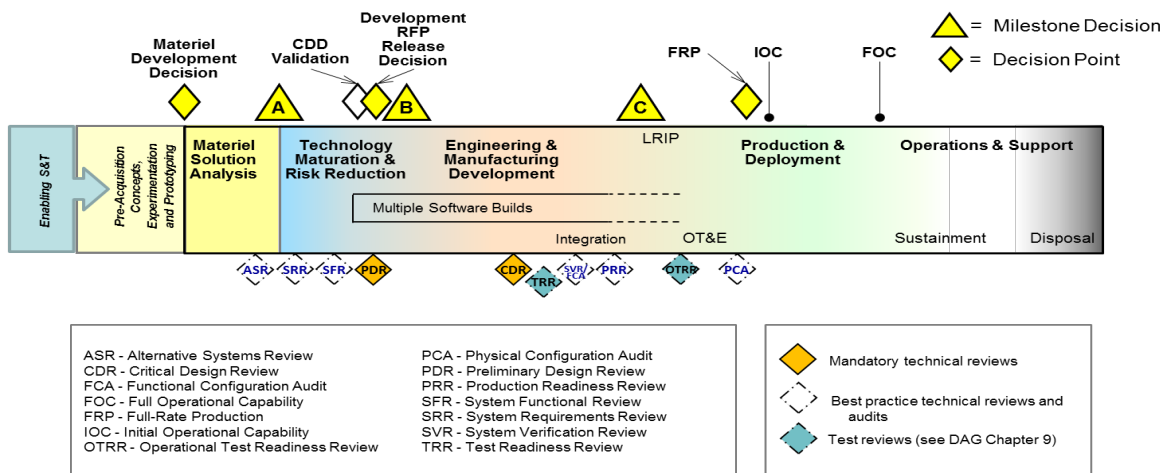
feasibility in the proposed new design is essential. Evidence from program reviews and testing demonstrate that programs achieve effective R&M only when they apply procedures in a systems engineering approach to materiel acquisition. This approach demands that program personnel remain mindful of the importance of R&M during all phases and in all functional areas of acquisition management. The R&M activities, procedures, and review criteria are allocated to the functional areas into which a program can normally be divided:

- *R&M Engineering Management* – pertaining to the planning, definition, and implementation of R&M activities, procedures, in-process reviews for compliance, and R&M decision-making criteria. The R&M engineer should ensure that all the R&M activities are properly integrated across all functional areas of the program for an effective R&M engineering program.
- *Systems Engineering* – pertaining to R&M design analyses, trade-off study, R&M problem and correction, and R&M design support. Systems engineers and contractors should establish and execute the in-process reviews, technical reviews, and milestone reviews necessary to achieve the degree of R&M integration in functional areas of a program.
- *Test and Evaluation* – pertaining to planning and conducting tests for evaluation and demonstration of R&M.
- *Procurement* – pertaining to the definition, documentation, and review of R&M requirements and provisions in procurement requests, requests for proposals, contracts, and exhibits.

HOW TO USE THE BODY OF KNOWLEDGE

Determine the Life Cycle Phase

Determine the acquisition life cycle phase (Figure 1) to which the design of each item or piece of equipment has progressed, keeping in mind that activities in previous phases may still be relevant or required in order to proceed.



Notes:

- Derived from DoDI 5000.02 Hybrid "A" Model.
- The actual number and type of builds during the program will depend on system type and program strategy.

Source: Defense Acquisition Guidebook

Figure 1. Major Phases of Defense Acquisition Life Cycle

Determine Functional Area

R&M activities within each of these life cycle phases are grouped according to the functional area or in which R&M data are needed for the activity or for a technical decision. Identify the activities within each of the following functional areas and determine the specific decision points required for effective in-process review:

- R&M Engineering Management
- Systems Engineering
- Test and Evaluation
- Procurement

Table 1 lists the DoDI 5000.02 R&M engineering activities, functional area, and life cycle phase in which they should occur.

Table 1. R&M Engineering Activities by Functional Area

Functional Area	R&M Engineering Activities	MSA	TMRR	EMD	P&D	O&S
R&M Engineering Management	Formulate a comprehensive R&M program using appropriate reliability growth strategy	•	•	•	•	•
R&M Engineering Management	Integrate R&M Engineering Program in SEP including a system reliability growth curve	•	•	•		
R&M Engineering Management	Prepare/Update RAM-C Report and attach to the SEP	•	•	•		
R&M Engineering Management	Report R&M status during formal design review process and technical reviews (SRR, PDR, CDR, etc.)	•	•	•		
R&M Engineering Management	Prepare reliability growth assessment of the likelihood of meeting the CDD threshold by IOT&E			•		
R&M Engineering Management	Evaluate reliability growth and report status in DAES reviews until the threshold is achieved		•	•	•	
Systems Engineering	Prepare allocations of R&M requirements	•	•			
Systems Engineering	Prepare R&M Block Diagrams	•	•	•		
Systems Engineering	Predict R&M to estimate feasibility	•	•	•		
Systems Engineering	Prepare/Update failure definitions and scoring criteria	•	•	•		
Systems Engineering	Perform FMECA with supporting Software FMEAs		•	•		
Systems Engineering	FRACAS		•	•	•	•
Test & Evaluation	Demonstrate specified maintainability and Built-In-Test development		•	•		
Test & Evaluation	Specify in the TEMP how R&M will be tested and evaluated in the associated acquisition phase	•	•	•		
Test & Evaluation	Perform system/subsystem reliability growth testing		•	•	•	
Procurement	Define the activities, processes and R&M requirements to be stated in the RFP	•	•	•	•	
Procurement	Describe in the Acquisition Strategy the activities, processes and R&M requirements to be stated in the RFP. Describe how R&M values in CDD/CPD have been translated into design and contract requirements	•	•	•	•	
Procurement	Translate CDD/CPD R&M values into design and contract requirements	•	•	•		

CDD: Capability Development Document; CDR: Critical Design Review; CPD: Capability Production Document; DAES: Defense Acquisition Executive Summary; FMEA: Failure Mode and Effects Analysis; FMECA: Failure Mode, Effects, and Criticality Analysis; FRACAS: Failure Reporting, Analysis, and Corrective Action System; IOT&E: Initial Operational Test and Evaluation; PDR: Preliminary Design Review; R&M: reliability and maintainability; RAM-C: reliability, availability, maintainability, and cost; RFP: Request for Proposals; SEP: Systems Engineering Plan; SRR: System Requirements Review; TEMP: Test and Evaluation Master Plan

R&M OBJECTIVES WITHIN THE ACQUISITION LIFE CYCLE

The following paragraphs highlight R&M objectives for each life cycle acquisition phase.

1. Materiel Solution Analysis (MSA) Phase

The Initial Capabilities Document (ICD) describes the need for a new system or capability. The Service acts on the ICD by developing an Analysis of Alternatives (AoA). The AoA should include the estimated R&M performance and maintenance concepts for each alternative investigated. The primary objectives of this phase are to:

- Develop a technically feasible, cost-effective, and logistically supportable design concept to satisfy the draft Capability Development Document (CDD) threshold for a new system, for release to the Technology Maturation and Risk Reduction (TMRR) phase.
- Translate draft CDD thresholds to design requirements; develop initial performance expectation and contractual documentation that clearly define prospective quantitative R&M requirements, the R&M verification criteria, and the contractor R&M engineering activities required in the follow-on TMRR phase.
- Identify technical problems and associated technology risks that either have not been identified, have not been adequately investigated, or have not been clearly documented.

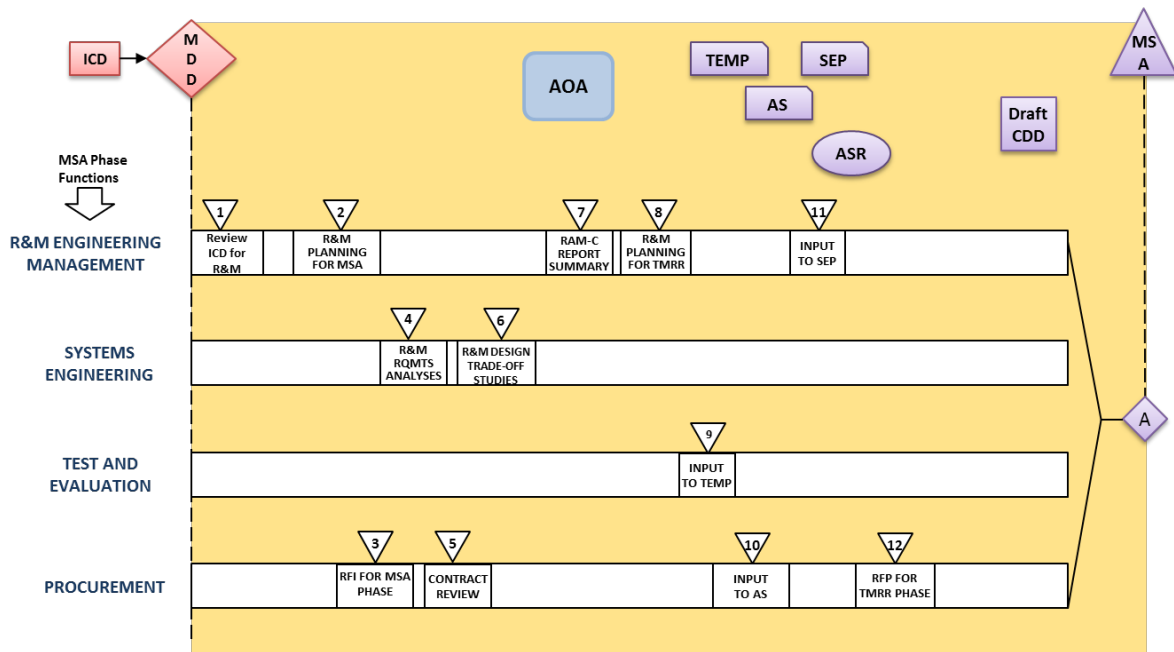


Figure 2. MSA Phase R&M Activities by Functional Area

Figure 2 lists the primary activities necessary to achieve MSA phase R&M objectives, in approximate chronological order. The PM can develop the R&M program around the activities that best fit the particular program and thus acquire the degree of control needed to ensure attainment of the specified R&M requirements. Some core MSA activities include:

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- Estimate the feasibility of the R&M draft CDD thresholds using block diagrams and math models and preliminary prediction analysis.
- Perform trade-off studies among R&M, availability, and other system performance parameters to verify optimum balance using techniques in the [DoD Reliability, Availability, Maintainability, and Cost \(RAM-C\) Rationale Report Outline Guidance](#)
- Support development of system use cases defining desired system behavior for failures including software maintenance (e.g., installing new release or patch).
- Prepare initial specifications and include quantitative R&M requirements, operational mode summary/mission profile (OMS/MP), system duty cycles, success/failure definition and scoring criteria, functional and alternative modes of operation, specific R&M design characteristics, utilization rates, and reporting requirements.
- Describe TMRR phase R&M program plans, design reviews, and program reviews at major program milestones and criteria for acceptance.
- Use data from the RAM-C Rationale Report to provide the following for logistics design support:
 - a. The initial failure mode assessment, including effects of failure on system performance and the probable manner in which each failure mode would be detected to provide guidance to planning and conceptual design of the diagnostics concept, recovery designs, and maturation process.
 - b. Failure rate and removal rate estimates, for both corrective and preventive maintenance, to provide a realistic basis for equipment and replaceable unit spares provisioning planning.
- Define the appropriate contractor R&M engineering activities for analysis; design review; allocation; block diagram and modeling; predictions; Failure Mode, Effects, and Criticality Analysis (FMECA) with supporting software Failure Mode and Effects Analysis (FMEA); subsystem and system-level growth planning activities; failure reporting, analysis, and corrective action, etc., in the Request for Proposal (RFP) and contract Statement of Work (SOW) for the TMRR phase.
- Identify R&M drivers and associated risks, validate reliability growth strategies, ascertain that proposed alternatives prove the feasibility of accomplishing R&M requirements, and modify requirements as required to demonstrate feasibility and practicality.
- Prepare and document R&M inputs, including the system reliability growth planning curve, to the SEP and Test and Evaluation Master Plan (TEMP) before soliciting Service approval for Milestone A.

When the program accomplishes the objectives and provides supporting analysis, the Milestone Decision Authority (MDA) convenes a milestone review or its equivalent for a decision on permitting the program to move into the TMRR phase.

Material Solution Analysis Results

- R&M requirements developed.
- Initial maintenance concept established.
- Conceptual design approaches formulated and R&M feasibility confirmed analytically.

- R&M thresholds in the draft CDD validated and documented in RAM-C Report.
- R&M engineering activities included in the TMRR contract.

Initiate a materiel solution.

2. Technology Maturation and Risk Reduction Phase

The TMRR phase starts with additional detailed concept and technology development to define the design requirement in the system specification resulting from the MSA phase. The TMRR phase is completed when the following objectives are accomplished:

- The preliminary design, specifications, and design data are adequate for Engineering and Manufacturing Development (EMD).
- The technical feasibility of the design has been confirmed.
- The allocated baseline for contract definition has been established for the follow-on EMD phase.

Technology Maturation and Risk Reduction Phase

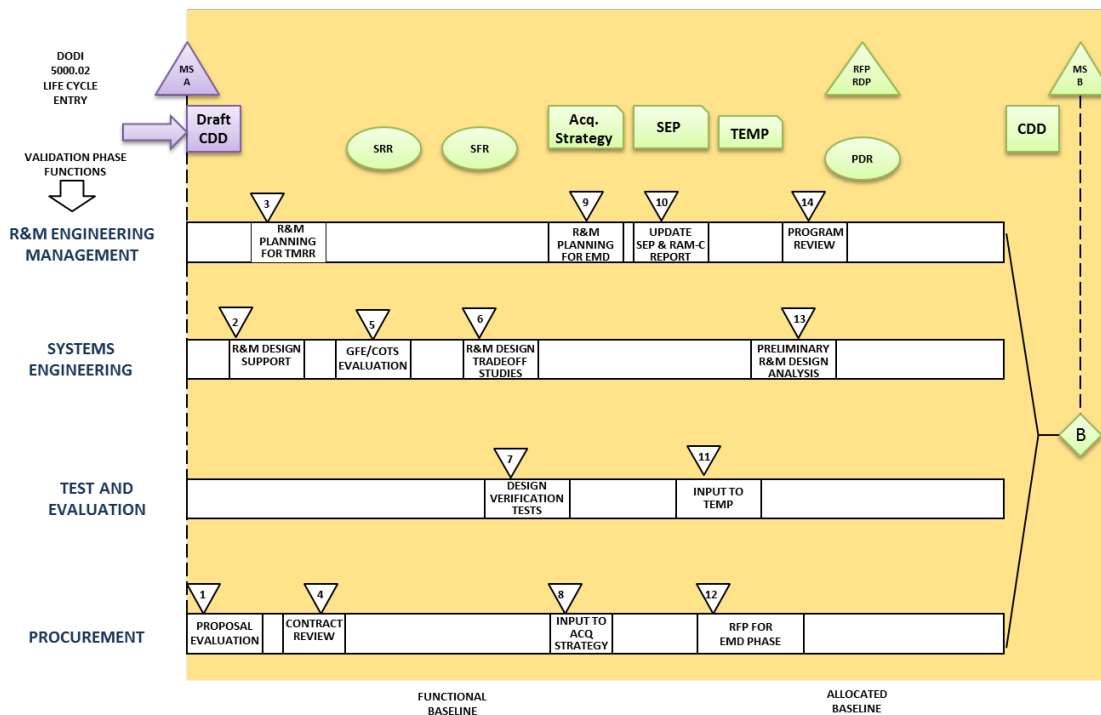


Figure 3. TMRR Phase R&M Activities by Functional Area

Figure 3 lists the R&M activities for the TMRR phase in approximate chronological order. Some core TMRR activities include:

- Provide design guidance by conducting in-process design reviews to monitor and evaluate R&M engineering design activities (e.g., modeling, allocations, predictions, FMECA, applicable tests, and analysis of data).
- Conduct a Preliminary Design Review (PDR) to ensure special design emphasis and test effort is applied to critical system components and failure modes, identified by the preliminary FMECA (with supporting software FMEA) that could result in personnel injury or mission loss. Assess the modeling, allocations, and predictions of the proposed design configuration to verify conformance to the specification requirements.
- Evaluate R&M modeling, allocation, and prediction analyses to identify potential problem areas.
- Integrate R&M engineering analyses with product support in the following areas: requirements and functional analysis for the maintainer; test and demonstration planning; Reliability-Centered Maintenance (RCM) and Condition-Based Maintenance Plus (CBM+); and refinement of the maintenance concept, including the preliminary Level of Repair Analysis (LORA) and maintenance task analysis.
- Contribute to preliminary integrated test planning to provide a cost-effective test program that will integrate and coordinate all testing (from equipment to system level) to afford a more complete utilization of all test data for R&M assessment. The program should integrate test planning events into the EMD Integrated Master Schedule. Test planning should include equipment and subsystem reliability growth and maintainability and Built-in Test (BIT) demonstrations where appropriate.
- Incorporate R&M quantitative requirements, test requirements and verification methods, data requirements, and specific contractor R&M engineering activities, e.g., models, allocations and prediction analyses, FMECA, parts and materials program, design reviews, a closed-loop FRACAS, etc., in the specifications and contract documents for the EMD phase.
- Prepare and document the R&M inputs in the SEP and TEMP prior to soliciting approval.

After determining that the TMRR requirements have been met and the MDA has confidence that the program is ready to proceed into detailed design and development, the milestone review process continues. The RAM-C Report is updated to reflect any changes that resulted from the TMRR phase. The milestone review or its equivalent is convened and the decision for commitment to EMD is made.

Technology Maturation and Risk Reduction Results

- R&M design approach and initial maintenance concept, optimized by trade-off and conformance to specified requirements, verified analytically.
- Critical technology areas identified, and risk reduced via prototype test.
- R&M engineering activities and acceptance criteria updated in specifications and contract documents.

3. Engineering and Manufacturing Development Phase

The results of the TMRR phase are translated into the development effort, to produce initial production-representative articles for engineering evaluation and Service tests. The RAM-C Report will provide a clear statement of how the system’s sustainment requirements will be measured throughout the EMD, P&D, and O&S phases. At Milestone B, the RAM-C Report will be submitted with the SEP. The general objectives of the EMD phase are as follows:

- Production-representative system configuration, materials, and manufacturing techniques and processes should demonstrate conformance to the contractually specified requirements.
- Technical data and proposed contractual documentation are complete and ready for release to production.
- Logistic and maintenance support plans and provisions are adequate and demonstrate conformance to specified requirements for test equipment, tools, technical data, spares and repair parts, training, etc.

Engineering & Manufacturing Development Phase

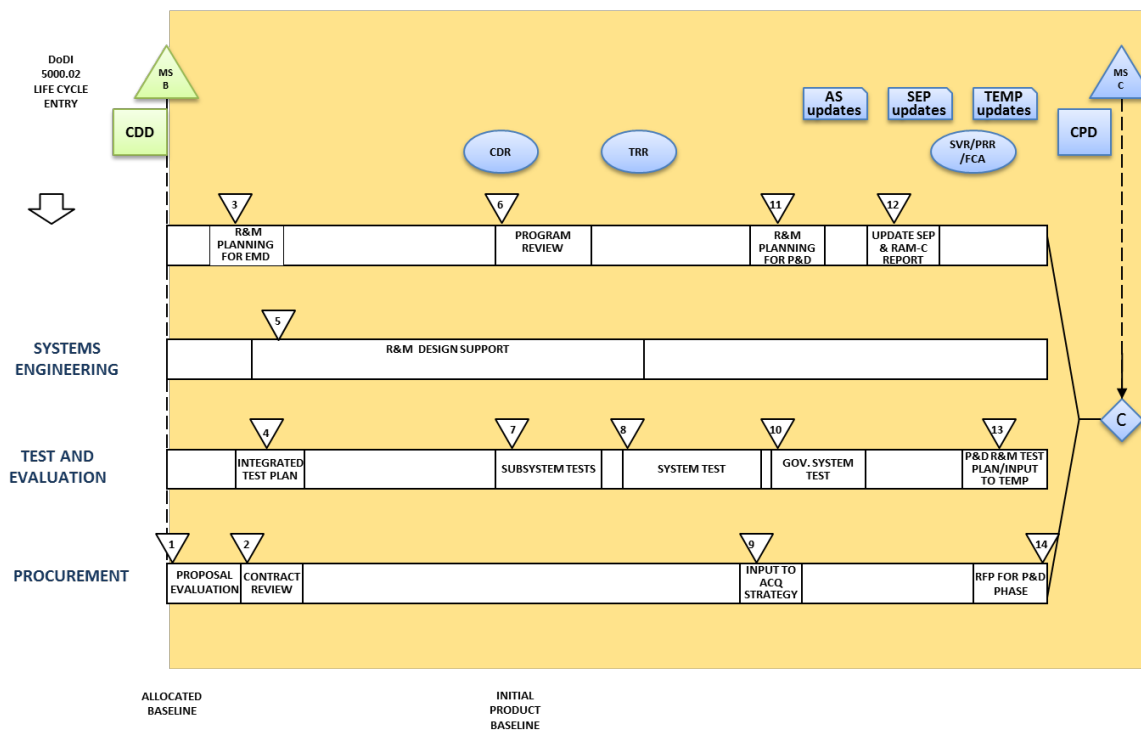


Figure 4. EMD Phase R&M Activities by Functional Area

Figure 4 lists the R&M activities to be addressed in this phase in approximate chronological order in. Some core EMD activities include:

- Describe in the SEP the R&M program for monitoring and evaluating contractor, subcontractor, and supplier conformance to contractual R&M requirements.
- Conduct design reviews, R&M assessments, and problem evaluations at scheduled milestones. Assign and follow up on action items to correct noted deficiencies and discrepancies.

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- Conduct a CDR to ensure that the product baseline design and required testing can meet the R&M requirements, the final FMECA identifies any failure modes that could result in personnel injury and/or mission loss, and the detailed prediction to assess system potential to meet design requirements is complete.
- Perform specified development, qualification, demonstration, and acceptance tests to show conformance to contractual R&M requirements and assess the readiness to enter system-level reliability growth testing at or above the initial reliability established in the reliability growth curve in the TEMP. Verify the adequacy of corrective action taken to correct design deficiencies.
- Ensure the Software Development Plan (SDP) and TEMP include software test methods to identify and correct software failures and that there is high degree of confidence the system can be recovered from any software failures that may occur after fielding.
- Implement a FRACAS to ensure feedback of failure data during test to design for corrective actions. Provide a data-collection system for data storage and retrieval suitable for R&M tracking analysis and assessment.
- Coordinate with Operational Test Agencies (OTAs) to ensure that the data collection, R&M monitoring, and failure definition and scoring processes are compatible with the processes of both the OTA and the program office to evaluate contractual and operational R&M performance and suitability characteristics.
- Ensure the configuration control program includes the total life cycle impact (including R&M) of proposed changes, deviations, and waivers. Ensure the systematic evaluation, coordination, timely approval or disapproval, and implementation of approved changes.
- Apply and evaluate allocation and prediction analyses using latest test data to identify potential R&M problem areas.
- Prepare initial production release documentation to ensure adequate R&M engineering activities in production test plans, detailed drawings, procurement specifications, and contract SOW. Ensure that documentation provides adequate consideration of R&M in re-procurements, spares, and repair parts.

When the program has accomplished the objectives of the EMD phase and the system has demonstrated adequate progress toward achieving the contractual requirements, the MDA convenes a milestone review or its equivalent to consider approval for commitment of resources for initial production and deployment. Although system-level R&M requirements may have been achieved, subsystem and Component R&M failing their individual R&M requirements can affect logistics, support equipment, and manpower.

Engineering and Manufacturing Development Results

- Conformance to specified R&M requirements and maintenance concept verified by appropriate demonstration and test.
- R&M requirements and control procedures defined in production release documentation.

4. Production and Deployment Phase

The production-representative design is translated into a production system in accordance with the production release documentation developed during the EMD phase. The P&D phase may be initiated by a limited or pilot run to provide additional assets for test and evaluation. If successful, the Full-Rate Production program is implemented for the procurement of quantities required for deployment. The objectives of the production phase are as follows:

- Consistently manufacture, and deliver to the operational forces, equipment and systems that meet the R&M thresholds specified in the CPD.
- Deliver the technical data, support equipment, operating and maintenance instructions, etc., required for system operation and maintenance in the field.
- Provide the required quantities, of specified quality and in correct proportions, of maintenance spares, repair parts, contractor augmented support, operating and maintenance manuals, trained personnel, etc., to achieve and sustain specified CPD thresholds.
- Update R&M predictions and FMECAs based on production tests, demonstration tests, operational evaluation, and field results and apply to the models previously developed to assess maintenance procedures, spares, manpower, packaging design, test equipment, and other mission and logistics impacts.
- Continue to implement a FRACAS by maintaining surveillance of systems in the field through a maintenance data collection system to correct problems in the operational environment.

Production & Deployment Phase

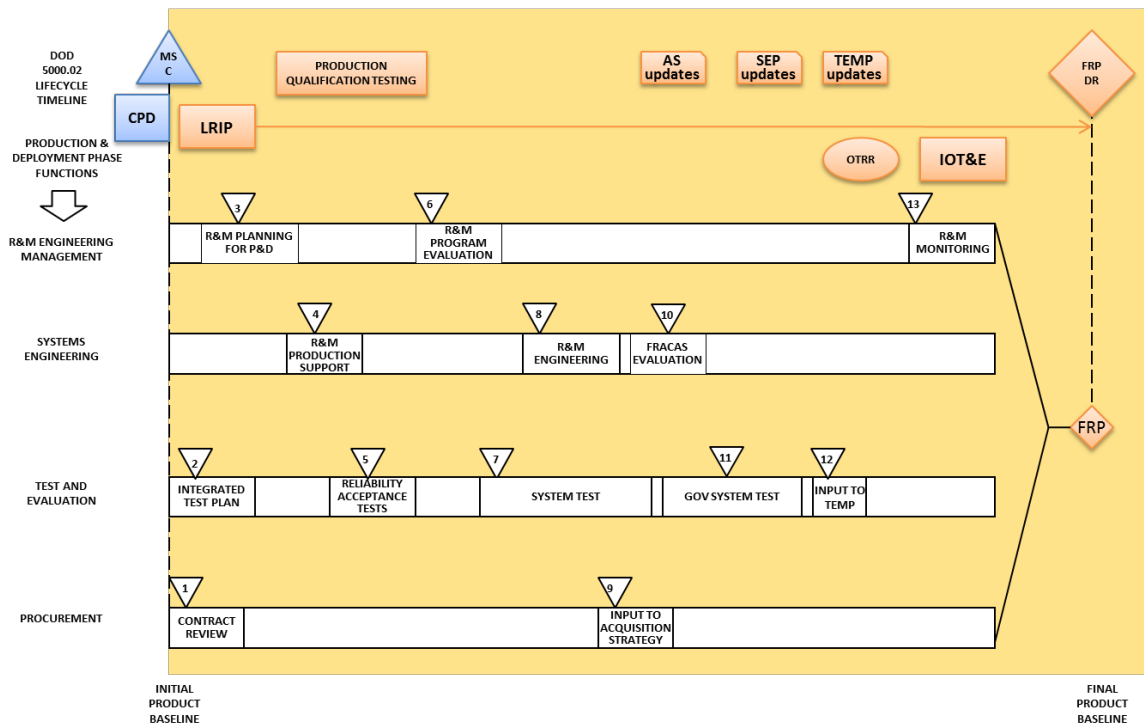


Figure 5. P&D Phase R&M Activities by Functional Area

The R&M activities to be considered during the production phase are listed in approximate chronological order in Figure 5. Some core P&D activities include:

- Describe the R&M program planning for monitoring contractor, subcontractor, and supplier conformance to specification and contractual requirements.
- Monitor the production process and evaluate trends reflected in results of production tests and acceptance tests, to determine the impact on R&M.
- Identify all discrepancies and implement corrective action to prevent recurrence.
- Review Engineering Change Proposals (ECPs), operational mission/employment changes, deviations, and waivers for impact on R&M, as a routine function of the configuration control procedure.
- Monitor acceptance tests to exercise control of process variation, workmanship errors, and other R&M-degrading production discrepancies.

Production and Deployment Results

- Initial production control of R&M degradation factors verified by test, production data analysis, and supplemental tests.
- R&M characteristics, maintenance concept, repair policies, Government test and evaluation and IOT&E, and maintenance procedures verified by Follow-on Operational Test and Evaluation (FOT&E).

5. Operations and Support Phase

The O&S phase of a system begins with its introduction to service use and ends with its removal from use. The basic objectives of this phase are as follows:

- Operational features and characteristics (including R&M) achieved in EMD and maintained under control throughout initial production are experienced consistently in the field under operational conditions.
- Operational and maintenance documentation, training programs, spares and repair parts, provisioning plans, and other features of the product support package are adequate to support the system in the operational environment.

Figure 6 identifies the R&M activities during the O&S phase. The activities should show the continuation of the iterative design-evaluate-redesign-reevaluate doctrine practiced in design and development.

Operations & Support Phase

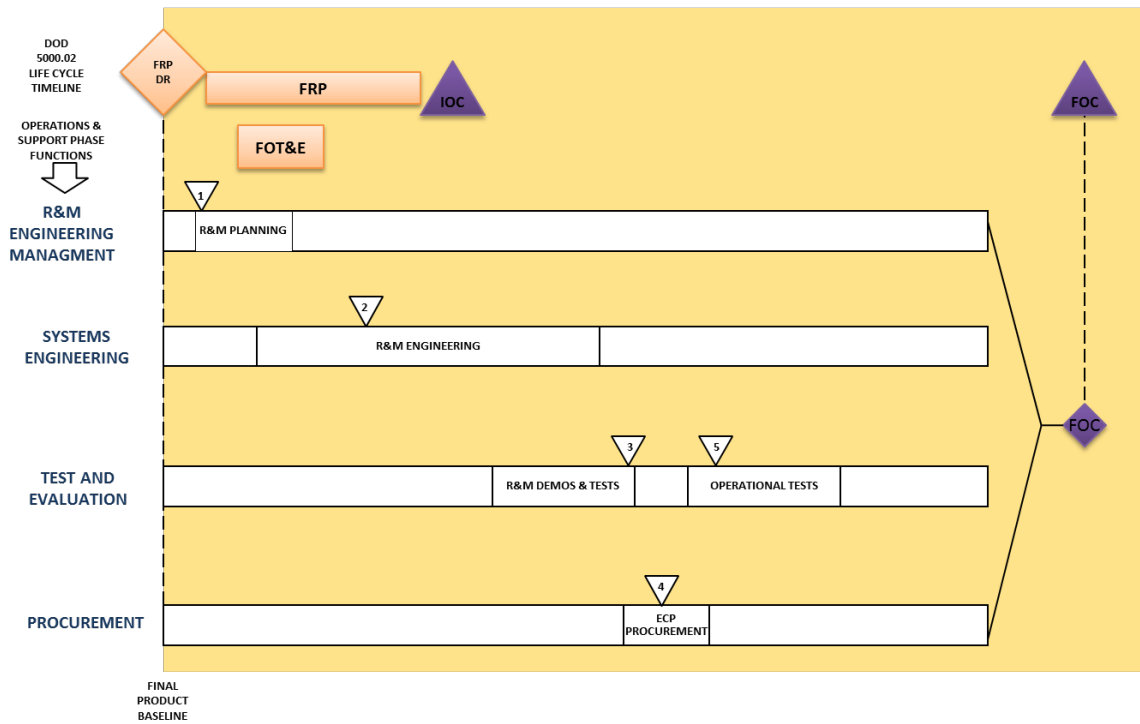


Figure 6. O&S Phase R&M Activities by Functional Area

Typically, a system or piece of equipment begins its introductory period of service use under the surveillance and with the augmented support of the production contractor to identify and investigate problems and implement corrective actions.

After the system or equipment completes a successful introductory period, the program should keep close surveillance of R&M performance and logistics support by analyzing experience data reports from Service and other reporting systems. System readiness degradation ranking reports provide management with visibility of subsystems and replaceable components that most affect system availability. Availability reports are the primary documents for influencing management and other disciplines to ensure availability of materiel to support mission requirements. Many activities performed during the P&D phase continue during O&S to ensure continued availability.

The software for most systems will continue to change and evolve as long as the system is used and the R&M activities will mirror those of the EMD phase with the extent of development being significantly reduced. Software will also be subject to continuous updates for security, corrections, and user enhancements. These changes must be analyzed to ensure that the system's R&M performance does not degrade over time.

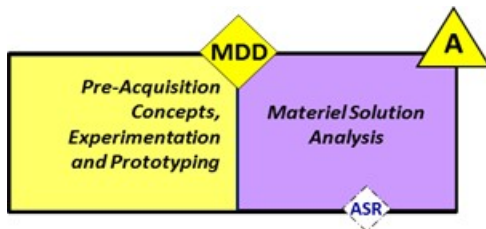
Many factors may degrade R&M performance of a system over time. These factors include aging, obsolescence, changes in the supplier processes, configuration creep, integration of new technologies, changes in use or doctrine, and changes in the environment. It is important to continue measuring the R&M performance as part of the implemented life cycle sustainment plan. It is also important to plan for and establish an ongoing closed-loop FRACAS process to mitigate reliability problems as they begin to affect field performance.

Operations and Support Results

- R&M characteristics; maintenance planning, features, and procedures; provisioning plans; test equipment design; maintenance training; and support costs determined by periodic assessment of operational data to be consistent with the capability document thresholds.
- Problem areas identified for correction. Although changes to maintenance processes or increased inspections may be cost-effective for acquisition, the impact on operational suitability can be staggering. A balanced approach is needed to preserve total ownership cost and to control unintentional consequences.

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1. R&M in the Materiel Solution Analysis Phase



Objectives of the Materiel Solution Analysis Phase

During the Materiel Solution Analysis (MSA) phase, the program explores materiel concepts and alternatives, identifies potential solutions to stated Service needs, and evaluates technologies to include in the Technology Maturation and Risk Reduction (TMRR) phase. The objective for R&M engineering in this phase is to ensure that potential materiel development efforts include actions to identify and reduce risk. This R&M effort seeks to ensure that, if a system is fielded, the operational and maintenance impacts of any R&M risk are adequately mitigated and the impacts that remain are fully understood.

Sustainment concepts that affect standard skill sets, unique/new tools/training, or special product support concerns (e.g., shelters, repair facilities) should be identified and included in the preferred system concept to be worked in the next phase. Those technologies and R&M needs should not reflect a single solution but should support the preferred system concept.

The DoD acquisition component prepares the Analysis of Alternatives (AoA), from which the best concept to pursue will be selected. The DoD acquisition component should include in the AoA not only the estimated R&M requirements relating to design but also the product support parameters to ensure adequate coverage in subsequent acquisition documents. The exit criteria from Milestone A should include those R&M-related results from the Reliability, Availability, Maintainability, and Cost (RAM-C) Report that are critical to begin the TMRR phase.

R&M Activities in the Materiel Solution Analysis Phase

Figure 1-1 presents the R&M activities to be accomplished by the designated DoD acquisition component during the MSA phase (or early in the TMRR phase if the program initiates in that phase) in approximate chronological order. Table 1-1 lists the activities. The succeeding sections describe the activities in the context of the four functional areas (R&M Engineering Management, Systems Engineering, Test and Evaluation, and Procurement) and in relation to the applicable DoDI 5000.02 R&M engineering activities.

1. R&M IN THE MATERIEL SOLUTION ANALYSIS PHASE

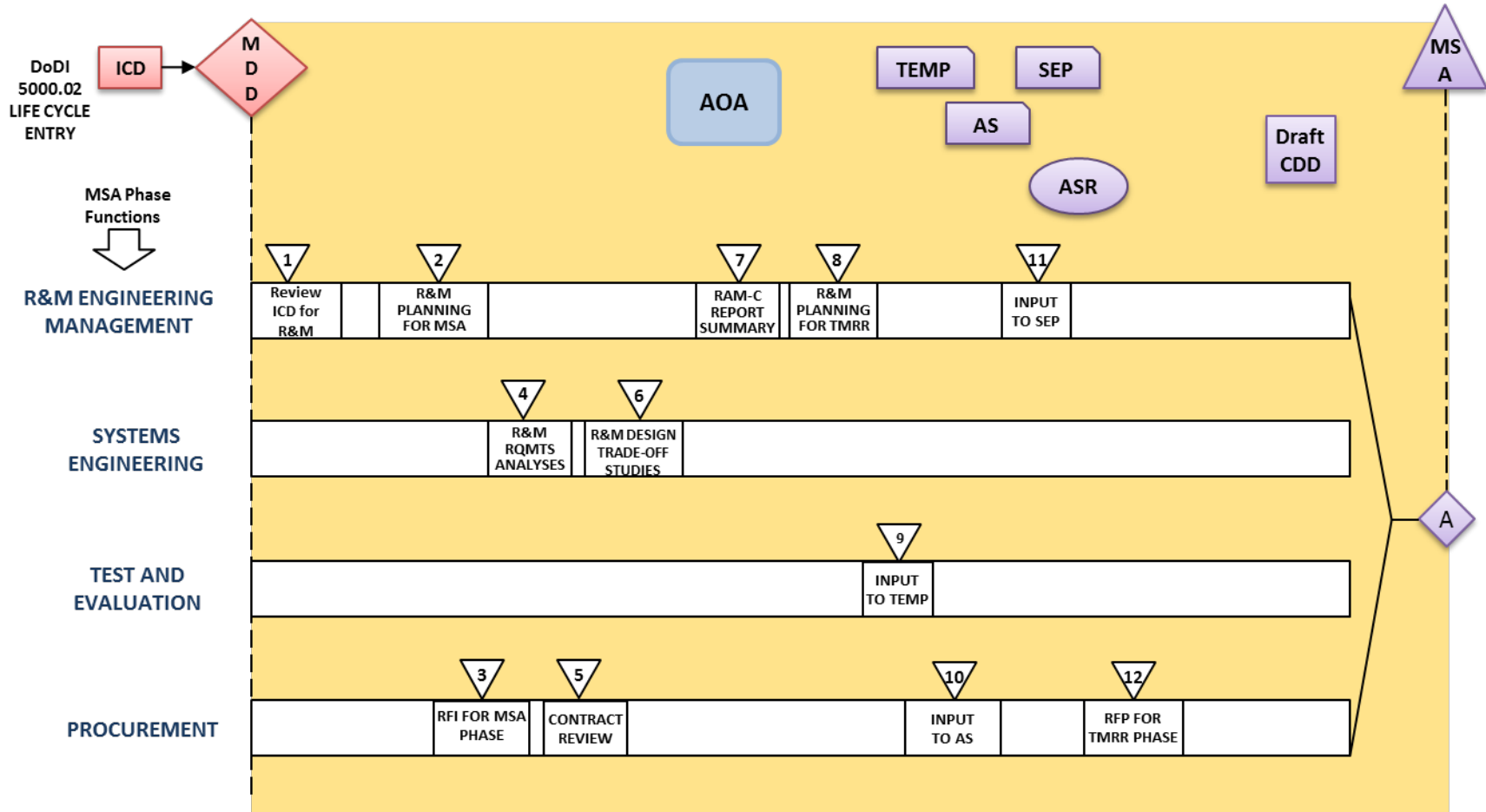


Figure 1-1. MSA Phase R&M Activities by Functional Area

Table 1-1. R&M Activities in the MSA Phase

MSA R&M Activity	Functional Area	Paragraph
1 Review ICD for R&M objectives	R&M Engineering Management	1.1.1
2 Develop R&M planning for MSA phase	R&M Engineering Management	1.1.2
3 Prepare R&M input to MSA phase RFI or study contracts	Procurement	1.4.1
4 Perform R&M requirements analysis	Systems Engineering	1.2.1
5 Review MSA phase RFI or study contracts	Procurement	1.4.1
6 Perform design trade-off studies	Systems Engineering	1.2.2
7 Prepare RAM-C Report	R&M Engineering Management	1.1.3
8 Develop R&M planning for TMRR phase	R&M Engineering Management	1.1.4
9 Provide R&M input to TEMP	Test and Evaluation	1.3.1
10 Provide R&M input to AS	Procurement	1.4.2
11 Provide R&M input to SEP	R&M Engineering Management	1.1.5
12 Prepare R&M input to RFP for TMRR phase	Procurement	1.4.3

1.1. R&M ENGINEERING MANAGEMENT

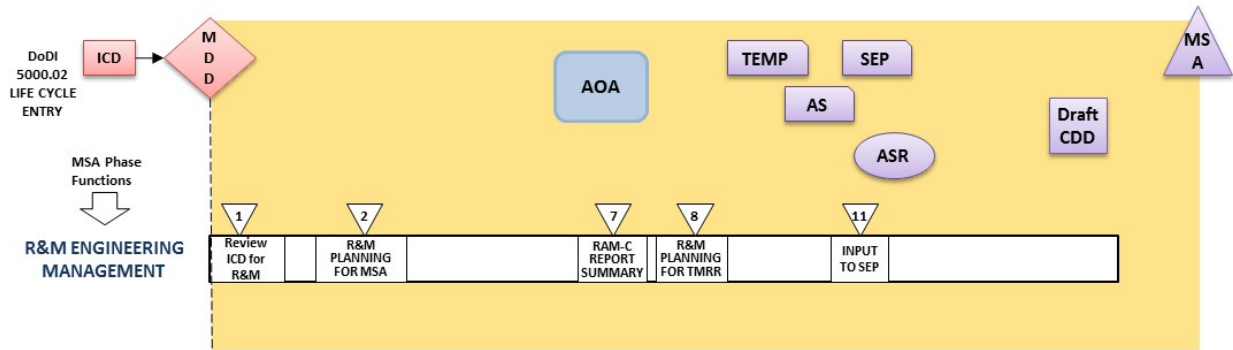


Table 1-2 lists the primary R&M activities associated with the R&M Engineering Management functional area in the MSA phase.

Table 1-2. R&M Engineering Management Activities – MSA Phase

R&M Activity	Description
1 Review ICD for R&M objectives	<ul style="list-style-type: none"> Review the ICD and extract the desired R&M capabilities.
2 Develop R&M planning for MSA phase	<ul style="list-style-type: none"> Develop the preliminary Government R&M planning for the MSA phase to ensure adequate consideration of R&M analyses, trade-off studies, and feasibility estimates.
7 Prepare RAM-C Report	<ul style="list-style-type: none"> Prepare and append the RAM-C report describing the reliability, maintainability, and availability feasibility and trade-off analyses for each alternative.
8 Develop R&M planning for TMRR phase	<ul style="list-style-type: none"> Develop Government R&M planning for the TMRR and subsequent acquisition phases to identify specific R&M activities and provisions.
11 Provide R&M input to SEP	<ul style="list-style-type: none"> Prepare the R&M inputs to the SEP for major programs prior to soliciting Service approval for Milestone A.

1.1.1. Review ICD for R&M Objectives

The ICD provides basic system characteristics, desired performance capabilities, and projected operational environments from which definitive system requirements and design concepts can be developed. For reliable and maintainable systems to be delivered to the field, R&M should be considered early during the system requirements process. R&M requirements for a proposed system are derived from an analysis of the applicable joint capabilities document. Although it may be broad, the ICD should provide a tentative basis for estimating R&M at the system and major

subsystem levels. These estimates should be realistic in terms of need, yet consistent with the state of the art.

REVIEW ICD: PROCEDURE

Review the Concept of Operations (CONOPS) established by the applicable joint capabilities document to refine (if necessary) the operational sequence, sustainment functions, and R&M capabilities. The CONOPS should provide enough information to establish operational tempo and constraints for releases, patches, and failure recovery for software services (functions) and interfaces. These constraints will include periods of continuous operations, deployed to a connected or disconnected mode and the composition of the operations team.

Examine the CONOPS to ensure uniformity in formulating design concepts, performing R&M analyses, planning sustainment activities, and so on, as a common denominator for all study efforts in the program.

REVIEW ICD: DATA

The desired sustainment functions, availability of software services, and other relevant R&M information from the ICD should be used as an initial starting point for R&M feasibility and trade-off studies performed during the MSA phase.

REVIEW ICD: REVIEW CRITERIA

- ICD and CONOPS are adequate to begin estimation of tentative R&M quantitative values and to perform initial R&M feasibility and trade-off studies.

1.1.2. Develop R&M Planning for MSA Phase



The R&M engineering management planning performed by the DoD acquisition component early in the MSA phase should be updated continuously in subsequent phases of acquisition, to provide the program manager and other participating organizations with a dynamic source of data pertaining to specific R&M requirements, current status, problems, and progress relative to established R&M activities. The planning for R&M is peculiar to each program and is initiated in the appropriate phase and should be updated thereafter to reflect the maturity of the program. R&M planning should be keyed to the program's overall acquisition strategy to provide a systems engineering-oriented approach. Government R&M engineering planning serves four basic management purposes:

- (1) Define the R&M activities and review criteria to be integrated into the program.
- (2) Define the specific R&M criteria and supporting data for technical decisions at designated R&M events and milestones.
- (3) Provide the basis for defining R&M program plans and the basis for their inclusion in the SEP, Acquisition Strategy (AS), and other management and reporting documents.
- (4) Provide the basis for specifying compatible R&M program requirements in contracts.

1. R&M IN THE MATERIEL SOLUTION ANALYSIS PHASE

The DoD acquisition component's R&M program planning should be tailored to the specific needs of the particular program. This approach fosters adoption and integration of R&M as essential system characteristics into existing activities of the program. R&M engineering should consider both the acquisition strategy and the program's acquisition phase to determine the activities needed for a cost-effective R&M engineering program.

R&M PLANNING FOR MSA: PROCEDURE

Develop the following R&M program elements in the MSA phase:

- *Government R&M Management Planning* – Outline the management, staffing, monitoring, and schedule related to the R&M activities required to support the designated program milestones.
- *R&M Technical Requirements* – Using the results of the R&M requirements analysis and feasibility studies, assess the difficulty of achieving the overall R&M requirements. Identify all technical risks that require mitigation plans. This evaluation provides the basis for the definition and scheduling of R&M analyses, design reviews, evaluation and verification tests, modeling, simulation, accelerated life tests, demonstration tests, and other R&M activities.
- *R&M Support Requirements* – Evaluate the program activities and milestones (events) in the Integrated Master Schedule (IMS) and determine the R&M analysis required to achieve these milestone objectives.
- *R&M Control Requirements* – Identify critical R&M activities required for the program milestone network. Derive the criteria that should be applied for each critical R&M activity, and determine the appropriate method (e.g., failure mode and effects analysis, prediction analysis, completion of accelerated stress tests, R&M progress against TPMs, etc.) that can best support the R&M decisions.
- *R&M Schedule* – Develop a schedule for all R&M activities planned and include these in the program's IMS.
- *Resource Requirements* – Determine manpower, skills, and facilities (including test) required:
 - For the management of the R&M program alone.
 - For all the R&M activities throughout the MSA phase of acquisition and (tentatively) for the TMRR phase.

R&M PLANNING FOR MSA: DATA

Planning results from the activities performed under the procedure above should be prepared and should contain the elements described above. Planning results should be included in appropriate program planning documents.

R&M PLANNING FOR MSA: REVIEW CRITERIA

- *Validity of Requirements* – Quantitative R&M requirements and proposed design requirements are consistent with the ICD. Capabilities are feasible (within current state-of-the-art) and can be validated using the RAM-C outline guidance.
- *Adequacy of Requirements Verification Provisions* – Any demonstration or technology risk reduction tests are adequate to demonstrate R&M design requirements. At a minimum, the tests validate the results of models/analyses to provide confidence in R&M results.
- *Adequacy of Control Provisions* – R&M checkpoints in the form of technical reviews and in-process reviews and supporting R&M analysis are keyed to program milestone schedules.
- *Validity of Contract Requirements* – The R&M requirements and required data within the appropriate contracts are consistent with the R&M activities with correct data item descriptions noted when required.

1.1.3. Prepare RAM-C Report



Using the DoD RAM-C Rationale Report guidance, attach to the SEP describing the sustainment parameters, maintenance concept, feasibility, and trade-off analyses for each alternative investigated. The report may be limited in scope due to the unknowns at this stage of the program, but it should articulate the life cycle sustainment requirements and sustainment concepts for each of the alternatives. The RAM-C analysis and RAM-C Report are required for all Major Defense Acquisition Programs (MDAPs) and designated special interest programs and for Milestone A.

RAM-C REPORT: PROCEDURE

Refer to the RAM-C rationale report guidance and activities 4, 7, and 8 of this chapter for specific procedures. Use data from the RAM-C Rationale Report to provide the following for product support design:

- The initial failure mode assessment, including effects of failure on system performance and the probable manner in which each failure mode would be detected to provide guidance for the design of the diagnostics and sustainment concepts.
- Initial failure rate and removal rate estimates, for both corrective and preventive maintenance, for early basis for equipment level of repair and replaceable unit spares provisioning planning.

RAM-C REPORT: DATA

RAM-C data resulting from the activities performed under the procedures above.

- *RAM-C Report* – Prepared using with the DoD RAM-C Rationale Report guidance.
- *FDSC* – Preliminary failure definitions, criteria for maintainability and Built-in Test (BIT) and impact of downtime for essential software services and interfaces, should be integrated into the RAM-C Report. The FDSC may evolve as the system matures and should be updated

as needed. However, it is preferable to finalize the criteria as early as possible to support contract requirements and to avoid mismatches between planned and achieved/demonstrated R&M. For cases where software failures are the cause of system failure, FDSC considerations include the time for the system recovery and execute the mission.

RAM-C REPORT: REVIEW CRITERIA

- RAM-C results have shown that the sustainment KPP and supporting KSA thresholds are valid and feasible.

1.1.4. Develop R&M Planning for TMRR Phase



R&M engineering planning should address the full life cycle of the program. Planning activities typically commence in the MSA phase and continue through the Operations and Support (O&S) phase. A properly tailored R&M engineering program ensures that all elements are cost-effectively implemented, properly conducted, evaluated, reported, and integrated in a timely manner for design, analysis, development, testing, and manufacturing. Planning during this early stage should include the approach and procedures by which the Contractor will ensure compliance with the proposed contractual requirements. The approach should also provide results of R&M design analyses and test results needed to support all major design reviews, program reviews, and milestones. These planning activities should be documented in the appropriate DoD acquisition component program plans and IMS.

R&M PLANNING FOR TMRR: PROCEDURE

R&M program planning should include the following:

- Description of the Government R&M organizational structure, functional responsibilities, interrelationships, methods of operation, management efforts, and level of authority at the systems engineering and Integrated Product Team (IPT) levels. The detailed description of the internal organizational structure also should include a definition of interfaces with other critical organizational activities such as systems engineering, software development, product support, and T&E.
- Description of procedures to ensure that planning documents, procurement documents (i.e., IMS, specifications, statements of work, Contract Data Requirements List (CDRL) items) and other program documents are reviewed for technical accuracy and adequate coverage of R&M requirements.
- The following R&M engineering activities:
 - R&M Block Diagrams/Math Models – R&M block diagrams and math models are prepared to reflect the system configuration. Preliminary block diagrams/math models are due by the System Functional Review (SFR) with an appropriate level of detail to support the design baseline, and should be completed by the Preliminary Design Review (PDR).
 - R&M Allocations – R&M requirements assigned to individual items to attain desired system-level performance. Preliminary allocations are due by SFR with an appropriate

1. R&M IN THE MATERIEL SOLUTION ANALYSIS PHASE

level of detail (to support the allocated baseline and subcontractor/supplier contracts awarded to that point) completed by PDR.

- R&M Predictions – R&M predictions that allow an evaluation of the proposed design or a comparison of alternative designs. Define R&M engineering analyses techniques, failure rate sources, and the maintenance rates to be used in prediction and trade-off studies. Preliminary predictions are expected by PDR with the final by Critical Design Review (CDR).
- Failure Mode, Effects, and Criticality Analysis (FMECA) – Analysis performed to assess the severity of the effects of component/subsystem failure modes on system performance. Preliminary analyses are expected by PDR with the final by CDR.
 - Failure Mode Effects Analysis (FMEA) on the software – Analysis performed to assess the severity of the effects of software component/subsystem failure modes on system performance. The FMEA should incorporate relevant views (e.g., Interface, Functional, and Usability). Preliminary analyses are expected by PDR with the final by CDR. The detection methods and mitigations from the FMEA informs the development of the error and exception handling concept for the Software Development Plan.
- Equipment and Subsystem Growth Tests – For new development items, the application of reliability testing of development systems (highly accelerated life test, conventional growth test, and so forth) to identify failure modes, which if uncorrected could cause the equipment to exhibit unacceptable levels of reliability performance during operation.
- R&M Demonstrations – Demonstrations to provide assessment of the quantitative and qualitative reliability, maintainability, and BIT characteristics of the subsystem and system design. The program should define applicable R&M evaluation and demonstration test requirements, procedures, and tentative acceptance criteria for TMRR phase test planning.
- Failure Reporting, Analysis, and Corrective Action System (FRACAS) – Engineering activity during development, production, and sustainment to provide management visibility and control. Essential to improve system R&M through timely and disciplined use of failure data to generate and implement effective corrective actions to prevent the recurrence of failures.
- Reliability Growth Strategy and Growth Planning Curve – A reliability growth strategy includes engineering activities and reliability growth tests applied during the design process to reduce the frequency of problems by forcing early consideration of the methods for achieving and evaluating reliability progress. The reliability growth strategy should help identify potential problem areas while there is still time to resolve them, minimizing impact on schedules and cost. Reliability growth planning, which includes a reliability growth curve, provides an objective yardstick for measuring progress and directing resources so that reliability requirements may be achieved in a timely and cost-effective manner.

- Description of contractor R&M requirements and delivery schedule associated with the activities above.

R&M PLANNING FOR TMRR: DATA

Applicable planning data should be prepared in accordance with this guide and with DoD acquisition component guidelines. Data from R&M planning should form the basis of the R&M engineering activities within the SEP and the procurement activities for the RFP for the TMRR Phase.

R&M PLANNING FOR TMRR: REVIEW CRITERIA

- Planning activities and their results are adequate to describe their purpose and how they will be used in execution.
- Planning documents are complete and conform to the planning requirements.

1.1.5. Provide R&M Input to SEP



The SEP is a “living” technical planning document and the blueprint for the conduct, management, and control of the technical aspects of the Government’s program from concept to disposal. The SEP defines the methods for implementing all R&M engineering activities, technical staffing, and technical management within the overarching systems engineering process.

R&M INPUT TO SEP: PROCEDURE

Provide the following information required by the [SEP Outline](#):

- Organizational structure of R&M engineering with the Systems Engineering organization.
- Integration of key R&M events in the program IMS.
- Reliability Technical Performance Measures (TPMs) and growth planning curve.
- Description of key related Service-Level Agreements for interfaces, services, government off-the-shelf (GOTS) software, and provided infrastructure (e.g. DoD provider services).
- Description of how the JCIDS sustainment characteristics were translated into R&M contract specifications.
- Description of the R&M engineering activities that will be placed on contract.

R&M INPUT TO SEP: DATA

The program should prepare and document the R&M inputs to the SEP before soliciting Service approval for Milestone A.

R&M INPUT TO SEP: REVIEW CRITERIA

- R&M TPMs, growth curve, requirements, and engineering activities are properly integrated into the systems engineering process and conform to the SEP requirements.

1.2. SYSTEMS ENGINEERING

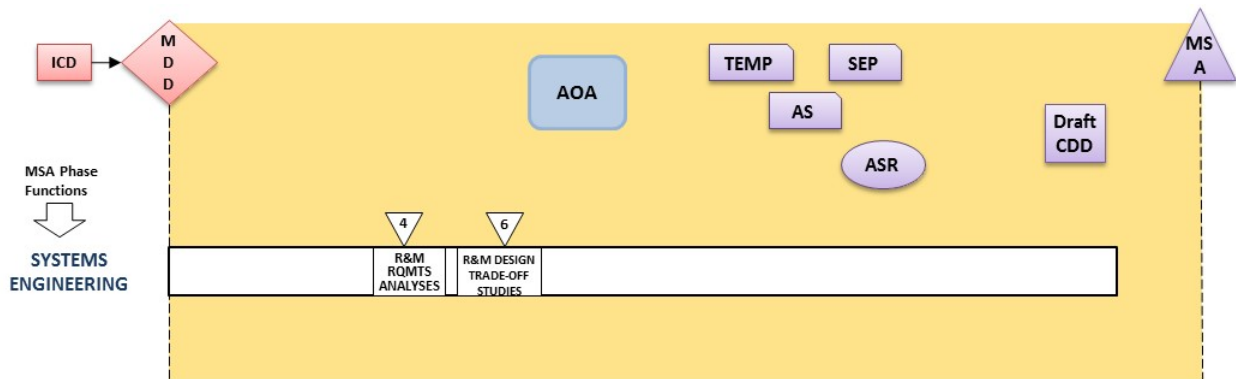




Table 1-3 lists the primary R&M activities associated with the activities for the Systems Engineering functional area in the MSA phase.

Table 1-3. R&M Systems Engineering Activities – MSA Phase

R&M Activity	Description
 Perform R&M requirements analysis	<ul style="list-style-type: none"> Perform system R&M requirements analysis supported by the mission profile, CONOPS and proposed sustainment concept.
 Perform design trade-off studies	<ul style="list-style-type: none"> Perform design concept, architectural, and requirements trades prescribed by the RAM-C report guidance to optimize the conceptual design with respect to reliability, maintainability, performance, availability, logistics factors, and life cycle costs.

1.2.1. Perform R&M Requirements Analysis

The R&M engineer should review the desired capabilities established in the ICD or updated by subsequent documentation to refine (if necessary) the OMS/MP, operational sequence, and maintenance concept. The goal is to ensure the OMS/MP, CONOPS, and sustainment concept are uniformly applied when formulating design concepts, performing R&M analyses, planning maintenance activities, and so on, as a common denominator for all study efforts in the program.

REQUIREMENTS ANALYSIS: PROCEDURE

Perform preliminary R&M analyses, feasibility, and trade-off studies of the design concepts. The R&M Engineer, product support specialist, and cost analyst:

- System Description* – Using the reference design concept from, identify major subsystems that are subject to R&M requirements. The system description should be user-oriented and

1. R&M IN THE MATERIEL SOLUTION ANALYSIS PHASE

operational and should include all elements of the system, including government-furnished and contractor-furnished hardware (whether developmental or not), system software, operating and support documentation, and the crew and maintainer personnel.

- *Sustainment Parameters* – Identify the sustainment capabilities and parameters being proposed in the JCIDS documentation (ICD, Draft CDD). During the MSA Phase, the data gathering should begin as soon as preliminary inputs are available from the (user) e.g., from working versions or informal review of the JCIDS documents. For each of the parameters, list the notes, rationale, and assumptions stated in the JCIDS documentation (e.g., the inclusion or exclusion of GFE or COTS, average sortie duration or mission time, failure definition). Ensure Failure Definitions and Scoring Criteria (FD/SC) have been developed. If so, ensure that the definitions in the JCIDS documentation are consistent with the FD/SC. During early system development, failure definitions are generally based on the functions of the system from an operational perspective and should also be consistent with service maintenance data collections practices.
- *OMS/MP, CONOPS* - Summarize the OMS/MP and environment expected for the materiel solution. An accurate and thorough OMS/MP, based on the CONOPs or combat scenario deemed to be the most representative, is critical to ensuring the fielding of new equipment that will meet the User’s needs. Highlight any special conditions of use, such as any unique high-intensity cycles of use within a mission or from the Concept of Employment (CONEMP) that would affect the sustainment of the system.
- *Maintenance Concept and Planning Factors* – List the maintenance concept planning factors for the system. The planning factors and their values used to determine Mean Down Time (MDT) and other maintainability KSAs or APAs are needed to validate Ao and AM and should provide a realistic, definitive, and uniform basis to determine downtime. The planning factors should support the sustainment capabilities as viewed by the user, maintainer, supplier and transportation providers, taking into account constraints (e.g., preventative maintenance, reset time, periodic depot maintenance) and limitations (e.g., “core” requirements, statutory requirements). Software use cases or equivalent should be performed to address the concept for deploying initial and subsequent releases, patches (OS, COTS, GOTS and applications) and failure recovery for each applicable level (self, on-site administrator, help desk, remote).
- *Validation* - Assess the sustainment parameters to ensure they are valid. The parameters should be consistent with the CONOPS, CONEMP, OMS/MP, environmental profiles, product support strategy, planned inventory, operating hours (mission durations), and planned downtimes. The parameters should support each other, as shown by calculation and/or modeling and simulation and be traceable to the appropriate JCIDS document.
- *Feasibility* - Assess the sustainment parameters to ensure they are feasible. The parameters should be assessed for feasibility by determining if all the sustainment parameters can be implemented in the system under consideration consistent with state of the art and technical maturity. Evaluate any observed disparity between predicted and required R&M (both of which should be based on the FDSC). Any disparity should be addressed to ensure the predicted and required estimates are based on the same criteria.

1. R&M IN THE MATERIEL SOLUTION ANALYSIS PHASE

- *Develop Composite Model* – First order breakdown of the system can usually be produced from the information available during the early system planning stage for the conceptual designs.
 - *Reliability Model* – Using the first order breakdown, prepare reliability block diagrams and math models to accurately reflect the equipment/system configuration, operating modes, and OMS/MP (reflecting series and redundant elements) to make meaningful reliability allocations and predictions possible. These models should be adequate for making preliminary allocations and feasibility estimates.
 - *Maintainability Model* – Develop functional architecture-level maintainability diagrams and mathematical models for the system to the levels at which repair or replacement is to be accomplished and to the levels to which fault isolation is to be extended. Failure and software release/patch use cases can be used to establish functional requirements for software maintenance.
 - *R&M Prediction* – The R&M of an individual item varies with the type of function to be performed, its complexity, and the method of accomplishing the function. Estimate the failure rate of individual blocks in the reliability model, based on validated experience data derived from fielded experience on other predecessor equipment of similar function and comparable complexity. Combine the corrective task times and maintenance support estimates in the models to update the estimated maintainability objectives for the selected concept. If this field experience data from predecessor systems are not available, engineering estimates should be made based on best practices.
- *R&M Requirements Trade Studies* – Perform sensitivity analysis (Figure 1-2) that shows the range of R&M parameters (e.g., Mean Time Between Failure (MTBF) and MDT) that will satisfy the Ao threshold. The results of the sensitivity analysis should illustrate the trade space for reliability and maintainability along with the associated O&S costs. Also, tentatively indicate any potential trade-off among design requirements that would enhance R&M, and estimate the growth potential inherent in this trade-off.

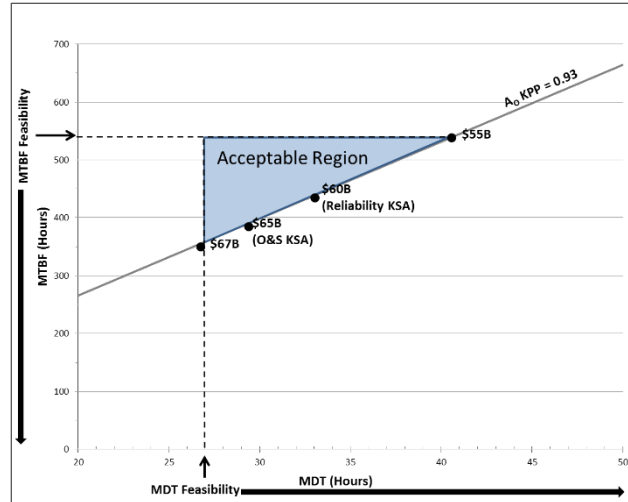


Figure 1-2. R&M Sensitivity Analysis

- *R&M Requirements* – On the basis of results above, recommend adjustment (if necessary) of the R&M thresholds. These adjusted thresholds should be established as the tentative R&M requirements to be translated to the R&M specifications.
- *Sustainment Requirements* - Based on the analysis conducted, summarize whether the sustainment parameters are valid and feasible. Identify any significant issues in the Operational Mode Summary/Mission Profile (OMS/MP), CONOPS, failure definitions, or maintenance approaches. Identify any issues with specific sustainment parameters and associated recommendations provided to the requirements developers or other stakeholders. For updates to the RAM-C at the RFP Release Decision Point, MS B, and MS C summarize notable program changes that influenced the outcomes of the RAM-C analysis. Provide the results of trade study to illustrate the acceptable region for R&M parameters consistent with the A_o and Operations and Support (O&S) cost thresholds.

REQUIREMENTS ANALYSIS: DATA

Results of the requirements analyses should be updated in the RAM-C as the MSA phase advances.

REQUIREMENTS ANALYSIS: REVIEW CRITERIA

- *R&M Conformance* – Feasibility estimates for the selected design approach equal or exceed the desired capabilities in the ICD.
- *Analytical Validity* – R&M analysis procedures and input data used in the analyses are valid and conservatively feasible.

1.2.2. Perform Design Trade-off Studies



Defining R&M requirements for potential design solutions in the MSA phase requires more than a one-time analysis. Optimizing the requirements involves a series of trade-off studies to achieve a balance among many factors that influence R&M, including performance parameters, design

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characteristics, availability, and life cycle cost factors that govern the operational suitability for the alternatives being considered in the AoA. The RAM-C analyses should be kept current with each design iteration of each alternative during the MSA phase. The program should provide dynamic feedback of analytical results to systems engineering from the conceptual design activities for future design iterations.

DESIGN TRADE-OFF STUDIES: PROCEDURE

Perform the following analyses in support of the trade-off studies:

- *Performance Analysis* – Evaluate reliability as a function of mission performance characteristics consistent with the OMS/MP and CONOPS.
- *Maintainability Analysis* – Evaluate the maintainability requirements for the alternative design concepts, life cycle cost objectives and maintenance concepts for specified levels of availability.
- *Availability Analysis* – Evaluate R&M trade-offs for several “acceptable” levels of availability and for several alternative approaches to achieving availability, e.g., design redundancy, turn-around time, preventive maintenance, diagnostics concept, automated versus manual failure recovery for software, etc.
- *Life Cycle Cost Analysis* – Evaluate the non-recurring acquisition cost of R&M for each alternative versus the cost of maintenance and support in the deployment phase.
- *Schedule/Risk Analysis* – Evaluate the technical risks and schedule requirements associated with the R&M performance objectives.
- *Operational Suitability* – Combine the results of the preceding analyses for each design alternative that would satisfy the objectives of the ICD. Include a projected quantitative assessment of operational suitability, logistics supportability, life cycle costs, and acquisition schedule for each alternative. Perform operational availability modelling for each alternative where necessary, to verify conformance to desired capabilities.

DESIGN TRADE-OFF STUDIES: DATA

Results of trade-off studies and availability modelling should be prepared and documented as appropriate in the RAM-C analysis.

DESIGN TRADE-OFF STUDIES: REVIEW CRITERIA

- *Conformance* – R&M as measures of operational suitability satisfy the R&M objectives derived from the ICD.
- *Analytical Validity* – R&M data and modelling used in the trade-off studies are valid, i.e., conservatively realistic with respect to current field experience.

1.3. TEST AND EVALUATION

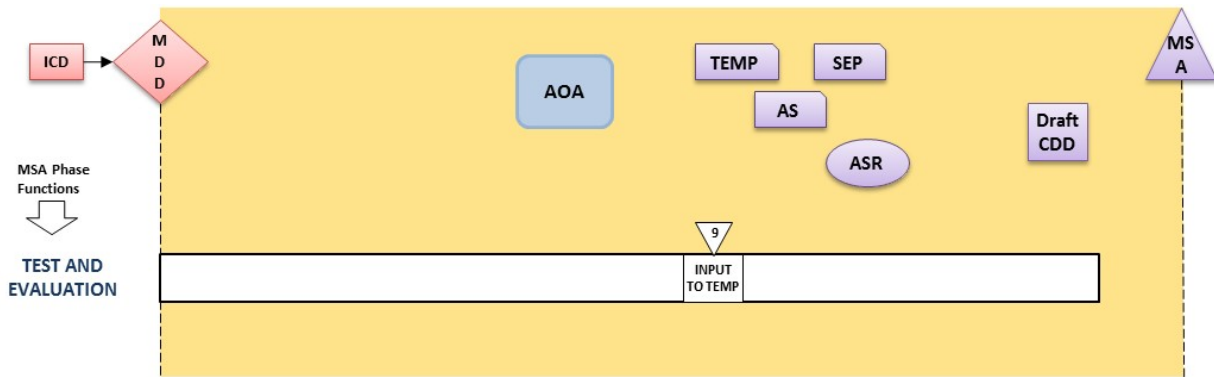



Table 1-4 lists the primary R&M activity for the Test and Evaluation functional area in the MSA phase.

Table 1-4. R&M T&E Activity – MSA Phase

Activity	Description
 Provide R&M input to TEMP	<ul style="list-style-type: none"> Specify in the TEMP how the reliability will be tested and evaluated in the associated acquisition phase.

1.3.1. Provide R&M Input to TEMP



The program must make an early determination of R&M test requirements in its TEMP, to ensure that the cost and schedule impacts are properly considered in the acquisition plans and in contractor proposals. The program can minimize the cost of R&M testing by integrating R&M measurement data requirements and test conditions into equipment and system-level environmental and functional tests for the program. These tests then also serve as R&M evaluation tests to provide failure-rate/failure-mode data and removal rate data to allow for identifying and correcting problems long before the scheduled system R&M demonstration tests.

INPUT TO TEMP: PROCEDURE

Define system R&M and BIT test requirements and acceptance criteria to determine the conformance to desired capabilities. Base the preliminary subsystem and system-level R&M test requirements on an analysis of both the criticality and feasibility of achieving the R&M requirements. Document the test requirements and planning criteria, and include them in the TMRR phase Request for Proposal (RFP) and contract. If testing is planned for the TMRR phase, the RFP should define test conditions, environmental factors, and accept/reject decision criteria to be referenced in the system specification and to be used for guidance in subsequent phases. Develop the following test planning data:

1. R&M IN THE MATERIEL SOLUTION ANALYSIS PHASE

- *System R&M Demonstration* – For planned testing during TMRR, summarize the R&M tests and demonstrations to be included in the specification to verify conformance to quantitative R&M thresholds derived from the ICD.
- *R&M Test Sequence* – Summarize for the TMRR and future phases, a preliminary outline of the overall test sequence for the program (Figure 1-3). Depict the progression of required system level R&M performance tests, to the system R&M demonstration described above.

Milestone	△ A	PDR △ B	CDR	PRR △ C	LRIP	FRP
Government Test				DT&E	IOT&E	FOT&E
Prime Contractor (System) Test		Vendor	EMD 1* Integration Test	EMD 2* M-Demo	EMD 3* RGT	Failure Reporting System

*Asset #

Figure 1-3. Sample Test Sequence

- *Reliability Growth Testing* – Summarize the reliability growth tests, including equipment, subsystem, and system-level tests, that are part of the reliability program. Address the initial amount of testing, test schedule, and resources available for achieving the requirements.
- *Integration of R&M Engineering Activities* – Summarize R&M engineering involvement in applicable testing from software development tests (Load/Stress, failure injection, out of bounds, etc.), functional tests, equipment qualification tests, and subsystem integration tests through system-level performance tests. Delineate responsibilities with regard to R&M for each test, for test design, test plan review and approval, test performance, data analysis, and FRACAS requirements.
- *R&M Measurement Requirements* – Define applicable R&M parameter measurements, operating time data, test conditions, and failure and maintenance and BIT information that should be provided by existing tests in the overall test plan to achieve maximum practical integration of R&M test requirements. Reference the preliminary R&M scoring and evaluation criteria (i.e., FDSC) and joint Government and contractor scoring boards that will be used to compute R&M performance based on the data collected during system testing.

INPUT TO TEMP: DATA

The R&M test planning above should be documented, referenced by, and summarized in the system specification, internal program management planning documents, and TEMP.

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INPUT TO TEMP: REVIEW CRITERIA

- *Demonstration Test Adequacy* – R&M demonstration test plans, acceptance criteria, and test conditions should be clearly defined, should be consistent with the specified system requirements, and should be adequate for demonstration of conformance to the requirements.
- *Integrated Test Requirements* – R&M test requirements and criteria for how it is integrated within the overall test program should be adequately defined for contractor guidance in the design of the desired integrated test program.

1.4. PROCUREMENT

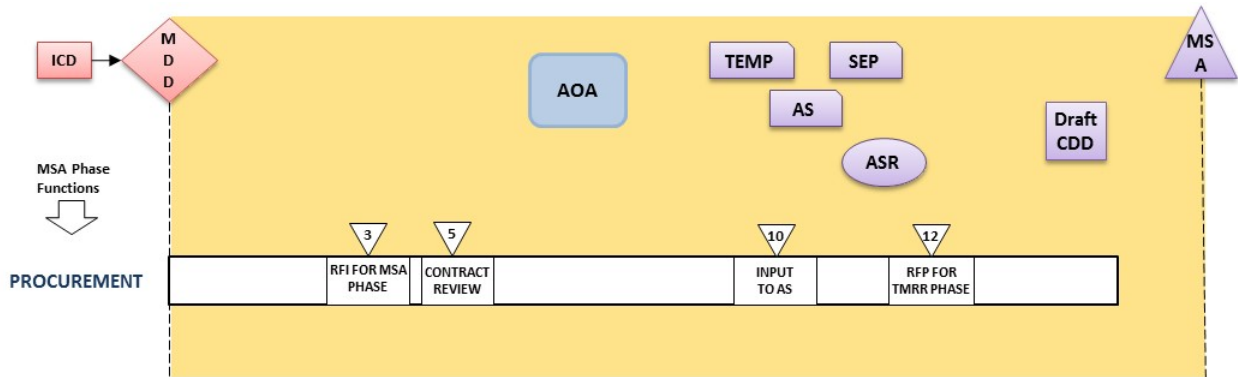
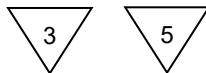


Table 1-5 lists the primary R&M activities associated with the activities for the Procurement functional area in the MSA phase.

Table 1-5. R&M Procurement Activities – MSA Phase

Activity	Description
3 Prepare R&M input to MSA phase RFI or study contracts	<ul style="list-style-type: none"> Prepare R&M inserts for prospective contractors who are to participate in the MSA phase RFI or study contracts.
5 Review MSA phase RFI or study contracts	<ul style="list-style-type: none"> Review negotiated MSA phase RFI or study contracts to verify conformance to requirements.
10 Provide R&M input to AS	<ul style="list-style-type: none"> Prepare input to the AS outlining the R&M requirements and activities for the TMRR phase.
12 Prepare R&M input to RFP for TMRR phase	<ul style="list-style-type: none"> Prepare R&M inserts for the RFP to prospective contractors who are to participate in the follow-on TMRR phase. Prepare the R&M portion of the proposal evaluation criteria based on requirements for subsequent acquisition phase proposals.

1.4.1. Prepare R&M Input to MSA Phase RFI or Study Contracts/Review MSA Phase RFI or Study Contracts



Having determined the specific activities and data essential to R&M during the MSA phase, the program should include these activities and any required data in the request for information (RFI) or study contracts.

The RFI or study contract should clearly define the R&M activities to be performed and any required data requirements to be prepared during the MSA phase. Following contract negotiation, but prior to formal execution by the Government contracting officer, all MSA phase contracts should be reviewed, to ensure that R&M activities and data requirements defined in the RFI or study contract are specified.

RFI OR STUDY CONTRACTS FOR MSA: PROCEDURE

Prepare the proposed contract Statement of Work (SOW) as an insert to the RFI or study contracts. Specific contract language guidance. The SOW should include the following primary ingredients:

- *Analysis Activities* – Describe the modelling methods, R&M estimates and failure mode analysis activities to be performed in support of system analysis and trade studies, BIT design mechanization and maintenance concept development.
- *Test and Evaluation Activities* – Describe any subsystem, equipment, component or technology maturation or risk reduction testing planned for R&M design evaluation.
- *In-Process Review Schedule* – Prepare a schedule of critical R&M activities, time-phased within the program schedule.

RFI OR STUDY CONTRACTS FOR MSA: DATA

Prepare data item descriptions or data exchange requirements for reports to be prepared as a result of the activities.

RFI OR STUDY CONTRACTS FOR MSA: REVIEW CRITERIA

- *Activity Description* – Descriptions of the R&M activities to include specific results to be achieved and the criteria by which results will be evaluated.
- *Data Requirements* – Data requirements are clearly defined in terms of both content and format.
- *Procedures* – Analytical procedures, measurements, and data sources to be used are specified.
- *Review* – In-process reviews are included as an R&M engineering management function.

1.4.2. Provide R&M Input to Acquisition Strategy



The Acq Strat for the program should include a short description of the R&M activities and R&M requirements. The Acq Strat should also specify how the sustainment KPP thresholds have been translated into R&M design and contract specifications.

INPUT TO AS: CONTROL PROCEDURE

Describe the requirements and appropriately tailored R&M engineering activities for the acquisition strategy being used. [Acquisition Strategy Outline](#) paragraphs 7.5.10.1 and 7.5.10.2 contain the following requirements for R&M input:

- Identify the engineering activities to be stated in the RFP and required of the contractor to demonstrate the achievement of the R&M design requirements.
- Provide a table to specify how the sustainment KPP thresholds have been translated into R&M design and contract specifications.

INPUT TO AS: DATA

R&M inputs should be appropriate for the particular acquisition strategy and integrated in the appropriate sections of the Acq Strat and updated as required.

INPUT TO AS: REVIEW CRITERIA

- *R&M Data* – The Acq Strat is appropriate for the intended acquisition strategy and includes the R&M data outlined above.
- *Verification* – R&M data summarized in the Acq Strat are consistent with the validated data presented in the RAM-C Report and the SEP.

1.4.3. Prepare R&M Input to RFP for TMRR Phase



The RFP for the TMRR phase should define the specific R&M performance requirements and activities the contractor is to perform during the TMRR phase (and tentatively during the follow-on EMD phase). Activities should include those required to provide support to systems engineering, design, and product support planning activities; to measure R&M achievement; and to identify, evaluate, and correct R&M problems. Activity descriptions should be integrated into the proposed contract SOW for the RFP. The contractually defined activities serve to implement the contractor R&M programs outlined in Activity 8, Prepare R&M Plans for TMRR Phase.

The RFP should include a specific description of the R&M activities, specification requirements and verification methods, design review, and demonstrations. If R&M tests or demonstrations are planned, they should be consistent with the those from the TEMP, along with the review points and milestones at which the contractor will need to provide analysis and measurements data for in-process review. The RFP should contain specific R&M data items listed on the CDRL.

The program should prepare instructions to prospective bidders, adequately specifying the R&M modeling procedures, analytical techniques, specific data sources, test planning criteria, and particular format to be used in responding to R&M requirements defined in the RFP. The program should emphasize the importance of the instructions and note that bidders will be evaluated on their responsiveness to the RFP. If the program holds a bidders conference, the agenda should include a description of R&M requirements and proposal preparation instructions.

The program should establish R&M criteria for evaluating proposals. The criteria should cover management aspects as well as technical and analytical aspects of the contractor's proposed approach to R&M acquisition. Areas for evaluation should include:

- The contractor's awareness of potential R&M risks and the proposed approach for identification, mitigation, and control of the risks.

1. R&M IN THE MATERIEL SOLUTION ANALYSIS PHASE

- The contractor's proposed R&M plans (as presented in the proposal) for conformance to requirements defined in the RFP.
- Each prospective contractor's plans from the standpoint of their commitment (in the proposal) to perform R&M assessments during scheduled formal design reviews and to measure R&M achieved in design and analytically demonstrate conformance to the specified requirements.
- R&M evaluation provisions offered by each prospective contractor for adequacy of integrated T&E plans, and for consideration of T&E requirements for the critical areas of design.

RFP FOR TMRR: PROCEDURE

Prepare the R&M inserts for the procurement request and RFP, to include the following:

- *R&M Activities* – Describe the R&M modeling, allocation, prediction, and FMECA to be performed in support of system analysis and trade studies, diagnostics design mechanization, integration of R&M activities with product support planning, change review, design review, and problem diagnosis.
- *Test and Evaluation Activities* – Describe the applicable R&M T&E activities to be performed for design evaluation, subsystem, and system test and demonstration.
- *Technical Review Activities* – Describe the R&M assessments to be performed at major systems engineering reviews System Requirements Review (SRR), SFR and PDR.
- *R&M Monitoring* – Describe the R&M monitoring and reporting activities to be performed in support of R&M engineering management activities.
- *In-Process Review Schedule* – Prepare an integrated schedule of R&M review and critical R&M activities, time-phased within the program schedule.
- *Proposal Preparation Instructions* – Prepare R&M proposal preparation instructions as a section of the RFP R&M requirements.
- *Evaluation Criteria* – Define proposal evaluation criteria for review of R&M aspects of the TMRR phase proposals and selection of the best technical proposal from the R&M point of view. Establish evaluation criteria to facilitate the relative ranking and grading of competitive proposals with respect to R&M.

RFP FOR TMRR: DATA

Contract R&M inserts to the RFP should include the activity descriptions and provisions described in this section.

Proposal preparation instructions and evaluation criteria should be prepared as part of sections L and M of the RFP exhibits.

The process, equations, and data used to translate the sustainment R&M thresholds to contract specification requirements should be documented to provide an audit trail to the capability document.

RFP FOR TMRR: REVIEW CRITERIA

- *Activity Description* – Activity descriptions include specific results to be achieved and the criteria by which results will be evaluated.
- *Data* – Data are clearly defined and describe the data to be presented and the format in which it is to be presented.
- *Procedures* – Analytical and test procedures, measurements, and input data sources to be used are specified.
- *Review* – In-process activity reviews are included as an R&M engineering management function.
- *Proposal Instructions and Evaluation Criteria* – Provisions are adequate to evaluate prospective contractor's R&M understanding, technical capability and willingness to achieve and apply effective controls to R&M.

1.5. MILESTONE A REVIEW

Achievement of Milestone A signifies satisfactory completion of the activities listed in Table 1-1, thus concluding the MSA phase. As part of the review, R&M assessments should be made of the conceptual design and the proposed R&M program for the TMRR phase. This assessment verifies the feasibility of the established R&M requirements and provides an estimate of the degree of conformance to the desired capabilities defined in the draft CDD. The assessment also identifies R&M risks for critical areas and evaluates the risks for impact and mitigation in the TMRR phase. The assessment includes a review of the R&M activities proposed by the Government in the RFP (statement of work and data requirements), specification(s), tests, demonstrations to ensure adequate control of R&M during the TMRR phase.

1.5.1. Procedure

The Milestone A review should look for inconsistencies that may be visible with the proposed solution in the integrated, system-oriented, program-wide review. The following documents, as applicable, should be evaluated for adequacy of R&M requirements and provisions in support of the Milestone A review:

- R&M Program Planning document(s)
- R&M portions of the system specification(s) or requirements document
- MSA phase R&M Reports
- R&M Test and Evaluation Planning for the TMRR phase
- R&M RFP documentation (Specification, Statement of work, CDRL, Sections L & M, H Clauses as appropriate for incentives, etc.) for the TMRR phase
- Program documentation such as the SEP (including the RAM-C report), TEMP, and Acq Strat

Major R&M concerns/risks should be identified with strategies to mitigate to acceptable levels during the TMRR phase.

Determine the R&M status and verify that the analytical procedures, input data, problem areas, growth potential, and performance requirements reflect the current system configuration by performing the following assessments, as appropriate:

- *Verify Analytical Procedures* – Verify accuracy and appropriateness of mathematical models and methods, their consistency with functional block diagrams, and their representativeness of “current” conceptual design configuration.
- *Validate Data* – Validate the input data (e.g., failure rates and corrective maintenance times) and sources used in analytic procedures.
- *Evaluate Conformance* – Evaluate the degree to which the conceptual design conforms to R&M thresholds.

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- *Confirm Criticality of R&M Risks* – Confirm the criticality of potential R&M risks tentatively identified in the MSA phase and evaluate corrective action/mitigation plan and feasibility.
- *R&M Assessment* – Evaluate R&M performance potential available through trade studies, proposed corrective actions, design approaches and mitigation steps reviewed in “*Confirm Criticality of R&M Risks*”; evaluate technical difficulty and operational significance of any remaining R&M risks; the result from specific R&M activities should provide an initial starting point for R&M test and demonstration planning. These points should be used to support initial measurements of R&M.
- *Evaluate Proposed Specified R&M Requirements* – Verify the adequacy of proposed specified design requirements, minimum acceptable requirements, R&M development test and demonstration requirements (including test conditions), and acceptance criteria for the TMRR phase.

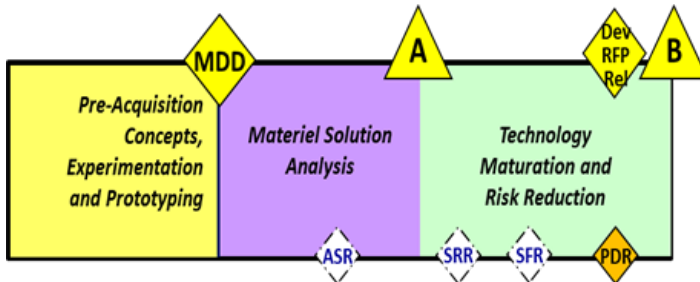
1.5.2. R&M Recommendation

On the basis of previous results, the R&M engineer should make recommendations, with adequate justification, for disposition by the program using one of the following alternatives:

- Recommend entering the TMRR phase when the assessment verifies conformance to desired capabilities defined in the draft CDD and risks are understood with acceptable mitigation plans; or for those items that have significant impact on R&M achievement in design, i.e., leave doubt that specified requirements can be achieved, further action may be required.

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2. R&M in the Technology Maturation and Risk Reduction Phase



Objectives of the Technology Maturation and Risk Reduction Phase

During the Technology Maturation and Risk Reduction (TMRR) phase, the requirements are transformed into practical design criteria suitable for system development. System configuration begins to take shape in the form of design drawings and specifications for major components of the system. Functional requirements are allocated to the lower tier components such that when recombined in the integrated system they will satisfy requirements defined in the functional baseline specification. Objectives of the TMRR phase are essentially twofold:

- Develop and verify adequacy of the allocated design for the system with respect to operational effectiveness and suitability, logistics supportability, and life cycle costs.
- Develop the allocated baseline (if the program completes a successful Preliminary Design Review (PDR) in this phase) and contract for the Engineering and Manufacturing Development (EMD) phase, by which the preliminary design can be transformed into engineering hardware and software for test and evaluation. If the contract overlaps the EMD and subsequent phases, the data and contract should also satisfy those subsequent phases.

The TMRR phase, like the Materiel Solution Analysis (MSA) phase, lends itself to R&M control both at a transitional milestone and at several important in-process decision points. This control is intended to prevent the premature release of a design to EMD by ensuring the design has the inherent potential to satisfy the operational thresholds.

R&M Activities in the Technology Maturation and Risk Reduction Phase

Figure 2-1 shows the primary activities to be performed during the TMRR phase. Table 2-1 lists the activities in approximate chronological order. The activities are usually performed jointly by DoD acquisition component program personnel and the contractor. Government R&M personnel are responsible for in-process monitoring and control of the activities.

2. R&M IN THE TECHNOLOGY MATURATION AND RISK REDUCTION PHASE

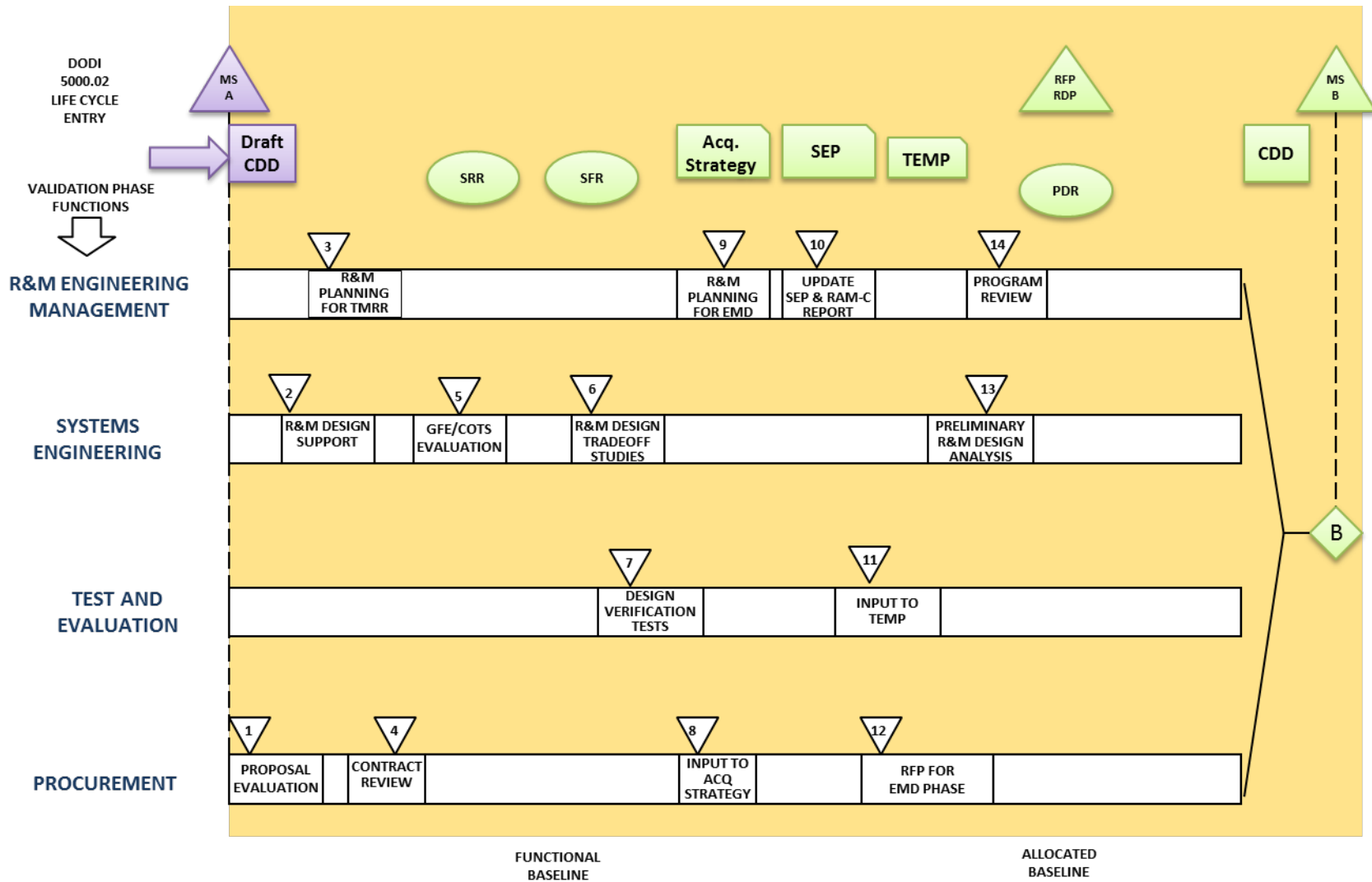


Figure 2-1. TMRR Phase R&M Activities by Functional Area

Table 2-1. R&M Activities in the TMRR Phase

TMRR R&M Activity		Functional Area	Paragraph
1	Evaluate proposals	Procurement	2.4.1
2	Provide R&M design support	Systems Engineering	2.2.1
3	Develop/review R&M planning for TMRR phase	R&M Engineering Management	2.1.1
4	Review TMRR phase contract	Procurement	2.4.2
5	Evaluate GFE/COTS	Systems Engineering	2.2.2
6	Perform design trade-off studies	Systems Engineering	2.2.3
7	Conduct design verification tests	Test and Evaluation	2.3.1
8	Provide R&M input to Acquisition Strategy	Procurement	2.4.3
9	Develop R&M planning for EMD phase	R&M Engineering Management	2.1.2
10	Update SEP and RAM-C Report	R&M Engineering Management	2.1.3
11	Provide R&M input to TEMP for EMD	Test and Evaluation	2.3.2
12	Prepare R&M input to RFP for EMD phase	Procurement	2.4.4
13	Conduct preliminary R&M design analyses	Systems Engineering	2.2.4
14	Conduct program review	R&M Engineering Management	2.1.4

2.1 R&M ENGINEERING MANAGEMENT

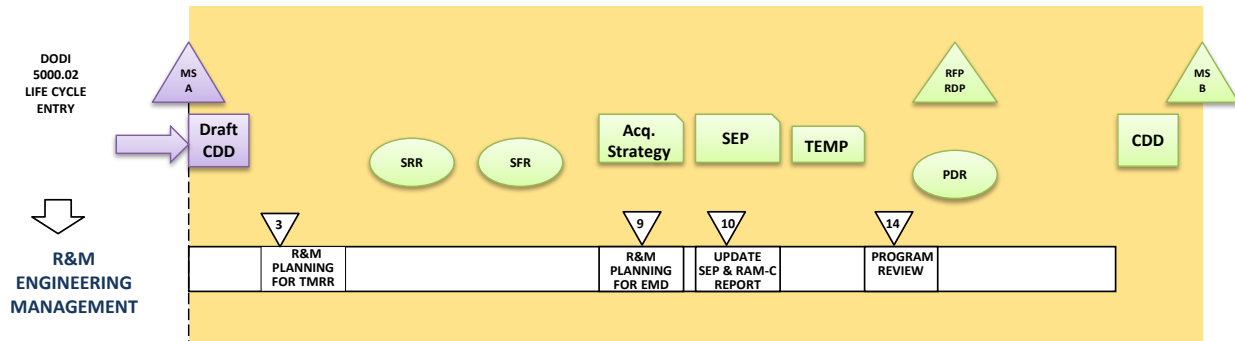


Table 2-2 lists the primary R&M activities associated with the R&M Engineering Management functional area in the TMRR phase.

Table 2-2. R&M Engineering Management R&M Activities – TMRR Phase

R&M	Description
3	Develop/review R&M planning for TMRR phase Review the R&M plans to ensure conformance to requirements defined in the RFP and contract and to verify consistency with requirements and provisions.
9	Develop R&M planning for EMD phase Review contractor-proposed R&M plans for EMD.
10	Update SEP and RAM-C Report Update the SEP and the RAM-C Report to account for changes that have occurred since Milestone A.
14	Conduct program review Perform R&M program reviews and support technical reviews (e.g. SRR, SFR, PDR) of the TMRR phase and evaluate contractor performance in accordance with the provisions of the contract.

2.1.1 Develop/Review R&M Planning for TMRR Phase



The R&M engineer and management team review the R&M program planning for the TMRR phase that the Government developed before initiating the TMRR phase and contract. The team updates the planning as appropriate to reflect specification changes approved during negotiations.

The program’s R&M requirements, as documented in the draft Capability Development Document (CDD) during the TMRR phase, are implemented by contractually specified contractor R&M plans. The contractor’s R&M plans should be submitted to and approved by the Government as part of the TMRR phase RFP. The contractor’s R&M plans should respond to the RFP and describe in detail the activities to be performed, the schedule of milestones and decision points to which the activities are applicable, and the data to be produced for design guidance and management decision at these decision points.

TMRR phase planning should be based on and convey the concept of R&M as integral parameters of system design, i.e., to be achieved, tested, evaluated, and controlled as design characteristics throughout the acquisition phases. The contractor's R&M plans should include provisions and procedures for integrating R&M controls into systems engineering, configuration management and change control, test and evaluation, logistics planning, and subcontractor procurement activities. The contractor's approved detailed plans become the plans of execution for the R&M activities specified in the contract and can be integrated into program planning documents as a part of the overall program R&M planning process. Design data the contractor produces allows the program to perform in-process reviews and periodic program reviews as part of its cross-functional and overarching R&M responsibilities.

When the TMRR phase involves multiple prime contractors, the activities outlined herein apply equally to all contractors. The activity flow diagram and schedule shown in Figure 2-1 and Table 2-1, respectively, are then duplicated for each contractor, and each contractor is monitored and evaluated against the provisions and requirements of the particular contract.

R&M PLANNING FOR TMRR: PROCEDURE

The Government R&M planning for the TMRR phase should be updated from the MSA phase. The planning as a minimum should address the following in the appropriate program planning documents:

- *Management* – Identify the organizational elements and personnel and clearly define their responsibilities and functions.
- *Management Activities* – Prepare a detailed listing and description of each R&M activity and the procedures to evaluate the status.
- *Resources* – Estimate the Government R&M funding and man-hours for each R&M activity (or for the activity the R&M team is involved in) required in the TMRR phase.
- *Problem and Risk Areas* – Establish procedures for identifying critical R&M problems and risks and the plans for resolving and mitigating these problems in the TMRR phase.
- *Acquisition Program Documents* – Provide steps for updating the R&M inputs to the Systems Engineering Plan (SEP), Acquisition Strategy (AS), the RAM-C Report, the Test and Evaluation Master Plan (TEMP), and other program documents as required.
- *R&M Demonstration/Verification* – Provide the demonstration and confidence levels, as applicable, necessary to be accomplished to proceed into the EMD phase. As applicable, provide R&M contributions to technology demonstrations and prototyping test efforts.
- *Surveillance* – Make provisions to conduct R&M program reviews and on-site monitoring of contractor activity.
- *Data Requirements* – Identify the R&M data to be developed, collected, analyzed, and leveraged in the TMRR phase.
- *R&M Specification* – Establish the procedure and the analytical relationship between the draft CDD thresholds and the R&M specification requirements. Ensure that the R&M system and

2. R&M IN THE TECHNOLOGY MATURATION AND RISK REDUCTION PHASE

allocated requirements definition results in accurate, complete, and verifiable requirements that trace to the source requirements or required capabilities.

- *Request for Proposal (RFP)* – Prepare R&M inputs for the RFP for the EMD phase and develop criteria for evaluating proposals.

The contractor's TMRR phase R&M program plans should define the following:

- *Program Management* – R&M assurance and control plans related to the contractor's program activities and functions, consistent with the Work Breakdown Structure, and showing how R&M is to be integrated into the program organizational functions.
- *Activity Description* – Detailed descriptions of the R&M activities called for in the RFP, with clear definitions of the objectives and performance criteria.
- *Activity Schedule* – A schedule of R&M activities and data related to major program activities, design reviews, milestones, and decision points.
- *Growth Planning and Procedures* – Description of the growth planning process, reliability growth planning curve, analytical procedures, and data sources to be used in the measurement and assessment of R&M.
- *R&M Data* – Description of data outputs and technical coordination and data interchange interfaces between R&M design activities and the program activities (such as systems engineering, test and evaluation, product support) that these data requirements support.
- *Test Plan* – Outline of the proposed integrated test plan with clearly defined quantitative requirements for R&M measurement, growth planning, and demonstration on which the contractor proposes to verify the requirements.
- *R&M Monitoring* – Description of the contractor's monitoring, management, and reporting procedures for keeping the Government informed of R&M progress, problems, and corrective action status.
- *R&M Collaboration* – As applicable, a description of the contractor's role and participation in Government and associate contractor activities and forums to support cross-community R&M participation to share R&M information and integrate efforts.

R&M PLANNING FOR TMRR: DATA

The contractor's R&M program plans should include the data requirements outlined above and as required by the RFP. The Government should review these plans in preparation for the System Requirements Review (SRR). The plans should allow for updating as plans or procedures change by mutual agreement to conform to the needs of the program. Essential features of the contractor's approved R&M plans should be integrated into appropriate sections of the SEP and internal program documents including technical review entrance criteria.

R&M PLANNING FOR TMRR: REVIEW CRITERIA

- The contractor's R&M program plans satisfy the requirements outlined in the control procedure and data requirements above.



2.1.2 Develop R&M Planning for EMD Phase

The contractor prepares the R&M program plans for the EMD phase during the final stages of the TMRR phase. These plans are the basis for R&M specifications, SOW activities, Contract Data Requirements List (CDRL) items, compliance specifications and standards, and instructions included in the RFP for the EMD phases. Government R&M planning should be updated in accordance with program status and the contractor's program plans.

The contractor's R&M plans also should include the procedures to control R&M of items that are sensitive to manufacturing and assembly operations, processes, workmanship, and ownership cost, necessary to achieve the inherent R&M design.

R&M PLANNING FOR EMD: PROCEDURE

Format and content of the EMD phase R&M plans should be similar to Activity 3, Develop/Review R&M Planning for TMRR Phase, and tailored as applicable. In addition, using the TMRR phase contract requirement and the current TMRR phase R&M assessments as the basis for review, evaluate the contractor's proposed R&M plans for EMD from the standpoint of applicability and projected actual need in the EMD phase to accomplish the following:

- *Activity Description* – Verify that the R&M program activities related to systems engineering, test and evaluation, and design review are consistent with requirements.
- *Data Requirements* – Verify that R&M data requirements adequately reflect any change in emphasis or schedules in the activity descriptions.
- *Reliability Growth* – Verify the adequacy of system and subsystem reliability growth plans, including an updated system level reliability growth curve that is compatible with the Government reliability growth planning curve in the SEP.
- *R&M Demonstration and Test* – Verify the adequacy of subsystem and system R&M demonstration and test plans and procedures (including ensuring that demonstration and test conditions, data collection methodologies, and personnel are sufficient).
- *R&M Control* – Evaluate provisions for R&M control procedures to be applied to contractor and subcontractor/vendor activities.

R&M PLANNING FOR EMD: DATA

The contractor's R&M plans for the EMD phase should include data as described in Activity 3, Develop/Review R&M Planning for TMRR Phase, and also should provide a detailed description of the following:

- *R&M Management* – A description of the organizational and management aspects of R&M monitoring, coordination, control, and reporting. The description should include R&M review and control points keyed to the schedule of major program milestones.
- *Activity Descriptions and Analytical Procedures* – A description of R&M activities associated with activities leading to each milestone, or to be performed in support of major milestone decisions. Include descriptions, by reference to standard procedures where appropriate, of

specific analytical and engineering procedures to be used in activity performance throughout the program.

- *Critical Review Activities* – Proposed schedule and description of R&M activities for design review and test plan review.
- *Failure Data Feedback System* – A description of the Failure Reporting, Analysis, and Corrective Action System (FRACAS) to be implemented.

R&M PLANNING FOR EMD: REVIEW CRITERIA

- *Adequacy of Planning* – The proposed plan is sufficient in terms of activity descriptions, procedures, schedules, and outputs to be immediately implementable if no further changes in program plans occur.
- *Compatibility* – The proposed plan is compatible with current plans for the program’s EMD phase of acquisition, as verified above.

2.1.3 Update SEP and RAM-C Report



The SEP should be updated to account for changes that have occurred since approval at Milestone A. The RAM-C Report should be updated to evaluate the implications to cost and availability resulting from any changes in the reliability or maintainability attributes.

SEP AND RAM-C: CONTROL PROCEDURE

Use the [SEP Outline](#) as a guide for developing SEP inputs, including the system reliability growth curve. Use the [DoD RAM-C Rationale Report Manual](#) for developing RAM-C inputs.

SEP AND RAM-C: DATA REQUIREMENTS

R&M information should be integrated into appropriate sections of the SEP with a RAM-C Report attached.

SEP AND RAM-C: REVIEW CRITERIA

- R&M Technical Performance Measures (TPMs), growth curve, requirements, and engineering approach are properly integrated into the systems engineering program and conform to the SEP and RAM-C requirements.

2.1.4 Conduct Program Review



The Government should conduct periodic R&M program reviews to evaluate contractor progress. Regular on-site R&M reviews should be planned to support the system design reviews: SRR, System Functional Review (SFR), and PDR, and the final R&M assessment conducted at the completion of the TMRR phase as part of the Development RFP Release Decision Point and Milestone B reviews. These R&M reviews will verify that the contractor’s R&M activities and deliverables, as required by the contract, are effective and have directly influenced the contractor’s system design and design team activities. The SRR should determine the adequacy of R&M

requirements and planning. The SFR should assess the R&M functional baseline. The PDR should assess R&M characteristics of the allocated baseline.

Each R&M review should include R&M assessments to evaluate the design's conformance to requirements and to update R&M requirements consistent with design trade-off decisions.

R&M PROGRAM REVIEW: PROCEDURE

Prior to the formal design review, R&M reviews should be held to assess the R&M design status against the formal design review's entrance criteria. Using the approved contractor R&M program plans (including schedule of activities) as a basis, evaluate the effectiveness of the implemented R&M program from the following points of view:

- *Activity Performance* – Assess the degree of conformance of the R&M program activities.
- *Design Documentation* – Evaluate the adequacy of R&M design documentation.
- *R&M Utilization* – Evaluate the degree to which results of the R&M program are being applied by different functional activities for which the results are considered essential.
- *R&M Management* – Evaluate the effectiveness of contractor program management in technical direction, coordination, monitoring, and control of R&M activity performance and integration of R&M activities into functional activities and program decisions.

R&M PROGRAM REVIEW: DATA

The following contractor-prepared data items are required at program review points:

- *R&M Design Analyses Results* – R&M allocations, block diagrams, and mathematical models; current prediction analysis of design R&M; Failure Mode, Effects, and Criticality Analysis (FMECA) and data sources for the basis of technology development; and assumptions relative to operational conditions, mission profiles, duty cycles, environments, and Government-furnished equipment (GFE) R&M underlying the analyses.
- *Problem Description* – Current evaluation of R&M problems as to criticality, corrective action alternatives considered, implementation status, risks, and estimated growth potential.
- *Interface Documentation* – Description of interface requirements and compatibility problems with GFE as well as contractor-furnished equipment (CFE) installation interface requirements and integration problems, risks, and recommended solutions/mitigations.
- *Trade-off Study Results* – Results of trade-off studies performed among system performance and effectiveness characteristics and ownership costs.
- *Subcontractor R&M Status* – Current evaluation of subcontractor R&M status relative to R&M analysis results, problem description, and interface data.
- *Procurement Documentation* – Description of how R&M requirements and control provisions flow to specifications, drawings, test plans, and subcontractor/vendor procurement documents.

2. R&M IN THE TECHNOLOGY MATURATION AND RISK REDUCTION PHASE

As a result of the program review, minutes of the review should be recorded to include defined R&M problems and deficiencies and R&M action items for assignment to the responsible party. The R&M program review minutes should include a summary description of the following:

- R&M assessment of system design progress and attainment of applicable design review entrance/exit criteria.
- Identification of program-level R&M risks, and identification of R&M design deficiencies to be corrected.
- R&M assessment for each design trade-off, as applicable.
- R&M growth to be realized by application of appropriate corrective action via the FRACAS.
- Definition of specific corrective actions, if applicable, as a result of the FRACAS. Schedule for follow-up review of assigned corrective actions, if applicable.

R&M PROGRAM REVIEW: REVIEW CRITERIA

- Applicable contractually specified entrance/exit criteria are satisfied; for example:
 - *Activity Performance* – Progress of individual R&M activities synchronizes with the scheduled needs for R&M data by other program activities in the Integrated Master Schedule (IMS).
 - *R&M Data Adequacy* – Data developed from R&M activity results are valid, unambiguous, and readily useful to the action recipient.
 - *R&M Risks and Problems* – R&M risks have been identified and elevated to the appropriate level of the program's risk management process. Previously identified R&M design problems have been corrected, or their correction by verified methods is imminent.
 - *Validity of R&M Estimates* – R&M analysis is based on valid data and analytical procedures.
 - *Degree of Conformance* – R&M predictions verify feasibility of achievement of design requirements as defined in the functional baseline specification.

2.2 SYSTEMS ENGINEERING

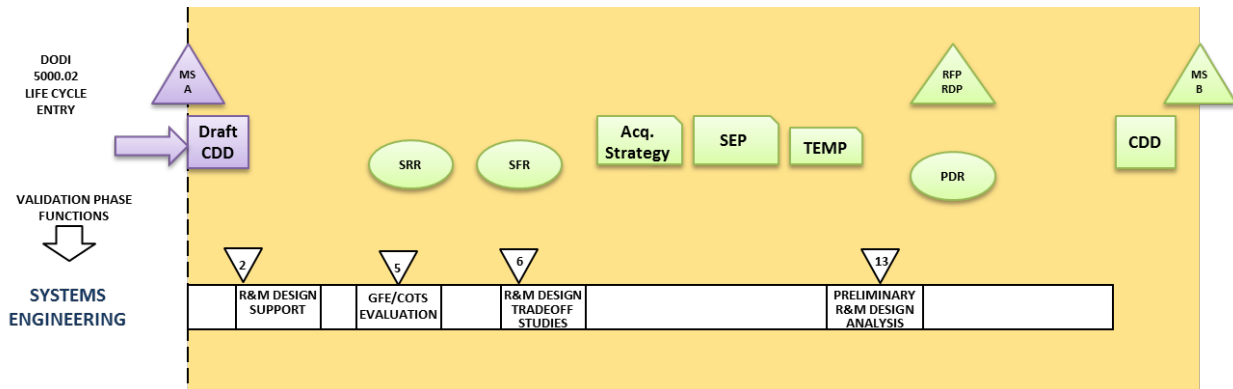


Table 2-3 lists the primary R&M activities associated with the Systems Engineering functional area in the TMRR phase.

Table 2-3. Systems Engineering R&M Activities – TMRR Phase

R&M Activity	Description
2 Provide R&M design support	Evaluate adequacy of contractor’s design analysis, critical area investigations, problem diagnosis, and corrective action.
5 Evaluate GFE/COTS	Review contractor’s analysis of R&M of GFE/COTS to be considered for integration into the system design.
6 Perform design trade-off studies	Verify contractor’s R&M design trade-off studies and mission R&M simulation analyses to ensure adequate consideration of R&M as design characteristics.
13 Perform preliminary R&M design analyses	Review contractor’s R&M analyses.

2.2.1 Provide R&M Design Support



To be effective, R&M engineering principles should be incorporated early in the design process. As part of its systems engineering function, the contractor should apply R&M engineering principles in each step of design. The contractor usually establishes these principles in its design guidelines and company policies on items such as design margins and parts derating. Evaluation of contractor effectiveness in achieving the desired level of R&M design integration should determine the degree to which the contractor’s design activity is receiving (and responding to) design guidance from the R&M engineering staff.

DESIGN SUPPORT: CONTROL PROCEDURE

Evaluate contractor R&M performance in the following areas:

- *Sensitivity Analysis* – Evaluate how the contractor will apply environmental factors and application stresses that affect the failure rate, failure mode, and maintenance action rate of critical items relative to the sensitivity of parts performance and characteristics to these stresses. This evaluation includes how modeled software performance will be analyzed for failure modes, maintenance and the loading of critical component sensitivity.
- *Design Margin* – Review the contractor’s procedure for analyzing performance characteristic degradation and for analyzing variability as a function of both non-operating and operating times. Evaluate the contractor’s guidelines for establishing design margins that jointly satisfy performance and R&M requirements.
- *Failure & Repair Distributions* – Evaluate the extent of contractor study of time-to-failure distributions and time-to-repair, and how they will be applied to identify cases in which appropriately scheduled preventive maintenance would enhance R&M of certain types of critical parts and components (e.g., pumps, motors, hydraulic components) used in subsystem design. Include the methods to control downtime and outages via detection and recovery mechanisms as well as other resilience design features.
- *Parts and Materials Application* – Evaluate contractor use of failure rate versus stress data, failure mode and maintenance action data information for critical parts, and materials to be used in the design, based on currently available experience data, vendor test data, and test data to be accrued on the current program.
- *Design Dos and Don’ts* – Review contractor design guidance documents to verify the adequacy of the use of approved design procedures, to avoid pitfalls of predecessor designs, and to provide guidance in areas such as software, human factors, environmental protection, and packaging.
- *Use of Redundancy* – Verify adequacy of redundancy in particular applications including consideration of the following: interactions among reliability, safety, maintainability, life cycle cost, and performance. Adequacy of approaches to achieve the required level of resilience within software components of the system.
- *Design Verification* – Evaluate contractor use of analytical techniques and verification methods as design tools for achieving specified design R&M in the system.
- *Statistical and Mathematical Data Sources* – Evaluate contractor use of mathematical and statistical data sources and assumptions, and lessons learned from similar fielded systems or other approved experience data in the design process.
- *Heat Dissipation* – Evaluate contractor methods for packaging, mounting, and cooling for components and parts subject to performance degradation or reliability failure under the design’s anticipated thermal environment.
- *Derating* – Review contractor and subcontractor derating guidelines as applied to particular equipment, parts, and components used in the design.

- *Protection Measures* – Evaluate adequacy of measures incorporated in the design to protect the equipment including the software from mishandling, operative abuse, installation error, and R&M deterioration due to maintenance error.
- *Stress versus Strength and Wearout Analysis* – Evaluate contractor analytical methods, ensuring they focus on understanding the physical processes and mechanisms that cause degradation and failure of materials and components. Identify existing evaluation methods that can be selected as needed during design and development activities to mitigate R&M risks. Evaluate the contractor’s methods to identify items or components that are prone to wear out during the intended service life for the system.

DESIGN SUPPORT: DATA

The contractor should provide the design guidelines it has established, which should include the items listed in the control procedure above. The Government should review the guidelines informally before the program SRR.

DESIGN SUPPORT: REVIEW CRITERIA

- The contractor’s R&M design guidelines are practical and applicable to the program or design problem.
- The guidelines cover the areas outlined in the control procedure and data requirements above.

2.2.2 Evaluate GFE/COTS



As part of its TMRR phase systems engineering function, the contractor must continue to evaluate Government-furnished equipment (GFE) and commercial off-the-shelf (COTS) equipment for possible use in the system design. Whenever practical, the contractor should use GFE/COTS that has proven to be reliable and effective. Using GFE/COTS can enhance operational effectiveness and reduce costs as the development and supply system for these items are already established.

To fully investigate GFE/COTS options and make informed decisions, the contractor should acquire design data, test results, and information on field performance and interface compatibility for the specific GFE/COTS items identified in the contract.

GFE/COTS: CONTROL PROCEDURE

Evaluate contractor progress in using GFE/COTS as follows:

- *Procedures* – Evaluate the contractor’s R&M assessment procedures to ensure appropriate environment, parts/materials, and installation/maintenance characteristics will be assessed when evaluating potential GFE/COTS.
- *Data Sources* – Determine the adequacy and validity of experience data used in the assessment, configuration status of items from which the data was acquired, duty cycles, environmental factors, and use conditions.
- *Analysis Results* – Evaluate the contractor’s analysis of GFE/COTS interface requirements, tolerances, incompatibilities, and other problems.

GFE/COTS: DATA REQUIREMENTS

The following data items are required for the GFE/COTS assessment:

- *GFE List* – List of GFE specified in the contract, to be included in or considered for integration into the system design.
- *GFE/COTS Data* –
 - Performance characteristics of GFE/COTS item(s) under consideration.
 - Physical and functional configuration as defined in applicable configuration documents and procurement specifications.
 - Observed (or predicted) failure rates, repair rates, and Built-in Test (BIT) performance derived from field or other approved data sources with associated environmental/ operational use conditions.
 - Environmental performance problems related to GFE/COTS operating outside their qualification levels that will jeopardize R&M in the integrated system.
 - When called for under the contract, an analysis to diagnose problems, determine root cause, and provide recommended corrective actions.

GFE/COTS: REVIEW CRITERIA

- *R&M Adequacy* – Reliability, maintainability, and failure mode characteristics of GFE/COTS proposed for integration into the design should be compatible with requirements that would otherwise have been allocated to CFE items in the same application.
- *Analytical Validity* – R&M analysis procedures and data sources should be validated.

2.2.3 Perform Design Trade-off Studies



At planned intervals, the program office will review the contractor’s effectiveness in applying R&M analyses and factors to the design trades and technical decision processes. The program office verifies realism, completeness, and objectivity in predictions, allocations, and modeling and simulation analyses made on each potential design configuration. Verify that the contractor’s proposed allocations are consistent with the mission models for the design, considering relative importance and duty cycle of constituent end items. R&M requirements should be defined in quantitative terms for integration into the allocated baseline specifications for constituent end items of the system.

TRADE-OFF STUDIES: CONTROL PROCEDURE

Evaluate Government and contractor trade-off analyses and simulation studies for compliance with requirements, and verify adequacy and validity of the contractor’s design analysis report in the following areas:

2. R&M IN THE TECHNOLOGY MATURATION AND RISK REDUCTION PHASE

- *System Description* – Verify the system description in terms of functional and physical configuration, maintenance concept applicable to the design, equipment utilization factors, and mission profiles for the defined missions with associated performance limits.
- *R&M Modeling* – Validate block diagrams, taking into consideration redundancy possibilities, alternate modes, and backup system capabilities.
- *Data Validity* – Validate equipment failure rates and repair rates and other data used in the simulation study.
- *R&M Allocations* – Verify consistency of allocated design requirements for each constituent subsystem, equipment, and separately procured end item of the system, and verify that the minimum acceptable R&M requirements to be demonstrated by test correspond to the allocated design requirements.
- *Test Requirements* – Verify adequacy and applicability of R&M demonstration and test requirements, conditions, and acceptance criteria for each allocated requirement.
- *Feasibility Study* – To determine feasibility of achieving the specified requirements, validate feasibility estimates for each of the allocated values, based on current design configuration; evaluate differences between specified, predicted, and allocated R&M for each subsystem; and evaluate alternative approaches under consideration by the systems engineering team.
- *Problems and Risks* – Review problems and risks identified within each subsystem/equipment and verify criticality ranking, corrective action requirements, and estimated growth available through problem correction. Identify areas in which further system design and operational analysis are required to determine essential equipment and backup capabilities.

TRADE-OFF STUDIES: DATA REQUIREMENTS

Contractor data requirements for this review point include the following:

- *R&M Analysis* – Design analysis covering the specific items outlined in the control procedure.
- *Supporting Data* – Individual analyses and data sources summarized in the R&M analysis.
- *Design Data* – Current design data to which the R&M analyses are applicable.

TRADE-OFF STUDIES: REVIEW CRITERIA

- *Conformance* – Allocated R&M requirements, when combined at the system level, satisfy system R&M requirements defined in the functional baseline specification.
- *Validity* – Analytical procedures and data used in the trade-off studies are validated by independent assessment.

2.2.4 Conduct Preliminary R&M Design Analyses



R&M design analyses serve two purposes, to guide the R&M design and to assess progress toward meeting the specified requirements.

2. R&M IN THE TECHNOLOGY MATURATION AND RISK REDUCTION PHASE

R&M engineering design analysis should be appropriately tailored for the phase and type of program. Each R&M engineering activity should be contractually specified. The Government must actively monitor the activities during on-site, in-process reviews and at established formal systems engineering design reviews. Results of these activities are also used as a basis for review of R&M requirements in specifications and drawings.

R&M design analysis are performed by the Government, contractor, and subcontractors on a continuous cyclic basis. This approach corresponds to the several configuration iterations (“design, test, re-design, test” cycles) through which system designs progress to achieve and demonstrate the specified requirements.

R&M design analyses will support the SRR, SFR, PDR, and Development RFP Release Decision Point during the TMRR phase. These design analyses implemented in accordance with approved R&M program plans ensure system designs are capable of acceptable R&M performance.

DESIGN ANALYSES: CONTROL PROCEDURE

The following resources may be required for this activity:

- R&M design analysis tools
- Commercial use data for COTS
- Operational use/failure data of equivalent or similar systems/equipment
- Prototyping of technologies and preliminary designs
- Applicable lessons learned data

The following processes constitute the R&M design analyses to be performed prior to appropriate design reviews. Not all of these analyses may be required for every program. The specific analyses to be performed should have been determined in the planning stages of the program. They should be tailored based on the acquisition strategy, acquisition phase, the complexity of the product being developed, the criticality of the product, life cycle cost considerations, and other programmatic concerns.

Government R&M engineers typically perform the R&M analyses for in-house developmental programs. For contracted programs, the contractor’s design or R&M engineers typically perform these analyses, and Government R&M engineers review the results, provide comments, negotiate improvements, and approve the final plans or reports. Perform R&M analyses in roughly the following order:

(1) Parts Derating Guideline and Stress Analysis

Establish, use, and maintain design derating for all types of electrical and mechanical parts and materials to provide for reliable operation at the maximum operating stress levels. These design deratings should be based on the maximum rating for the parts and materials that, as limiting values, define the electrical, mechanical, thermal, environmental, and special sensitive criteria beyond which either initial performance or operating is impaired. All critical parameters should be addressed for each part or material subclass.

(2) Mission Profile Definition

The specification of R&M is bound to a mission time period and includes war and peace missions, training, and disposal. This cycle repeats throughout the life of a system. For example, in the case of an aircraft, the operating time period is the normal number of flying hours defined in the specification (e.g., 2-hour mission). This mission time, however, is only a fraction of the aircraft's total operational life. The program must consider R&M for the aircraft's total operational phase, from acceptance-to-end-of-useful life. This life cycle profile should define all the significant objectives and constraints that affect each mission. Figure 2-2 illustrates a sample mission profile for an aircraft.

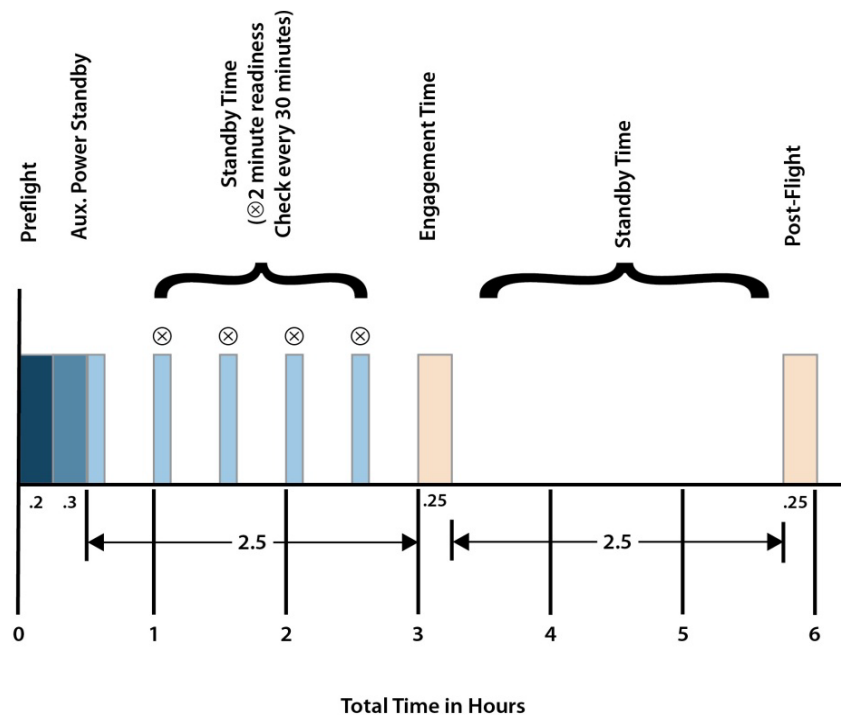


Figure 2-2. Sample Aircraft Mission Profile

Analyze the operational mode summary/mission profile (OMS/MP) provided by the Government to ensure it represents a description of system environmental and use duty cycles throughout the mission period for which reliability is to be specified and that it identifies a time sequence description of operational events required, in the mission period, to accomplish the objective(s). The OMS/MP should include identification of the environments that will exist in the mission sequence and the functions to be performed in the mission sequence.

(3) Environmental Studies

A system's life cycle includes exposure to natural or induced environments. Exposure to these environments places stress on the items that may cause system failure if the design is not capable of withstanding those stresses. A failure may not occur at the time of stress application, but may occur at another time because of a weakening process that may be dependent upon other factors.

2. R&M IN THE TECHNOLOGY MATURATION AND RISK REDUCTION PHASE

Develop an environmental study in order to understand the conditions that prevail on the total system or subsystem. The environmental study identifies anticipated use conditions as a significant part of the development of design and test criteria. Each identified use condition places a requirement on the system. It is essential that all the use conditions associated with the total life cycle be considered. Use conditions should include a description of the anticipated installation interfaces, interference characteristics of adjacent or associated systems, interactions with support systems, and the environments with which the system is to be compatible during its life cycle. The description should include manufacturing, packaging, handling, storage, transportation, maintenance, test, checkout, and operational conditions.

The more completely the life cycle profile is defined and understood, the better the system can be designed for reliability. In the total mission, the events and situations representing a significant portion of an item's life are systematically analyzed to determine their effect on reliability. The total life cycle includes conditions of transportation, handling, storage, maintenance, and operation, so the environmental study will involve other systems engineering and logistics efforts. Figure 2-3 shows an example environmental study outline.

2. R&M IN THE TECHNOLOGY MATURATION AND RISK REDUCTION PHASE

Interfaces with Connecting Systems	Description
Primary Electrical Power Source: Terminal Voltages and Tolerances Frequency and Tolerances Phases and Connection Regulation (full load to no load) Peak and Average Capacity (available to system) Primary Hydraulic and Pneumatic Power Source: Nominal Pressure and Tolerances Peak and Average Capacity Control Signal Sources (analog and digital): Frequency or Bit Rate Signal Levels and Tolerances Impedances Vibration and Shock at Physical (mounting) Interfaces: Frequencies G-levels Duration Thermal and Humidity: Heat Sink Characteristics (water coolants, etc.) Cooling Capacity	
Interactions with Support Systems	
Maintenance Policy: Off-board/Onboard Maintenance Tools Preventive and Marginal Testing Procedures Level of Technician Qualification Operating Policy: Procedures Qualifications of Personnel Failure Dependencies: Isolation Requirements Protective Features, Inherent Fail-Safe Protection Required	
Interference from (and to) Adjacent Systems	
Radio Frequency Interference (noise and power): Frequency Spectrum Modulation Characteristics Radiation Pattern and Power Isolation (shielding), Required Physical Interference: Structural Shadows and Beam Deformation Induced Vibration, Shock, and Thermal Environments	

Figure 2-3. Example of System Environmental Study

(4) R&M Block Diagrams and Math Models

Prepare the R&M block diagrams and math models to reflect the equipment/system configuration from an R&M perspective (reflecting series and redundant elements) and to develop R&M allocations and predictions. One approach to R&M block diagrams contains several levels of indenture. Figure 2-4 illustrates a sample block diagram.

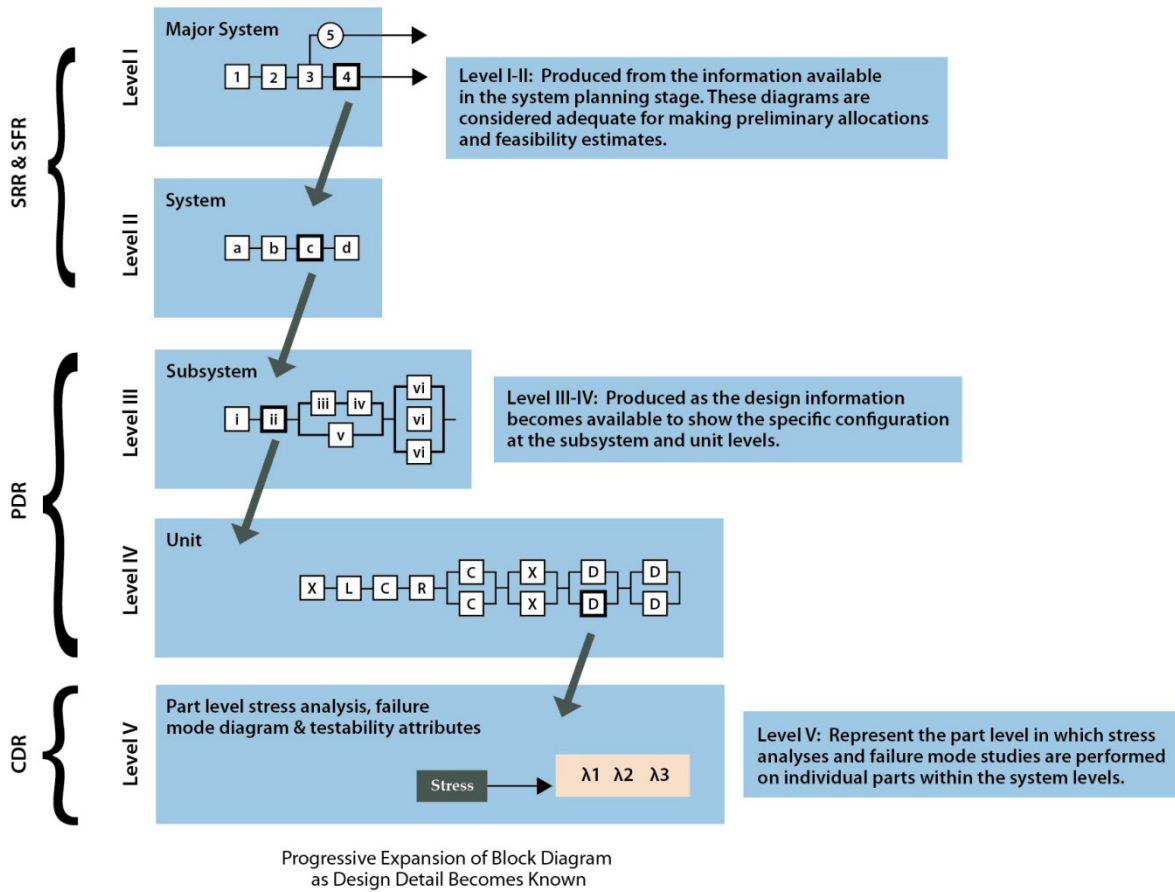


Figure 2-4. Block Diagram Levels

(5) R&M Allocations

The Government generally establishes R&M requirements, which the contractor allocates to the appropriate level of system design. The allocation process should result in the most economical use of available resources.

First, construct system models, which break down the overall requirement into separate requirements for the numerous items that make up the system. The R&M of an individual item varies with the type of function to be performed, its complexity, and the method of accomplishing the function.

To arrive at the most economical and realistic requirements, take into account the factors influencing the R&M of each item; however, the process is approximate and usually results from a trade-off between the R&M of the individual items. If the R&M of a specific item cannot be achieved at the current state of technology, then the system design should be modified and the allocation reassigned. Repeat this procedure until one allocation is achieved that satisfies the system-level requirement and results in items that can be designed.

Exercise caution in allocating system requirements when GFE/COTS items are part of the system. Often the source data originally specified for such GFE/COTS items are used in lieu of the actual

field data. Use of original source data (i.e., specification or lab-demonstrated values) can affect the achievement of system requirements, development time, and cost. If the actual GFE/COTS source data are significantly worse than the original specification values, then the allocation for the contractor items will be inadequate to satisfy the system requirement. On the other hand, if the GFE/COTS source data are significantly better than the specified value, then the allocations for the contractor items will be higher than required and could cause an increase in development time and cost necessary to satisfy the system requirements.

(6) R&M Predictions

The role of R&M predictions during design is to provide an evaluation of the proposed design or a comparison of alternative designs. R&M prediction is the process of quantitatively assessing the system's R&M performance during its development. There is inherent uncertainty involved in R&M predictions. Care should be taken to understand the level of uncertainty present in the prediction, and to make design and management judgements accordingly.

Determine the R&M performance levels of the lowest system-level item through intermediate levels to arrive at an estimate of system performance. The value of the quantitative expression lies in the decisions made from the insights that resulted from the assessment. Predictions should be used as the basis for refining design alternatives and for evaluating the feasibility (prediction versus specification requirement) and risk factors associated with R&M requirements.

Reliability prediction methods include parts count, stress analyses, and physics of failure prediction methods. These methods require different types of data sets to operate, and they vary in degree of information needed to apply them. Consequently, each prediction effort is evaluated in view of the development phase it represents.

Perform maintainability predictions determine the amount of time needed to restore an item to full operational capability (corrective maintenance) and the time needed to conduct preventive maintenance. All prediction methods require that the maintenance tasks needed (from locating the fault to verifying the repair) are identified for each maintenance event. Repair times for individual items can be combined with appropriate failure rate weighting to determine the overall mean time to repair (MTTR) of a system.

A subset of maintainability is BIT or testability. For systems with BIT, perform predictions for fault detection and fault isolation percentages. False alarm rate can be determined only during demonstrations and tests.

(7) Failure Mode, Effects, and Criticality Analysis (FMECA)

Perform a FMECA in conjunction with the reliability prediction to assess the severity of the effects of component and subsystem failures on system performance and to assess the likelihood of occurrence of the various failure modes. This analysis should include supporting software FMEAs to assess the severity of the effects of software failure modes. The software FMEA should incorporate relevant views (e.g. interface, functional and usability) and the results used to inform error and exception handling methods for software development. The FMECA is a joint effort between design, software development and R&M engineering teams. Perform a functional FMECA during the

TMRR phase to support the PDR, and a physical FMECA during the EMD phase to support the Critical Design Review (CDR). The FMECA should be updated throughout the life cycle as the design is changed and more information is discovered during verification, production, and deployment. Use the results of the FMECA in conjunction with design engineers to improve the design by addressing the most frequently occurring failure modes and the failure modes having the most serious effects, particularly the single-point failures that directly result in mission failure or create unsafe conditions. Programs also may use FMECAs to support the design of built-in diagnostics and test capabilities. Ensure the results of the FMECA are provided to safety engineers, who use the results to perform safety analyses, and logistics personnel, who use the results for system and maintenance planning.

(8) Reliability Critical Items

Based on the FMECA, perform an analysis of reliability critical items to identify those components/subsystems that require exercise of special care and control because of unusual or exceptional risk and to develop the special program controls necessary to mitigate the risk. Through review of design and R&M analysis information, identify those items that for reasons of complexity, criticality, application of advanced state-of-the-art techniques, ownership cost drivers, or other special R&M risk require special controls to mitigate risks. Controls may include special oversight over subcontracts, special testing, special design analyses, special attention to failure tracking, analysis, and corrective action development, or other items to ensure achievement of R&M objectives and control risks.

DESIGN ANALYSES: DATA

The following data should be available for the in-process review of R&M analyses results during the TMRR phase:

- By SRR:
 - Preliminary environmental studies.
 - R&M block diagrams, allocations, and predictions for major system and subsystems.
 - Reliability growth curve that is compatible with the Government reliability growth planning curve included in the SEP.
- By SFR:
 - R&M Specification – Approved specification R&M requirements reflecting functional baseline.
 - The OMS/MP definition (provided by the Government) is used by the contractor to provide the following:
 - Mission objectives, including what, when, and where a function is to be accomplished.
 - Constraints that affect the way objectives are to be accomplished (e.g., launch platform, design ground-rules for various flight conditions).

2. R&M IN THE TECHNOLOGY MATURATION AND RISK REDUCTION PHASE

- Time scale of system-level functions to accomplish the mission objectives.
- BIT functional requirements for operations and maintenance have been properly allocated to the functional baseline and are supported by maintainer use-case analysis.
- The system architecture contains required BIT functionality.
- By PDR:
 - Design derating guide and criteria.
 - Final environmental studies.
 - R&M block diagrams, allocations, and predictions to subsystem and unit levels.
 - Current, approved version of allocated baseline R&M requirements.
 - Preliminary functional FMECA with supporting software FMEAs to the subsystem and unit that addresses 100 percent of the functions, and preliminary Critical Items list.
- All R&M analyses reports should also include:
 - Definition of equipment failure in terms of required performance parameters.
 - Description of source of data and analytical models and methods used in the prediction analysis and basis for the assumption of validity.
 - Preliminary identification and description of R&M problems, solution alternatives, and growth potential.

DESIGN ANALYSES: REVIEW CRITERIA

- Contractor design progress satisfies the criteria specified in the contract and the following:
 - *Requirements Analysis* – The OMS/MP, alternative modes of operation, logistics support and maintenance concepts, use conditions, and limitations are complete and adequately reflect the expected use environments in the field to the equipment level.
 - *Application Conditions* – Application stresses and environmental factors for which the R&M analyses are applicable are realistic.
 - *Data* – Failure rate data used in the analysis are derived from an approved (validated) source, and analysis models and procedures are documented and valid.
 - *Conformance* – The contractor’s preliminary design approach conforms to CDD thresholds. R&M allocations and predictions support all R&M specification requirements.
 - *Problems* – R&M problems, correction feasibility, and growth potential are addressed and adequate. Results from the acquisition program’s risk management program and FRACAS are included as necessary.

2.3 TEST AND EVALUATION

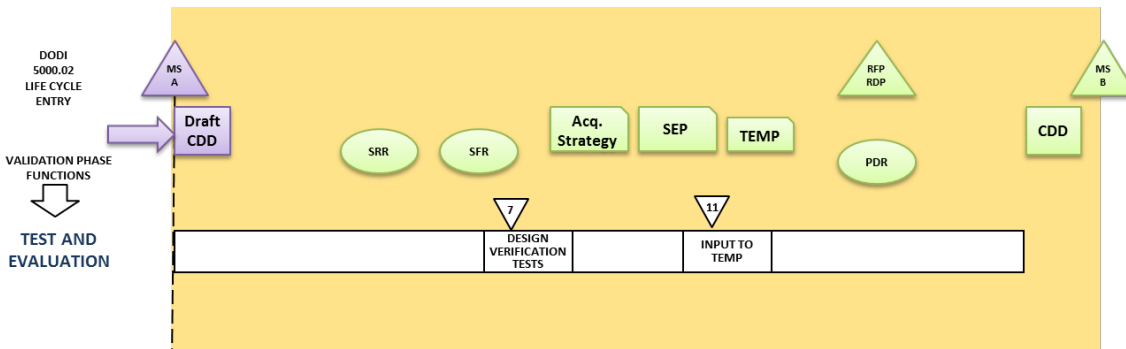




Table 2-4 lists the R&M engineering activities applicable to the TMRR phase Test and Evaluation functional area.

Table 2-4. Test and Evaluation R&M Activities – TMRR Phase

R&M Activity	Description
 Conduct design verification tests	Review R&M verification tests to verify adequacy of the test program and evaluate significance of test results.
 Provide R&M input to TEMP for EMD	Review contractor-proposed integrated test program, to verify adequacy of R&M test provisions and provide input to the TEMP.

2.3.1 Conduct Design Verification Tests

The Government and contractor’s T&E activities begin to provide a source of in-process R&M review data in the TMRR phase. The activities usually consist of design verification tests called for under the contract as appropriate to evaluate known critical technology areas, assess prototype characteristics in the proposed design. R&M tests may be called for as a component of technology studies and other technology demonstrations during the TMRR phase.

Design verification and/or risk reduction tests should be performed whenever there is reasonable doubt as to the adequacy or validity of analytical results related to a critical (high-risk) area of design.

DESIGN VERIFICATION TESTS: PROCEDURE

The Government should review critical areas of the design as revealed by the results of design verification tests have on the contractor’s R&M design analyses (e.g. predictions, FMECA, etc.).

- *Critical Areas* – Verify the existence and evaluate the nature of specific critical areas in the design, and assess significance of criticality in terms of impact on R&M.
- *Investigation of Unknowns* – Investigate and evaluate unique (or unpredictable) approaches to design problems to verify the adequacy of the solution and to quantify R&M parameters that otherwise would have remained uncertain.

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- *Tolerance and Interaction Problems* – Evaluate design interface tolerances, interaction and interference problems, and other problems that are more readily solved empirically than analytically.
- *Test Reports* – Verify that the test reports incorporate data analysis adequate for the guidance of design and the circumvention of problems revealed in the test program.

DESIGN VERIFICATION TESTS: DATA

The following data should be available for review:

- *R&M Report* – Description of R&M problems and critical areas and unpredictable (unknown) areas of design.
- *Design Verification Test Reports* – Individual test reports covering the following:
 - Description of problems or hypotheses investigated.
 - Test plan, including test conditions, duration, measurements, criteria, and test procedures.
 - Analysis procedures and verification criteria.
 - Analytical results of test data analysis.
 - Failure analysis, including root cause and assigned category.
 - Extrapolated estimates of R&M based on data analysis.

DESIGN VERIFICATION TESTS: REVIEW CRITERIA

- *Scope of Coverage* – The contractor’s design verification tests evaluate all areas of design for which experience data are not available for R&M analysis, or which (because of complexity) are not readily predictable by available analytical techniques.
- *Reporting* – Results of verification tests are reported in sufficient detail for design guidance.

2.3.2 Provide R&M Input to TEMP for EMD



As the TMRR phase nears completion, the contractor develops the proposed integrated test plan for EMD. This plan includes the R&M demonstrations and tests required to verify conformance to R&M requirements in the allocated baseline specifications developed during the TMRR phase.

T&E planning for the EMD phase includes the definition of all R&M test requirements and support activities. This step includes appropriate subsystem reliability growth tests (e.g., equipment accelerated life tests), maintainability and BIT demonstrations, system reliability development growth tests, and system-level R&M demonstration and test. These tests should be integrated into the contractor’s proposed overall T&E program for EMD. T&E planning should include measurement requirements and test conditions such that planned contractor tests and other planned tests can be adapted to as many of the R&M test requirements as possible.

R&M inputs are integrated and updated with the TEMP developed during the MSA phase. Test requirements and planning criteria should then be documented and accompany the EMD phase RFP

2. R&M IN THE TECHNOLOGY MATURATION AND RISK REDUCTION PHASE

and contract, defining test conditions, environmental factors, approval/disapproval decision criteria, and so on, to be referenced in the system specification.

INPUT TO TEMP: PROCEDURE

Review the contractor’s proposed EMD test program plan, and provide input to the TEMP:

- *System R&M Demonstration and Test* – Summarize the applicable R&M tests and demonstrations planned, with a description of conditions and measurement requirements to be integrated into applicable equipment, subsystem, and system development tests scheduled during the program. Include specific references to the applicable sections of the specification.
- *Reliability Testing* – Describe the test schedule and resources for subsystem-level reliability tests (i.e., Highly Accelerated Life Test (HALT)) and the adequacy of system-level growth test provisions for achieving requirements. For software, the reliability test approach should include appropriate tests (load/stress testing, failure injection testing, out of bound, database re-indexing, data aging, hard drive re-optimization, etc.) to precipitate software failure modes and associated defects. Update the TEMP with the reliability growth curve documented in the [SEP](#). Figure 2-5 shows a sample growth curve that summarizes the overall R&M test sequence for the EMD phase in relation to key decision points (i.e., system Test Readiness Review, first system-level test) and major program milestones (i.e., Milestone C, IOT&E). Include a description of the quantity and identification of items to be tested, test objectives, test conditions, test duration, measurements to be recorded, and provisions for recording measurement data required for R&M evaluation.

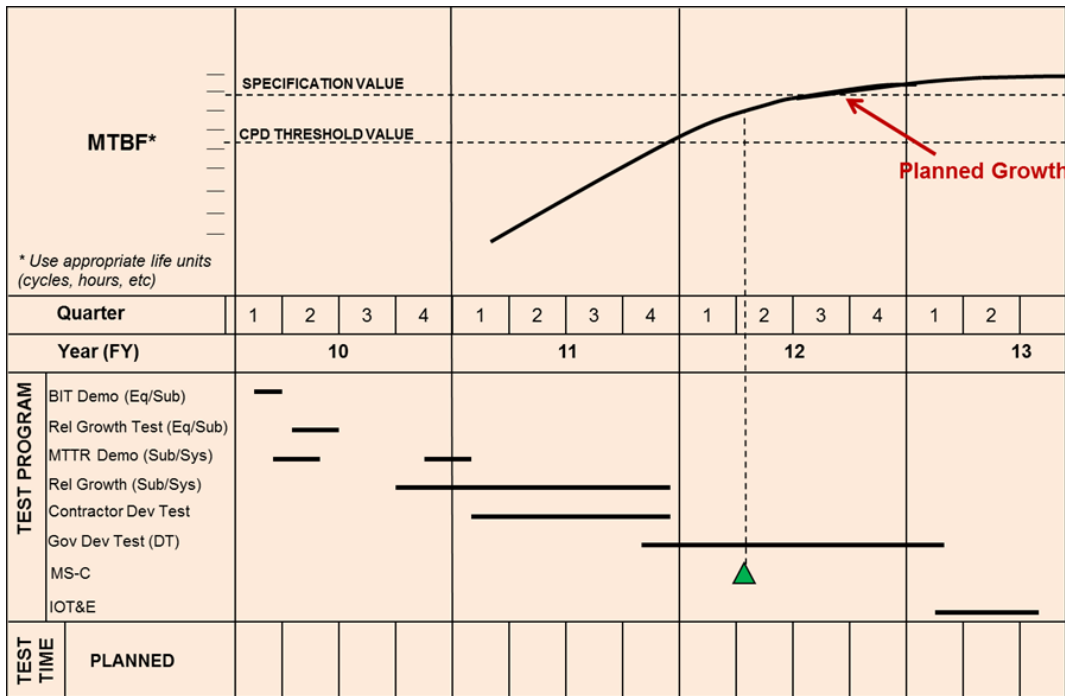


Figure 2-5. Sample EMD Test Sequence and SEP/TEMP Sample Growth Curve

- *Integration of R&M Engineering Activities* – Summarize R&M engineering involvement in applicable testing from functional tests, equipment qualification tests, and subsystem integration

2. R&M IN THE TECHNOLOGY MATURATION AND RISK REDUCTION PHASE

tests through system-level performance tests. Delineate responsibilities with regard to R&M for each test, for test design, test plan review and approval, test performance, data analysis, and FRACAS requirements.

- *R&M Measurement Requirements* – Define applicable R&M (includes BIT) parameter measurements, operating time data, test conditions, and failure information that should be collected during existing tests in the overall test plan to achieve maximum practical integration of R&M test requirements. Attach preliminary R&M scoring and evaluation criteria (i.e., Failure Definition and Scoring Criteria), including the corrective action evaluation methodology that will be used to compute R&M performance based on the data collected during system testing.

INPUT TO TEMP: DATA

Data typically include the following:

- *Proposed EMD Test and Evaluation Plan* – The contractor’s tentative plan for integration of R&M test conditions and measurement requirements into the EMD program.
- *Development Specifications* – Proposed functional and allocated baseline R&M specifications for EMD to verify that the test plan adequately covers all test requirements defined in these specifications.

INPUT TO TEMP: REVIEW CRITERIA

- *Test Plan Adequacy* – Contractor-proposed test plans conform to engineering and statistical test design criteria and environmental conditions defined in the baseline R&M specification and provide an adequate description of individual test plans to verify this conformance requirement. All R&M requirements are covered by a verification method.
- *Reliability Growth Test Adequacy* – The reliability growth planning curve as a function of test time is adequate to grow to the specification value and amount of test schedule and resources available to reach the requirement.
- *Demonstration/Test Criteria* – The proposed demonstration and test plan is designed for a clear-cut approval/disapproval decision on specified R&M acceptance criteria.

2.4 PROCUREMENT

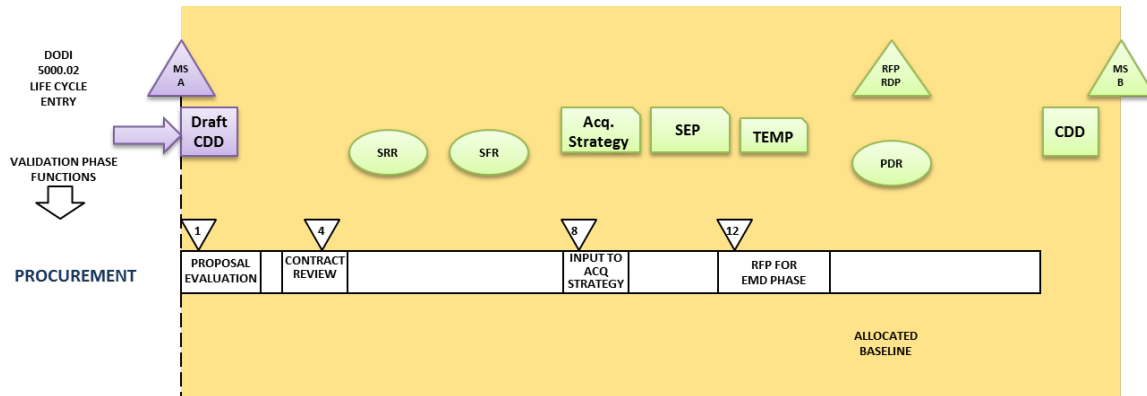






Table 2-5 lists the primary R&M activities associated with the Procurement functional area in the TMRR phase.

Table 2-5. Procurement R&M Activities – TMRR Phase

R&M Activity	Description
 Evaluate proposals	Evaluate the proposal responses to RFP-specified technical and program R&M requirements to evaluate the depth of understanding of the requirements and the capability to achieve and control the required level of design R&M.
 Review TMRR phase contract	Review R&M provisions and requirements in contracts as finally negotiated prior to formal execution by the Government, to verify that requirements have not been jeopardized in the negotiation process.
 Provide R&M input to Acquisition Strategy	Provide R&M-specific language for incorporation into the Acquisition Strategy.
 Prepare R&M input to RFP for EMD phase	Review the contractor-prepared RFP/proposed contract SOW for the EMD phase to verify conformance to the procurement documents, and conformance to guidelines prescribed in the TMRR phase contract.

2.4.1 Evaluate Proposals

The TMRR phase starts with the evaluation of proposals to select the TMRR phase contractor(s), if this evaluation was not performed during the MSA phase. When the TMRR phase is to proceed to contract award under the provisions of DoDI 5000.02, two or more contractors may be selected to participate competitively, the winner to be awarded the EMD phase contract. Any deficiencies or ambiguities noted in the selected proposal(s) should be corrected, either by obtaining clarifying supplemental material to the original proposals or by specifically correcting the deficiencies in the

2. R&M IN THE TECHNOLOGY MATURATION AND RISK REDUCTION PHASE

finalized TMRR phase contracts. Either approach requires technical negotiation with the prospective contractors that, when completed, should provide an adequate basis for contract award.

The Government must critically review all proposed contract documentation following final negotiation and before execution. This review must ensure that R&M requirements have not been inadvertently jeopardized in cost/schedule/performance trade-offs or changes in terminology in the process of negotiation.

Proposals submitted in response to the TMRR phase RFP should conform to R&M requirements specified in the RFP. Proposals must be fully responsive to the requirements, including appropriate detail and quantitative terminology. Inadequate response to R&M requirements specified in the RFP is indicative of inherent deficiencies in contractor capability, lack of understanding of the requirements, or lack of appreciation of its importance to the success of the program.

EVALUATE PROPOSALS: PROCEDURE

Review R&M responsiveness of bidders in the TMRR phase proposals, in the following areas:

- *R&M Analysis* – Evaluate the adequacy of R&M analysis of the bidders’ proposed design approach from the standpoint of requirements interpretation, modeling accuracy, realism of R&M source data, conservatism of analytical results, and procedures used for the analyses.
- *R&M Test Plans* – Evaluate the adequacy of proposed R&M test and evaluation plans for the TMRR phase and (tentatively) for the follow-on EMD phases.
- *R&M Control* – Evaluate the adequacy of plans and depth of procedures proposed for executing RFP-specified R&M activities and related management functions.
- *R&M Integration* – Verify that R&M considerations are reflected in other sections of the proposal, covering in particular the design, verification and program review functions.

EVALUATE PROPOSALS: DATA

Data for R&M evaluation of TMRR phase proposals includes the following:

- *TMRR Phase Proposals* – Complete proposal, including systems engineering, program management, R&M, test and evaluation, and other sections.
- *RFP Data Package* – Complete data package that accompanied the RFP.
- *Proposal Evaluation Criteria* – R&M evaluation guidelines for TMRR phase proposals.

EVALUATE PROPOSALS: REVIEW CRITERIA

- *Responsiveness* – The proposal is responsive to specific R&M activities, requirements, and criteria defined in the RFP.
- *Analytical Validity* – R&M analyses of proposed design configurations are conservatively realistic as verified by analytical procedures and data.

2.4.2 Review TMRR Phase Contract

4

Adequacy of R&M requirements and provisions defined in the proposed TMRR phase contract (SOW, specifications, and data requirements) should be reassessed following negotiation but before formal execution by the Government contracting officer.

REVIEW CONTRACT: PROCEDURE

Review the proposed contract to determine if, during negotiation, changes in contract requirements have voided (or severely decreased) the emphasis on R&M that the DoD acquisition component had initially intended. Proceed as follows:

- *Evaluate Changes* – Identify and evaluate any noted changes for their effect on achievable R&M.
- *Recommend Specific Changes* – Submit recommendations for the correction of noted discrepancies in the contract package.

REVIEW CONTRACT: DATA

The following R&M data supports the basis for an approval/disapproval decision by the designated contracting officer:

- *Conformance* – Degree to which the proposed contract fulfills the letter and intent of R&M requirements defined in the original RFP, including adequacy of R&M engineering activities.
- *R&M Deficiencies* – Major omissions, deviations, or word changes made during negotiation that would seriously jeopardize established R&M requirements of the program, and quantitative impact of these changes.
- *Recommended Changes* – Recommended changes to be incorporated in the contract by further negotiation as a prerequisite to formal execution by the Government.

REVIEW CONTRACT: REVIEW CRITERIA

- *Adequacy of Requirements* – R&M requirements, control provisions, and demonstration acceptance criteria have not been degraded in the negotiation process.
- *Conformance Requirements* – Rigidity and enforceability of conformance requirements initially defined in the contract have not been degraded in the negotiation process.

2.4.3 Provide R&M Input to Acquisition Strategy

8

The AS for the program should include a description of the activities essential for achieving and verifying the achievement of R&M requirements. The AS also should specify how the sustainment key performance parameter (KPP) thresholds have been translated into R&M design and contract specifications. The AS is updated from the MSA phase and is to be updated in each phase of acquisition. R&M engineers review the AS to evaluate its readiness to proceed to a higher level for review and approval.

INPUT TO AS: PROCEDURE

Prepare R&M Input to RFP for EMD, describes the activities to be performed that will result in the inputs to the AS. The [Acq Strat Outline](#) contains the R&M requirements:

- Identify the engineering activities to be stated in the RFP and required of the contractor to demonstrate the achievement of the R&M design requirements.
- Provide a table to specify how the sustainment KPP thresholds have been translated into R&M design and contract specifications.

INPUT TO AS: DATA

Consists of R&M language integrated into appropriate sections of the AS and updated as required.

INPUT TO AS: REVIEW CRITERIA

- *R&M Data* – The AS includes the R&M data outlined in the AS outline.
- *Verification* – R&M data summarized in the AS is consistent with the validated data presented in the CDD and the updated RAM-C Report.

2.4.4 Prepare R&M Input to RFP for EMD Phase

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Near the end of the TMRR phase, the contractor typically is required to prepare a proposed procurement package for the follow-on EMD phase, according to guidelines provided in the TMRR phase contract. The Government must review the documents to ensure completeness, accuracy, objectivity, and absence of ambiguities.

RFP FOR EMD: PROCEDURE

Evaluate proposed EMD phase RFPs and contract R&M requirements as follows:

- *R&M Program Plans* – Verify adequacy of contractually specified program plans, activities, and schedule, to support the EMD phase.
- *R&M Verification Plans* – Verify technical adequacy of contractually specified R&M test and evaluation requirements, to ensure detection and correction of problems in the EMD phase.
- *Subsystem and System Level Reliability Growth Plan* – Verify technical and programmatic adequacy of the reliability growth plan to ensure subsystem and system-level verification methods are part of the program's IMS. This will also ensure resources and schedule are available to reach the requirement.
- *R&M Demonstration Requirements* – Verify statistical and technical adequacy of demonstration and test plans and acceptance criteria.
- *Data Requirements* – Verify adequacy of R&M data requirements and data descriptions to be called for by the contract.
- *R&M Design Review* – Verify adequacy of provisions for design reviews, at designated major milestones in the EMD phase.

2. R&M IN THE TECHNOLOGY MATURATION AND RISK REDUCTION PHASE

- *R&M Change Review* – Verify that provisions for formal change control and analyses of R&M impacts are stipulated in the contract.

RFP FOR EMD: DATA

Data required at this point include the following:

- *Proposed RFP/Contract SOW* – Description of R&M activity, activity schedule, activity performance criteria, and demonstration requirements proposed for the EMD phase.
- *Contract Exhibits* – Proposed addendums (requirements and provisions) to the contract, including:
 - (1) Data requirements (CDRLs and Data Item Descriptions (DIDs)).
 - (2) Integrated test requirements, including demonstration and test design requirements and criteria.
 - (3) R&M program requirements, including design and test readiness review procedures and schedule.
- *Specifications* – System and end item (allocated baseline) EMD specifications, specifically the R&M design requirements and demonstration acceptance criteria.

RFP FOR EMD: REVIEW CRITERIA

- *Adequacy of Requirements* – The proposed RFP package defines firm quantitative requirements for reliability, maintainability, and BIT achievement; design review; control; test readiness review; and demonstration consistent with requirements defined in approved EMD specifications.
- *Provisions for Government Control* – The proposed RFP clearly defines the provisions for in-process review and control of R&M at designated systems engineering reviews.

2.5 MILESTONE B REVIEW

The Milestone B review at the conclusion of the TMRR phase requires an R&M assessment (often coincident with the scheduled program PDR) to provide the data necessary for an evaluation of R&M conformance to requirements in the system specification. The PDR, the final systems engineering design review before entering EMD, signifies completion of all assigned activities in the TMRR phase. It verifies the acceptability of activity results as a basis for a decision to proceed into EMD.

The contractor's prediction analyses, test results, problem evaluations, and root failure cause/categorization (by which the detail design has been guided) are verified analytically. The Government review team evaluates the program's progress and effectiveness in correcting deficiencies noted in the earlier assessments, and evaluates the status of any remaining R&M problems. The team evaluates the seriousness of problems to determine whether correction should be required before release of the design for development and manufacture. R&M requirements and provisions defined by the contractor in the proposed follow-on contract data package are critically reviewed to determine compliance with contract requirements (e.g., R&M plans, specifications, reliability growth plans, test and evaluation plans, demonstration acceptance criteria and procedures, data requirements, and contract work statement).

2.5.1 Procedure

Assess the following R&M aspects of the TMRR phase, and make recommendations to approve or disapprove the status of the proposed final design for EMD:

- *R&M Achievement* – Evaluate inherent R&M achieved by the design in its preliminary configuration (based on validated contractor R&M analysis or from test results), compared with specified requirements.
- *Problems* – Evaluate criticality to the system of R&M problems that still remain uncorrected and verify feasibility of correction before (or after) release to EMD.
- *R&M Growth Potential* – Compare predicted R&M growth potential (available through correction of remaining deficiencies) to specified requirements. Evaluate cost and schedule requirements related thereto.
- *R&M Allocations* – Evaluate R&M allocations for the proposed allocated baseline specification, and verify consistency with the estimated growth potential.
- *R&M Test Plans* – Evaluate the adequacy and compatibility of R&M demonstration and test requirements defined in functional and allocated baseline specifications.
- *R&M Contract Requirements* – Evaluate the adequacy of overall contractor conformance to R&M program requirements and activity descriptions as specified in the contract.

R&M Data Requirements – Evaluate the adequacy of R&M data submitted by the contractor in accordance with CDRLs appended to the contract. The following data items, updated from the PDR data package if necessary, are generally required at this review point:

- *R&M Analysis Reports* – Final TMRR phase R&M analyses and allocation reports.

2. R&M IN THE TECHNOLOGY MATURATION AND RISK REDUCTION PHASE

- *System Specifications* – Updated functional and preliminary allocated baseline specifications.
- *Integrated Test Plans* – Proposed integrated test plan for R&M evaluation and demonstration in the EMD phase.
- *R&M Program Plans* – Contractor-proposed R&M plans for the EMD phase.
- *Proposed Contract SOW* – R&M activities for achievement, monitoring, and control of R&M in the EMD phase.
- *Data Requirements Exhibit* – R&M contract data requirements and corresponding DIDs.
- *Program Documentation* – Input to program documentation such as the SEP, TEMP, and AS.

Assessment of R&M “readiness” for EMD should be performed for the Government by independent Government R&M personnel (i.e., not directly associated with the program to prevent bias) due to carryover of prior knowledge in the minds of those who participated in the earlier in-process reviews. The review should proceed as follows:

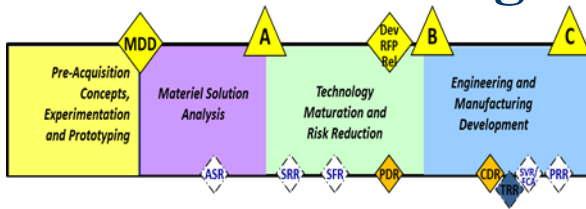
- Verify adequacy of R&M achievements and current status as reflected in the key documents needed at Milestone B for decision to initiate the EMD phase. Identify any inconsistencies or deficiencies noted in the review. Key references for evaluating adequacy of compliance with checklists are identified in each checklist.
- Reassess results of those activities that accounted for or produced noted inconsistencies or deficiencies.
- Prepare an assessment report to accompany the completed checklists, with an evaluation of the seriousness of noted R&M deficiencies and discrepancies.

2.5.2 R&M Recommendation

On the basis of the procedure above, make recommendations (with justification) for disposition of the program according to one of the following alternatives:

- Proceed into EMD: Design requirements are achieved and validated; EMD phase R&M requirements and provisions are adequately documented for release to EMD. Approve the design and design release data package for EMD (i.e., allocated baseline).
- Extend the TMRR phase to correct deficiencies: Design R&M requirements are not achieved or not verifiable, or requirements and provisions for EMD are not adequately defined. Update the design and data package to reflect correction of deficiencies.

3. R&M in the Engineering and Manufacturing Development Phase



Objectives of the Engineering and Manufacturing Development Phase

The Engineering and Manufacturing Development (EMD) phase continues the design that evolved in the preceding Technology Maturation and Risk Reduction (TMRR) phase and transforms it into a system for test and evaluation. Production-representative articles of the design are fabricated and packaged in the physical configuration called for in the product baseline specification. These production-representative articles are submitted to functional and environmental tests to verify that the design satisfies specified performance requirements under simulated environmental and use conditions.

Reliability, failure mode, and maintainability characteristics of the design (hardware and software) are evaluated during these early tests as a part of the contractor's integrated test program. Known critical areas and interfaces are evaluated in detail through specially designed verification methods early in the EMD phase, both to accurately define the problems and to empirically verify the solutions in an iterative (design-evaluate-redesign-reevaluate) approach to system development. For software and information systems, this should include testing throughout development to identify failure modes, evaluate failure detection and system recovery.

R&M data and assessments are required at the conclusion of each design iteration to support a decision to proceed into the next stage of development, or to require further redesign. These activities demand accurate and comprehensive R&M analyses on a timely basis to permit effective pursuit of program requirements in full knowledge of trade-offs involved in design approval decisions.

Final review of the proposed production design at Milestone C provides the basis for a decision for release to production. R&M assessments required at this milestone are typically derived from test results of formal system-level tests of the production-representative article with supporting R&M engineering analyses. The EMD phase is complete when the following general objectives have been satisfied:

- Production-representative articles demonstrate conformance by test in all aspects to requirements specified in product baseline specifications.
- Technical data and proposed contractual documentation are complete and adequate for release to production.

R&M Activities in the EMD Phase

Figure 3-1 shows the primary activities to be performed during the EMD phase for a typical program. Table 3-1 lists the activities in approximate chronological order. The activities ordinarily are performed by, or under direction of, the system contractor.

The designated Government R&M engineer is responsible for monitoring and evaluating contractor performance and for maintaining overall control of the EMD R&M program. The contractor should document the outcome of R&M Engineering activities required by the contract. The data should be available at designated design review and program review points, for use by the acquisition manager to evaluate contractor progress and activity performance against criteria defined for the individual tasks.

3. R&M IN THE ENGINEERING AND MANUFACTURING DEVELOPMENT PHASE

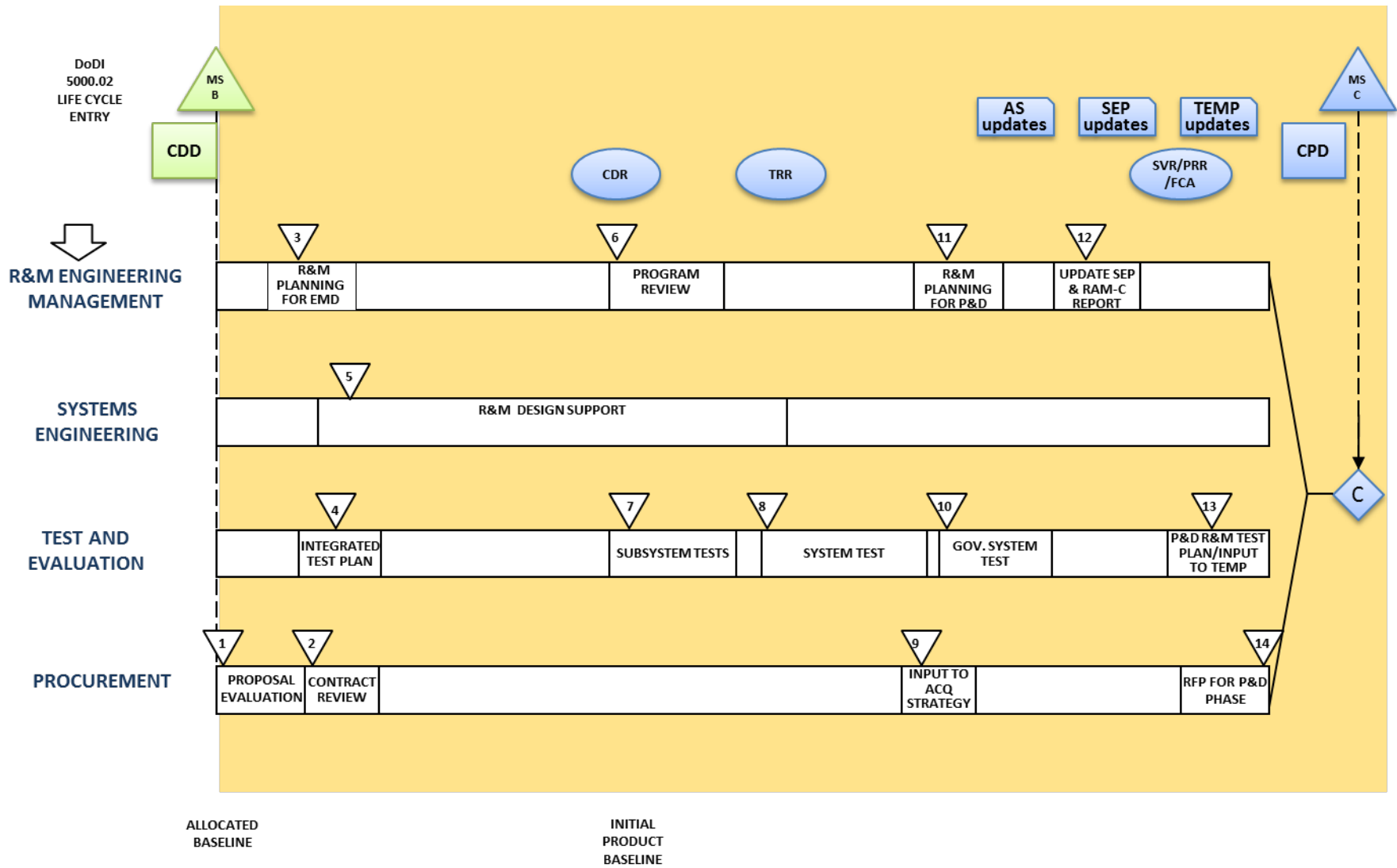


Figure 3-1. EMD Phase R&M Activities by Functional Area

Table 3-1. R&M Activities in the EMD Phase

R&M Task	Functional Area	Paragraph
1 Evaluate proposals	Procurement	3.4.1
2 Review EMD phase contract	Procurement	3.4.1
3 Develop/review R&M planning for EMD phase	R&M Engineering Management	3.1.1
4 Review integrated test plan	Test and Evaluation	3.3.1
5 Provide R&M design support	Systems Engineering	3.2.1
6 Conduct program review	R&M Engineering Management	3.1.2
7 Perform subsystem tests	Test and Evaluation	3.3.2
8 Perform system test	Test and Evaluation	3.3.3
9 Provide R&M input to Acquisition Strategy	Procurement	3.4.2
10 Perform Government system test	Test and Evaluation	3.3.4
11 Develop R&M planning for P&D phase	R&M Engineering Management	3.1.3
12 Update SEP and RAM-C Report	R&M Engineering Management	3.1.4
13 Review P&D R&M test plan/input to TEMP	Test and Evaluation	3.3.5
14 Prepare R&M input to RFP for P&D phase	Procurement	3.4.3

3.1 R&M ENGINEERING MANAGEMENT

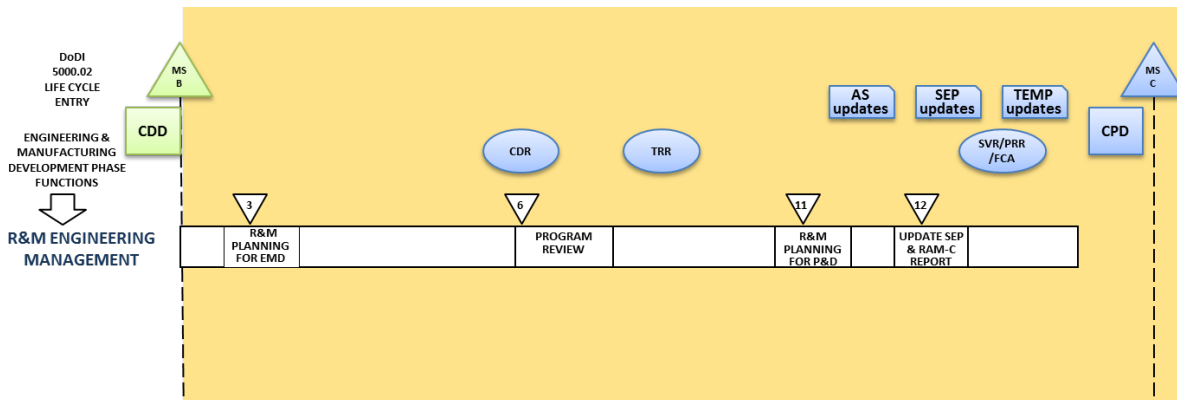






Table 3-2 lists the primary R&M activities associated with the activities for the R&M Engineering Management functional area in the EMD phase.

Table 3-2. R&M Engineering Management Activities – EMD Phase

R&M Task	Description
 Develop/review R&M planning for EMD phase	Update Government R&M program planning and review and approve contractor R&M program plans for EMD to verify compliance with contract requirements.
 Conduct program review	Perform on-site program reviews to evaluate effectiveness of contractor R&M performance to coincide with system critical design review and system-level test readiness reviews. Use status at reviews to update reliability growth assessment for DAES reporting and operational test assessment.
 Develop R&M planning for P&D phase	Prepare (or review contractor preparation of) R&M requirements, program plans, and specific R&M activities for the P&D phase.
 Update SEP and RAM-C Report	Update the SEP and RAM-C report to account for any changes that have occurred since Milestone B.

3.1.1 Develop/Review R&M Planning for EMD Phase

Government R&M planning for the EMD phase should be reviewed and revised, if necessary, to reflect any changes incurred during contract negotiations. The Government should review the contractor’s proposed R&M activities and schedule for the EMD phase, to ensure compliance with requirements. If the R&M plans were written in response to a request for proposal (RFP) for the follow-on EMD phase, the plans should be approved by the Government prior to signing the contract. If the contractor’s R&M plans were written in response to an RFP that covered the

previous acquisition phase and the EMD phase, the plans would have been approved by the Government before signing the contract for the previous phase. In this case, the plans should be reviewed for areas that may require updating because of new requirements or technology maturity. Any revisions would require approval by the Government.

R&M PLANNING FOR EMD: PROCEDURE

The Government planning should be reviewed to ensure it is in compliance with all program requirements. The various program planning documents should address the points listed below as a minimum:

- *Resources* – Ensure that applicable planning, financial, scheduling, and contractual documents for all systems, equipment, and material include adequate time and funding for R&M engineering and verification, and that the system delivery schedule and cost include such considerations. Ensure that the planning fully considers appropriate scheduling of R&M activities, and deliverables, that the schedule for R&M are resource loaded, and that sufficient funding exists to execute the plans and schedules.
- *Program Documentation* – Establish and incorporate appropriate qualitative and quantitative R&M requirements in all applicable documents such as solicitation documents and specifications, Procurement Requests for systems, equipment, and associated material, spares, or repair parts.
- *Contractor R&M Plans* – Ensure that contractor R&M program plans are required for solicitation responses for all new procurements.
- *Quantitative Requirements* – Ensure that the specification R&M requirements support the thresholds in the Capability Development Document (CDD).
- *Acceptance Requirements* – Define and designate the R&M acceptance requirements for contractor-developed equipment and supporting spares. Ensure that equipment recommended for low-rate production approval, including the spares to be procured by the Government, has met these R&M requirements.
- *Configuration Management* – Ensure R&M is an essential part of the configuration management program to ensure that achieved levels of R&M are not degraded.

Using the EMD phase contract as the requirements basis, review the contractor's proposed R&M program plans to verify compliance with contract requirements. Evaluate consistency with Government and Service policies and requirements. Verify that the contractor's R&M plans provide the following information:

- *R&M Schedule* – A schedule of R&M activities and monitoring, which includes:
 - Designated Service monitoring and decision points and major program milestones specified in the contract.
 - Contractor's monitoring of subcontractors, suppliers, and vendors.

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- R&M performance assessments, risk assessments, problem identification, and corrective action effectiveness assessments.
- Government-furnished equipment (GFE), commercial off-the-shelf (COTS) equipment, and contractor-furnished equipment (CFE) review and coordination points.
- Installation/system integration review and coordination points.
- *Description of R&M Activities* – R&M activities and their results to support each decision point and milestone identified in the schedule.
- *R&M Test Program* – Reliability growth management with reliability growth planning curve, R&M demonstration and test planning and a description of conditions and measurement requirements to be integrated into subsystem and other tests scheduled during the EMD program.
- *Failure Data Feedback* – Description of the Failure Reporting, Analysis, and Corrective Action System (FRACAS) to be implemented by the contractor for recording, reporting, analysis, correction, and monitoring of design deficiencies, discrepancies, and problems at all levels of EMD testing.
- *Program Management* – R&M management procedures related to the contractor’s EMD phase primary functions, consistent with the Work Breakdown Structure (WBS), showing how R&M is to be integrated among the functions of participating organizations and subcontractors.
- *R&M Monitoring* – Contractor’s in-process monitoring, control, and reporting procedures for keeping both the contractor and Government informed of R&M progress, problems, and corrective action status.
- *Design Procedures* – R&M design techniques, analytical procedures, and data sources to be used in the design support and design assessment roles.

R&M PLANNING FOR EMD: DATA

The contractor’s R&M program plan should present the data identified above in a format to facilitate updating as plans and procedures change (with Government approval) to meet the needs of the EMD program. Highlights of the contractor’s approved plan (and changes thereto) should be integrated into both the Government and contractor’s Integrated Master Schedule (IMS).

R&M PLANNING FOR EMD: REVIEW CRITERIA

- *Contract Conformance* – The R&M plan is up to date, executable, and conforms to the contractually specified requirements. It references the specific contract requirements by which it is to be implemented and conducted as a legally binding program.
- *Descriptive Adequacy* – Activities and performance outputs are described clearly and in sufficient detail to disclose the exact purpose and the procedures to be used in execution.

3.1.2 Conduct Program Review



The R&M program review schedule should coincide to support the formal program design reviews at major technical decision points during EMD. The Government should conduct these reviews, at the contractor's site, and should assess the current status of the design relative to specified requirements. R&M problems should be identified, and resources should be allocated to accomplish the required corrective action.

Program design reviews are often identified with the evolutionary stages through which the system design usually matures:

- (1) **Product Baseline Stage** – The R&M review for this stage of development is scheduled to coincide with the Critical Design Review (CDR). Subsystem-level analysis in the area of R&M has been conducted and adequately supports the initial product baseline.
- (2) **Equipment/Subsystem Development Stage** – During this stage the program packages the equipment and subsystem design in the proposed physical configuration for environmental qualification tests including design maturation for reliability (e.g., Highly Accelerated Life Tests (HALT)) and maintainability (Built-in Test (BIT) assessments). Software is also tested to meet its performance requirements, planned operational tempo, timing and performance extremes. Following satisfactory completion of the tests, the design is usually “frozen” for fabrication.
- (3) **System-Level Low Rate Initial Production Representative Article Stage** – In this stage, design items are integrated into the production-representative design for system-level reliability growth and R&M demonstration and testing. A Test Readiness Review (TRR) is usually performed by the Government (following successful completion of the contractor-conducted subsystem and system-level tests) as a way to verify technical suitability of the proposed production-representative article design. The program review for this stage of development is scheduled to coincide with the TRR.

PROGRAM REVIEW: PROCEDURE

Using the approved contractor R&M program plan as the basis for R&M progress evaluation, assess the effectiveness with which the contractor has executed the program. The following aspects should be reviewed:

- *Performance* – Evaluate the degree of conformance to specified R&M activities in terms of depth, scope, and self-checking for validity.
- *Technical Results* –
 - Evaluate results of R&M analyses (predictions, FMECA, SFMEA), critical items, and final trade studies).
 - Evaluate R&M deterioration of the design in its packaged configuration under the environmental exposure (e.g., shock, vibration, temperature, humidity, salt spray) anticipated in the use environment. For software these stress will include operating in

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Denied, Degraded, Intermittent, and Limited (D-DIL) network environment, timing, loading, and other potential performance bottlenecks or externally induced failure modes.

- Evaluate equipment R&M failure mode patterns for each mission.
- Evaluate failure rate and failure mode behavior of parts and materials under environmental conditions related to local ambient and “hot spot” environmental stress levels measured under test conditions.
- Identify design changes required (and specific design change alternatives) to overcome R&M problems inherent in the current design configuration.
- *Schedule Compatibility* – Evaluate the degree of conformance to the schedule/IMS in terms of delivery of required services or data at the required time.
- *Documentation* – Evaluate adequacy of documentation of R&M results.
- *R&M Coordination and Data Utilization* – Evaluate contractor effectiveness in the coordination of the contractor’s R&M activity schedule with the needs of the contractor’s other program activities, and the effectiveness in integrating R&M results into the execution of those other activities, i.e., determine the degree to which the FMECA and SFMEA has been applied by system safety for the hazard analysis, product support for the maintenance analysis, and other activities for whom the data is considered essential in the “total system” engineering approach to EMD.
- *R&M Status Reporting* – Evaluate adequacy and timeliness of contractor reaction to and reporting of the discrepancies, deficiencies, and problems identified by the contractor’s in-process R&M monitoring function. As necessary, use the results of this evaluation as input to the program’s risk management process. R&M status should be reported against program Technical Performance Measures (TPM), to ensure effective management of R&M growth and quick identification of R&M problems. TPMs should be chosen in a manner that provides useful and relevant information to the program and user.

Using the R&M prediction and design data provided by the contractor, the Government should develop a reliability growth assessment to inform the DAES assessment to indicate the likelihood of meeting the CDD threshold at IOT&E.

PROGRAM REVIEW: DATA

Contractor data required for program review include the following:

- *R&M Program Plans* – Current approved contractor program plans for the EMD phase, describing the activities, performance requirements, and schedule.
- *R&M Data* – Specific items of data prepared in accordance with the Contract Data Requirements List (CDRL) and Data Item Descriptions (DIDs), appropriately updated consistent with R&M progress up to the time of the particular program review.
- *Configuration Data* – Specifications, parts lists, proposed engineering changes, waivers, deviations, design review and interface control documents, including requirements analysis

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reports detailing incompatibility problems between specified requirements, design constraints, and achievable R&M with an analysis of proposed alternatives for resolving these discrepancies, e.g., redefinition or reallocation of requirements, readjustment of design constraints.

- *Engineering Data* – Design data, GFE/COTS evaluation reports, and environmental surveys, including:
 - Problem Status Reports – Interface problems between elements within the system, between the system and its proposed installation or application environment, between GFE and CFE, between test equipment and system components, currently under investigation.
 - Feasibility Study Reports – R&M growth potential achievable by correction of problems and introduction of changes recommended by the contractor.
- *Test Plans* – Integrated test plan and individual test plans to include R&M verification, evaluation, and demonstration.
- *Test Reports* – Reliability, maintainability, and failure analysis based on available test data accrued to date, particularly equipment environmental tests, demonstrations, and special design evaluation tests.
- *Procurement Documents* – Subcontractor/vendor R&M program plans and related contractor control procedures, vendor procurement specifications and purchase orders, and R&M plans.

The Government should prepare DAES reporting inputs in the required format. As part of regular program management reporting and to support the Milestone C decision, the program should provide growth assessments to indicate the likelihood of meeting CDD thresholds by IOT&E.

PROGRAM REVIEW: REVIEW CRITERIA

Contractor R&M program progress and performance status can be approved at each review point when the following criteria are satisfied:

- *Conformance* – R&M achieved equals or exceeds specified requirements as measured analytically, empirically, or by a combination of both.
- *Growth* – R&M achievable in the development program will equal or exceed the specified requirement with the correction of specifically designated problems within an acceptable period, subject to continued development when corrective actions have been implemented.
- *Performance* – Technical performance of individual R&M activities conforms to the descriptions and procedural requirements defined in the approved program plan.
- *Timeliness of Performance* – Individual activities whose outputs are critical to the success of other activities have been completed in time for use by those activities.
- *Adequacy of Documentation* – results have been documented in the depth and scope of content and in the format prescribed by the applicable CDRL item.

- *Effectiveness of Utilization* – Outcome of individual activities, in terms of services or data, have been properly considered and effectively integrated into the activities for which the results are considered essential inputs.



3.1.3 Develop R&M Planning for P&D Phase

The contractor should prepare an R&M plan for the P&D phase in response to a production contract RFP in the final stages of EMD. At this point, the program can take full advantage of the design knowledge gained from the production-representative article development, manufacturing, and testing.

R&M PLANNING FOR P&D: PROCEDURE

Review the contractor's proposed P&D R&M plans, to evaluate the following essential elements:

- *Requirements Analysis* – Perform a technical evaluation of production R&M requirements based on knowledge and experience gained in the production-representative article design and manufacturing stage of EMD. Verify that requirements are defined in quantitative terms in end item production specifications consistent with those specified in product baseline specifications.
- *Production Phase R&M Activities* – Develop a schedule of production phase R&M activities and required data for evaluation of production processes, workmanship standards, and parts and materials. Include appropriate R&M monitoring activities during the production flow. Consider the following significant points:
 - Subcontractor/vendor plans and procedures.
 - Incoming parts and materials inspection.
 - In-process assembly and workmanship inspection.
 - Equipment functional tests.
 - Acceptance tests.
 - Change review process.
 - Configuration audits.
 - Contractor's monitoring and control points.
- *Activity Description* – Describe the R&M activities associated with each control point in the production flow.
- *Test Program* – Describe the production verification program, including translation and integration of R&M criteria into functional tests.
- *Reliability Acceptance Test* – Describe reliability criteria and provisions incorporated in production acceptance tests for individual items or production lots, as applicable.

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- *R&M Surveillance* – Describe the production surveillance program for continuous monitoring and evaluation of R&M.
 - *R&M Discrepancy Control* – Describe the FRACAS to control recurrence of problems and discrepancies.
 - *R&M Change Control* – Describe procedures for R&M analysis and verification of all proposed changes.
 - *Reporting* – Describe data to be reported as the basis for monitoring and control of R&M throughout the P&D phase.
- (4) Software is tested to not only meet its performance requirements but also the planned operational tempo and potential timing and performance extremes.
- (5) Software is tested to not only meet its performance requirements but also the planned operational tempo and potential timing and performance extremes.

R&M PLANNING FOR P&D: DATA

The contractor should provide the following data:

- *Contract Documents* – IMS that define the contractor’s R&M requirements and responsibilities.
- *Proposed Plan* – The proposed plan embracing the essential elements described above.
- *Production Specifications* – Specification tree, specifications, and lists being proposed as the product baseline configuration documentation package.
- *Engineering Data* – Appropriate design data and R&M analysis reports pertaining to critical areas, problems that should be controlled in production.

R&M PLANNING FOR P&D: REVIEW CRITERIA

- *Adequacy of Procedures* – Procedures outlined in the proposed plan cover those items defined above.
- *Adequacy of Documentation* – Plans and procedures, inspection criteria, and instructions are clearly defined and documented as working documents for use by personnel who execute the R&M procedures. Production processes and acceptance testing, are translatable to and consistent with requirements specified in the corresponding end item specification.
- *Applicability to Product* – Procedures outlined in the proposed plan are based on the product baseline configuration being proposed as the production prototype.

3.1.4 Update SEP and RAM-C Report



The SEP should be updated to account for changes that have occurred since Milestone B. The RAM-C Report should be updated to evaluate the implications of any changes to the sustainment KPP or its supporting attributes.

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SEP AND RAM-C: PROCEDURE

Use the [SEP Outline](#) as a guide for developing SEP inputs, including the system reliability growth curve and the [DoD RAM-C Rationale Report Manual](#) for developing RAM-C inputs.

SEP AND RAM-C: DATA

Include the R&M P&D activities in the SEP and attach the updated RAM-C Report as appropriate.

SEP AND RAM-C: REVIEW CRITERIA

- R&M Technical Performance Measures (TPMs), growth curve, requirements, and R&M engineering approach are properly integrated into the systems engineering program and conform to the SEP and RAM-C requirements.

3.2 SYSTEMS ENGINEERING

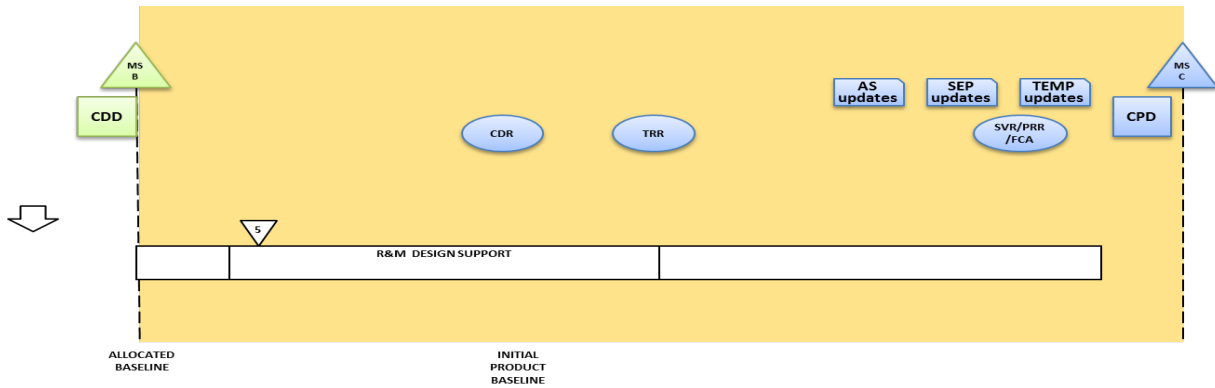



Table 3-3 lists the R&M activities applicable to the EMD phase Systems Engineering functional area.

Table 3-3. R&M Systems Engineering Activities – EMD Phase

R&M Task	Description
 Provide R&M design support	<ul style="list-style-type: none"> Review and verify adequacy of contractor/subcontractor R&M analyses and engineering activities in support of the design stage, using applicable, design standards and specifications. Review and verify adequacy of contractor/subcontractor of R&M requirements incorporated in production representative article.

3.2.1 Provide R&M Design Support



The objective of systems engineering during EMD is to refine system requirements and ensure that design iterations result in a production-representative article that is demonstrated in an operational environment. Ultimately the R&M data obtained during EMD will establish the maturity of the system design by establishing R&M characteristics to support the Milestone C decision.

R&M design analyses serve two purposes: to guide the design toward specified R&M and to “measure” progress toward the specified requirements.

R&M engineering design analysis should be appropriately tailored for the phase and type of program. Each R&M engineering activity should be contractually specified and monitored by the Government during in-process reviews and at established formal systems engineering technical reviews. R&M design analysis are performed by the contractor and subcontractors on a continuous basis. This approach corresponds to the several configuration iterations (design-test-redesign-test cycles) through which designs ordinarily progress to fully achieve and demonstrate the specified end item design requirements.

All R&M design analysis activities will support the CDR (and PDR if not performed during the TMRR phase) during the EMD phase.

R&M DESIGN SUPPORT: PROCEDURE

R&M analyses should be performed as early as possible in the program, and design engineers should participate in the analyses. In this way the designers will be aware of R&M design issues that need to be addressed before the design proceeds to the point that it is not practical to incorporate needed improvements.

Analyses required at previous design reviews should be updated to support CDR-level analyses:

- Parts derating guidelines and stress analysis
- Operational mode summary/mission profile (OMS/MP) and environmental studies
- R&M block diagrams and math models
- R&M allocations and predictions
- FMECA, SFMEA and reliability critical items

Failure Definition and Scoring Criteria (FDSC) and FRACAS are components in developing the above deliverables for CDR and are described below.

Failure Definition and Scoring Criteria

The FDSC detail essential functions and failure definitions associated with reliability scoring requirements. Furthermore, the FDSC support the T&E process by establishing a framework for classifying and assessing R&M performance during test events. FDSC should be updated based on any changes made from the TMRR phase.

At EMD phase contract initiation, the Government and contractor should review the FDSC to ensure mutual understanding of performance requirements and the selected verification methodology. In the EMD phase, FDSC will be used in developing and updating contractor R&M allocation and prediction reports provided as part of contract deliverables as well as during subsystem and system testing.

The prime contractor should collect repair and failure analysis data for all components by the subcontractors at all sites and provide this data to the Government through the FRACAS. This data will then be classified/scored as part of regular internal contractor failure review boards and Service R&M review boards when system-level testing begins.

R&M performance, relevancy classification for all failures, maintenance actions, and BIT indications are needed to evaluate contract specification performance requirements. Contract specification–relevant values are called design controllable and are used in calculating contract requirements. CDD-relevant values are used to calculate operational thresholds. Non-relevant (e.g., maintenance-induced) values are to be excluded from the computation of system R&M and BIT performance metrics. However, non-relevant values may remain important to the overall

system development effort for failure identification and corrective action, so the data will remain documented in the R&M FRACAS database.

Failure Reporting, Analysis, and Corrective Action System

The ultimate objective of FRACAS is to devise corrective actions that prevent the recurrence of failures. The prime contractor should have the overall responsibility to design, develop, and manage the FRACAS and should flow the FRACAS requirement down to subcontractors. The overall goal would be to have a single “master” database used by all participants, including the Government, preferably in a Web-based environment. In that way, everyone has the same data upon which to base conclusions and recommendations.

The FRACAS should accommodate applicable scoring codes for R&M and BIT unique parameters scored by the contractor/Service R&M review boards. A FRACAS will be effective only if the reported failure data are accurate.

The failure reporting system is initiated with the start of the test program (including qualification, R&M tests/demonstrations, incoming inspection, manufacturing, and acceptance tests) and continues through system developmental and operational testing, and deployment.

Design Support Activities

During the design process, evaluate contractor performance of the following R&M design support activities, and the contractor’s effectiveness in applying results to the actual system design, to accomplish the following:

- *Requirements Analysis* – Verify that the contractor/subcontractor team is working to the same basic understanding of the R&M requirements defined at both system and allocated levels, to include:
 - System description of the OMS/MP, alternate modes of operation, performance requirements, success/failure definition and scoring criteria, and maintenance concept applicable to the system level.
 - Definition of dependencies and boundaries between end items in the R&M models, and duty cycle assigned to individual items throughout the mission profile.
 - Definition of application stresses and environmental factors, and identification of stress derating factors for each element of the design for which R&M analyses are applicable.
 - Definition of loading, timing, interface stability and data quality which will impact the mission software.
 - Description of a uniform set of failure and maintenance rate data used in R&M analysis derived from or validated by test results.
 - Prediction of meeting the operational requirements by the contractor/subcontractor current system design approach.
 - Description of problems, correction feasibility, and R&M growth verified analytically and empirically (whenever practicable).

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- Description of environmental factors and application stresses that affect the failure rate or failure mode of critical items.
- Description of time-to-failure distributions in which planned preventive maintenance (including recommended time between overhaul for dynamic components) will enhance R&M of critical parts and components (e.g., pumps, motors, hydraulic components) used in end item designs.
- Summary of approved design procedures and derating policies established by the contractor, to avoid design pitfalls seen in predecessor designs.
- R&M requirements and acceptance criteria are appropriately allocated to and quantitatively defined in each subsystem, equipment, and end item specification. Requirements allocated to subsystems and equipment are consistent with the current design.
- *Failure Analysis* – Review contractor failure analyses reports (FRACAS), and evaluate the depth to which the contractor’s failure analysis has probed for cause-and-effect relationships and failure modes and mechanisms. Verify that the contractor’s failure analyses have been used effectively to identify and correct problems in equipment design or manufacturing.
- *Parts and Materials Application Review* – Evaluate the extent to which the contractor has reviewed the application of parts and materials within the design. Each equipment design should be accompanied by a parts application review that lists each part used in the design, together with the following:
 - Application conditions and use environment relative to specified ratings and tolerances.
 - Specific parts characteristics requiring controls.
- *Environmental and Packaging Design* – Evaluate the adequacy of contractor attention to R&M considerations in equipment layout and packaging design relative to environmental conditions, maintenance requirements, and other use factors including the following:
 - Thermal survey within each piece of equipment, over the range of installation and climatic temperatures to which the system will be exposed in operation. The thermal survey should record local ambient conditions, thermal gradients, hot spots, and temperature rise as a function of operating time in the local ambient, for the different thermal protection and cooling provisions considered in the packaging design.
 - Vibration/shock survey at critical points within each piece of equipment over the range of vibration and shock levels anticipated in the installation environment, as a function of shock mounting and vibration isolation considered in the packaging design.
- *Redundancy Analysis* – Review the contractor’s analysis of potential benefits and limitations associated with the use of hardware or software redundancy to achieve significant improvement in system R&M. Evaluate the compatibility of planned use of redundancy with maintenance and logistic support plans for the system. Evaluate the impact of operative redundancy on safety features of the design.

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- *GFE/COTS Investigation* – Evaluate the adequacy of R&M assessments of GFE/COTS and to ensure that equipment that have a proven history of R&M are properly considered for use in the system design. Verify realism, adequacy, and compatibility of contractor’s R&M analyses of GFE/COTS.
- *Installation Provisions* – Evaluate the contractor’s analysis of the design for installation provisions, to ensure freedom from R&M degradation due to environmental factors, physical interference, support equipment loading, and maintenance/repair activity in the installed configuration (includes verification of mission software operating versions and distribution media).
- *Design Verification for Corrective Actions* – Evaluate fix effectiveness of the contractor’s corrective action test plans and procedures. Verify that operating conditions, monitoring provisions, and failure definition, reporting, and analysis procedures are sufficiently formalized to provide appraisal of design problems and useful data for their correction.

R&M DESIGN SUPPORT: DATA

The contractor analyses for design support activities described above should be available for review, as well as the following:

- *R&M Analyses* – Final analyses and feasibility study results, including the following:
 - Equipment-level R&M block diagrams of the current system configuration, showing independent series elements and dependencies between elements, that meet all R&M specifications requirements.
 - Mathematical models for equipment failure rate and system (mission) reliability.
 - Mathematical models for maintenance action rates and system maintainability.
 - Analysis of failure detection and restore times
 - Definition of system failure including time allowance for recovery, if applicable
 - Description of use stresses and environmental factors to which the system will be exposed in service use, to ensure that applied values of all parameters meet the design derating guide to eliminate or minimize overstressed components.
 - Description of stresses, loading, corner cases, fuzz (random, invalid or unexpected data) and out of bounds data which will be used to test the software.
 - Description of source of data used in the prediction analysis and basis for the assumption of validity.
 - Equipment failure rates and maintenance rates predicted for the design configuration that meet all R&M specification performance requirements.
 - System, subsystem, and equipment R&M estimates based on the foregoing.
 - Identification and description of R&M problems, solution alternatives, and growth potential to support assessment of system reliability performance.

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- *FRACAS Data* – Statistical analysis and criticality ranking of failures observed in EMD testing relative to failure effect on personnel safety, mission performance, and system operation. Failure data applicable to each significant failure, e.g., application stresses, use conditions, failure symptom, effect of failure, or underlying failure mechanism (detailed analysis), and cause or conditions that aggravated the failure.
- *R&M Specification* – Current, approved version of product baseline R&M requirements.

R&M DESIGN SUPPORT: REVIEW CRITERIA

- *Requirements Analysis* – OMS/MP, and alternative modes of operation; logistics support and maintenance concepts, use conditions, and limitations have been verified. Allocated design requirements and minimum acceptable demonstration requirements in end item specifications are quantitatively defined and are substantiated by validated design feasibility studies and test data.
- *Application Conditions* – Application stresses and environmental factors for which the R&M analyses are applicable have been verified as realistic.
- *Data* – Failure and maintenance rate data used in the analysis are derived from an approved (validated) source, and analysis procedures are valid.
- *Conformance* – The contractor's design approach conforms to the baseline (system) specification requirements and when combined with performance and availability requirements defined in the specification equal or exceed CDD operational thresholds.
- *Problems* – R&M problems, correction feasibility, and growth potential have been evaluated and managed appropriately.

3.3 TEST AND EVALUATION

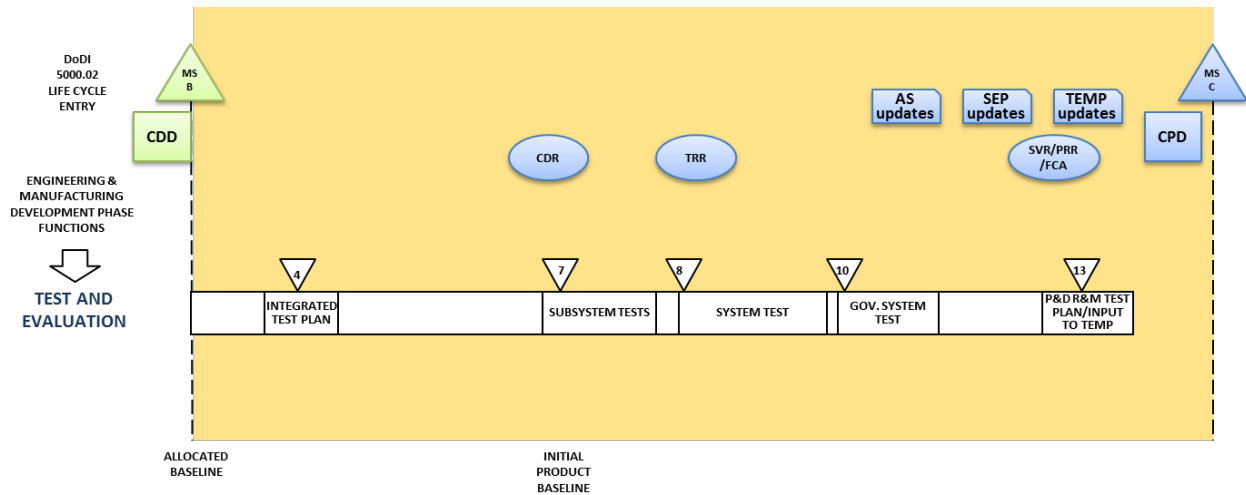


Table 3-4 lists the R&M activities applicable to the EMD phase Test and Evaluation functional area.

Table 3-4. R&M T&E Activities – EMD Phase

R&M Activity	Description
4 Review integrated test plan	Review the contractor's updated integrated test plan for the EMD program
7 Perform subsystem tests	Evaluate R&M status and problems on the basis of subsystem tests
8 Perform system test	Evaluate R&M status and problems on the basis of system test results.
10 Perform Government system test	Evaluate R&M conformance on the basis of Government system test results.
13 Review P&D R&M test plan/input to TEMP	Review and approve the contractor's proposed R&M test plan for production and update the TEMP for the P&D phase.

3.3.1 Review Integrated Test Plan 4

Service-specific instructions establish the procedures for planning, conducting, and reporting T&E in the EMD phase. Developmental testing and evaluation (DT&E) conducted during the EMD phase supports the first major production decision. It demonstrates that the design meets its specifications in reliability, maintainability, and supportability including other performance requirements.

Critical decisions in the EMD phase can be based almost entirely on test data, when the test program is properly planned and individual tests in the program are designed to yield the required data at the scheduled decision points. The contractor should finalize the integrated test plan for EMD within a specified time following award of the EMD contract. Finalizing the plan does not change the scope of contractually specified test requirements but fills in the details of the test design and test procedure consistent with the test plan outline submitted as part of the contractor's proposal and made part of the EMD contract.

The contractor should report test results and analyses in accordance with test report requirements and formats reviewed and approved by the Government during a review of individual test plans. CDRL items also should be updated as necessary by the contractor to reflect changes to test report requirements.

Provisions should be included for "real-time" reporting of significant results of tests as they become known during test, to provide the basis for tentative decisions and possible extension or modification of the test in progress. Test results should be reviewed in-process by the Government to verify that the test is being conducted according to plan and under the prescribed conditions, and that the required data is being recorded and analyzed according to the approved procedures. The program should apply the results of each completed test to correct problems identified during test and to decide the future course of the particular elements of the program evaluated by each test.

The Government uses the results of the R&M demonstrations and tests and reliability growth status to decide whether the design has achieved the R&M requirements specified as one of the acceptance criteria for release to production.

INTEGRATED TEST PLAN: PROCEDURE

The Government should review and approve the contractor's final integrated test plan for implementation at the start of EMD. Thereafter, the plan should be reviewed (and approved, with changes as necessary) with individual test plans as they are submitted by the contractor. All "acceptance" or "qualification" tests called for in the test plan should be monitored (during actual testing) by the Government or designated representative; other "evaluation" and "information" tests also should be monitored when the test results are to be used in a major program decision.

In reviewing the contractor's proposed integrated test plan, the Government should verify that the progression of tests in the plan will satisfy the need for R&M data at each of the major program/design review points and intervening critical decision points in the development program. To fulfill these needs, the test plan should show the derivation and definition of R&M measurement data requirements and test conditions, and indicate how these have been integrated into design support, subsystem, and other system-level tests planned for the program.

The contractor's test program should be evaluated for adequacy in the following areas:

- *Integrated Test Program and Schedule* – Verify that the master test program includes a network of all R&M test and test support activities planned for the development program, with a description of the following elements:

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- List of all R&M tests to be conducted by the contractor, subcontractors, and vendors participating in the program.
- R&M Tests planned by the Government.
- Compatibility of R&M tests with major program milestones outlined in the Test and Evaluation Master Plan (TEMP).
- Identification of individual R&M tests specifically keyed to major milestone decision points or entrance or exit criteria for the program.
- Definition of dates for submission of individual R&M test plans for approval, commencement of test, completion of test, and test report delivery, for each major test.
- Identification of GFE or Government-furnished test and support facilities that will be required in the test program, with required availability dates.
- *General Test Description* – Verify that the test program describes the types of tests required by the contract. Individual tests within these groups will be expanded into individual test plans:
 - Design Support Tests – Tests used to evaluate characteristics of parts, materials, and components for stability, interchangeability, failure rate, and other R&M design criteria; and to verify applicability of performance characteristics precluding the need for higher-level assembly tests.
 - Subsystem/Equipment Tests:
 - Design Verification Tests – Tests used to verify design adequacy in critical or high-risk areas (related to R&M achievement) in the proposed design configuration; and to verify adequacy of test points and sensor locations for health monitoring and BIT considerations consistent with failure mode analyses.
 - Design Evaluation Tests – Tests used to verify adequacy of packaging, thermal, and vibration considerations in the proposed design layout and physical configuration; to evaluate performance under environmental conditions; and to evaluate corrective maintenance and failure-mode characteristics of the design.
 - System Tests – Tests used to determine acceptability of the design for release to production, i.e., to verify conformance to specification requirements.
 - Government System Tests – Developmental tests performed by the Government to assess the system’s potential to carry out its mission and to determine that the equipment is ready to proceed into more formal and extensive tests; and to determine if the equipment or system meets its design/requirement and is acceptable for service use.
 - Operational Tests – Tests performed by the service operational test authority to evaluate operational suitability of the system for deployment to the field; usually conducted on production-representative articles to the maximum extent possible, but occasionally integrated with Government system test.

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- *Test Objectives* – Verify that each type of test identified in the test description summarizes the specific items to be tested, states the test objectives, and describes the following:
 - Test conditions, test procedures, test duration, environmental conditions, parameter measurements, and time elements to be recorded.
 - Factors to be evaluated, analytical procedures to be employed, and decision criteria.
 - Specific R&M data required, and provisions included in the individual test plan for acquiring these data.
 - Example analysis of hypothetical test results to demonstrate adequacy of the test plan and particular R&M measurements. This example is especially important for the collection of diagnostic data to support maintainability and BIT demonstrations.
 - Growth plan – how growth will be monitored and tracked.
 - Statistical R&M test design criteria as appropriate.
- *Individual Test Plans* – Review the detailed test plans to ensure measurements and data requirements for the specific test objectives defined in the contract are satisfied and are sufficiently definitive in the particular areas of test design.
- *Individual Test Reports* – Review test reports prepared and submitted by the contractor on completion of individual tests to verify conformance to approved test plans, and to evaluate consistency with data requirements defined in the contract.

INTEGRATED TEST PLAN: DATA

The review of the contractor integrated test plans requires the following R&M data as applicable, submitted in the overall integrated test plan and subsequently expanded in detail in the individual detailed test plans.

- *Test Purpose* – Justification and need for each R&M test, updated to reflect current baseline configuration requirements.
- *Test Objectives* – Identification of the R&M test or demonstration to be performed.
- *Engineering Requirements* – Explicit definition of the following engineering considerations:
 - Environmental stress spectrum to which the test item is to be subjected, e.g., thermal, vibration, shock, humidity.
 - Interfacing systems with which the test item is to be tested.
 - Test item duty cycles.
 - Software version(s) utilized.
 - Special stresses designed into the test, such as deliberate curtailment of cooling air and evaluation of performance at envelope extremes.
 - Operational compute (CPU, memory, and I/O) and network loading, and network and data quality.

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- Operating conditions and Maintenance procedures – practices, tools, test equipment, and personnel (contractor or Government) and their skill levels
- Performance limits on established parameters that will define the difference between satisfactory and unsatisfactory performance.
- *Statistical Criteria* (as applicable) – Test parameters established by statistical constraints, including:
 - Data analysis methods.
 - Consumer and producer risks (primarily applicable to acceptance tests).
 - Number of test items required.
 - Test duration expressed in one of the following ways: fixed test time, fixed quantity of data, sequential test plan.
 - Sample fault selection process.
- *Measurements Data* – Data required for description of test conditions and test results:
 - Definition of essential performance parameters to be measured.
 - Form of recording (whether actual values are to be recorded or whether discrete readings will suffice, i.e., within limits or not).
 - Accuracy and frequency of readings.
- *Facilities and Support Requirements* – Coordination and integration of activities required to conduct the test.
- *Test Procedure* – Detailed procedures for integrating engineering, administrative, and statistical requirements into a cohesive implementation plan.
- *Data Analysis Methods* – Planned use of each item of data, with a sample analysis of “canned” data to verify adequacy of both the procedure and the data elements:
 - List of planned primary and secondary analyses.
 - Format of data reduced from automatic recorders to support these analyses.
 - Data reduction routines for both on-system and off-system processed data.
 - Detailed description of reliability growth techniques to assess demonstrated and projected reliability.

INTEGRATED TEST PLAN: REVIEW CRITERIA

- *Adequacy of Test Program Plan* – The contractor’s integrated test plan includes provisions for performance of R&M tests as called for in the contract in accordance with the schedule of milestones defined in the contract.

- *Adequacy of Individual Test Plans* – The contractor’s individual tests plans conform to data requirements outlined above and have been submitted for approval in accordance with the approved master test program schedule.

3.3.2 Perform Subsystem Tests



A typical contractor test program consists of several basic tests that have complementary objectives. Specific R&M-led tests (e.g., HALT, Reliability Development Growth Test (RDGT), subsystem/equipment BIT assessments) generally fall under design verification tests. The broad objectives of these tests are to detect unforeseen failure modes, verify or revise predicted failure rates, verify equipment BIT performance capabilities, and evaluate equipment conformance to specification requirements under specified conditions.

SUBSYSTEM TESTS: PROCEDURE

All failures during contractor subsystem tests, and later during production and deployment, should be recorded in the FRACAS. The contractor should flow the FRACAS requirement to subcontractors and vendors to ensure failures are recorded, analyzed, and corrected. A regular failure review board should be held jointly with the contractor to review contractor failure analysis reports and to evaluate the depth to which failure diagnosis has probed for cause-and-effect relationships and failure modes and mechanisms.

Verify that the contractor’s failure diagnoses have been used effectively to identify and correct problems in equipment hardware and software design, parts and materials selection and evaluation, parts derating, packaging, and environmental design.

Using applicable documents called for in the test specifications, review results of individual R&M tests to accomplish the requirements described below.

- *Data Analysis* – Verify that the contractor’s R&M computations and problem assessments on the basis of test data are valid and realistic from the following standpoints:
 - Failure definition in terms of established performance success/failure criteria.
 - Data exclusions and “no-test” decisions.
 - Failure mode and cause determination.
 - Translation (or extrapolation) from test conditions to operational conditions.
 - Assumptions relative to the effect of interfacing items not included in test.
 - Confidence levels associated with test results.
- *Conformance Status* – Evaluate the degree of R&M conformance to requirements defined in applicable end item specifications.
- *Problem Description* – Evaluate the contractor’s failure diagnosis, problem analysis, and recommended corrective actions.

- *Reliability Growth* – Verify the contractor’s estimates of reliability growth available by correcting the problems discussed under the problem description, relative to specified or allocated requirements; assess prospects (and associated risks) of achieving the specified requirements within existing schedule and budgetary limitations and system design constraints.

Design development tests focus on R&M improvement as the configuration changes during the test. The design development test is an empirical technique used to generate information about failure modes so they can be eliminated during the development program. At later stages in the acquisition cycle, design development tests are followed by qualification, operational evaluation, and production reliability conformance tests. This testing will strengthen confidence in the design, manufacture, and operational suitability of the product. Verify that the test program describes the types of tests noted below.

- *Highly Accelerated Life Test (HALT) or Reliability Development Growth Test (RDGT)* – HALT and RDGT are planned test-analyze-fix processes in which development items are tested under simulated mission environments for conventional growth tests or accelerated environments or use conditions in the case of HALT. Both tests are designed to provide information on failure modes and mechanisms and to preclude their recurrence. These tests are conducted during EMD on subsystems representative of the production configuration to the maximum extent possible in materials, configuration, and workmanship. Whenever possible, the tests should include BIT monitoring of the naturally occurring faults to assess fault detection (FD), fault isolation (FI), and false alarms (FA).
- *Software Stress Testing* – For critical software components or CSCIs, software test should include testing to failure based on capacity required (ensure planned capacity is exceeded by at least 3x), fuzz testing, out of bounds testing and out of order execution. This should include reviewing logs, software error messaging and focus on fault detection, fault isolation and restore time.
- *Subsystem/Equipment BIT Assessment Tests* – The purpose of the subsystem/equipment BIT assessment test is to provide an early indication of actual hardware and software BIT capabilities at the subsystem level in the areas of FD and FI, and to identify potential BIT problem areas at the system level. Corrective action resulting from these tests should be implemented in the hardware, software, and procedures prior to system test. This test is not intended to be pass/fail but rather a BIT maturation process that may result in optimization of the hardware and software design.

The test should consist of inserting faults that do not require any hardware manipulations or can be simulated through software manipulation as well as faults that require hardware manipulation such as lifting of leads and soldering jumpers. The equipment-level BIT assessment test should be performed at the contractor/vendor’s facility using their technicians, tools, and support equipment.

- *Mockup Demonstration* – Digital Mockup, or DMU, technology allows product design engineers to replace physical prototypes with virtual ones, using 3-D computer graphic

techniques. DMU allows engineers to design and configure complex products and validate their designs without needing to build a physical model. Mockup reviews, either computer generated or actual physical construction, should be conducted to assess the maintainability aspects, e.g., accessibility, removal and replacement, cabling, doors, and panels of new designs or modifications to existing weapon systems.

SUBSYSTEM TESTS: DATA

Test reports should be delivered for each test as required by the contract. All failures and corrective actions as a result of tests should be tracked as part of the FRACAS program.

Review of failure diagnosis requires the following data:

- Statistical analysis and criticality ranking of failures observed in subsystem testing relative to failure effect on personnel safety, mission performance, and hardware operation.
- Failure data applicable to each significant failure, e.g., application stresses, use conditions, software error message and user actions to recover the system, failure symptom, effect of failure, underlying failure mechanism (detailed diagnosis), and cause or conditions that aggravated the failure.

R&M assessment of current system design configuration requires the following data:

- *Test Reports* – Test reports for each test conducted on the particular system design under review. Test reports should present the following R&M data:
 - Analyses of system failure modes, failure rates, and causes.
 - R&M estimates at the system level, updating previous predictions.
 - Definition of R&M problems, design margins, and interaction problems.
 - Estimated R&M growth and feasibility by correction of problems.
 - Review of program progress in the implementation and operation of the FRACAS, with an evaluation of contractor response to failure analyses.
 - Recommendations concerning possible trade-offs between R&M and other system performance parameters.
 - Recommendations for specific design changes for correction of R&M discrepancies.
- *Design Data* – Appropriate design disclosure data and drawings applicable to the items discussed in the Test Reports.
- *Specifications* – Product baseline specification requirements for the items under test.

SUBSYSTEM TESTS: REVIEW CRITERIA

- *Validity of Test* – Tests on which the R&M assessments are based have been conducted in accordance with the approved test plan, and test results have been validated.

- *Conformance* – Assessed R&M for the end items equal or exceed the allocated design requirements for these end items; or the estimated R&M growth available through corrections equals or exceeds allocated requirements, and corrective action feasibility is verified within current schedule limitations and physical design constraints.

3.3.3 Perform System Test



It is essential that the system test program verify all specified R&M performance requirements (i.e., specification, TEMP, CDD). These requirements are also an integral part of the R&M risk assessment that will be presented during the Operational Test Readiness Review (OTRR). Therefore, the requirements should be adequately tested and measured in the system test program. The ultimate test of any system is when it is used under actual environmental and operational conditions. A good system test program can ensure effective verification of R&M requirements under actual conditions.

R&M acceptability of the design for conformance to contract requirements is determined on the basis of R&M system test results. These tests and the Government's formal system tests for R&M are designed so a decision can be made without a subjective evaluation of the test results. The system tests are conducted by the Service-designated cognizant T&E activity or by the contractor, in compliance with the approved test plan.

SYSTEM TEST: PROCEDURE

During system testing it is essential to evaluate the R&M of the system and equipment on the weapon system to determine if there are any design problems that were not discovered during the subsystem laboratory testing and development work and to establish effective corrective actions to eliminate these problems. During system testing, all maintenance tasks should be monitored, and all data related to each maintenance action should be recorded for analysis against specified requirements. This data will be recorded in the FRACAS/maintenance data collection system database and reviewed and scored as part of the Service R&M review boards. The FDSC will be used to score the data and calculate metric values against the appropriate specification requirements and CDD thresholds.

System tests to demonstrate R&M and BIT include the maintainability demonstration, the system BIT demonstration, and the system R&M assessment:

- *Maintainability Demonstration* – From a maintainability standpoint, it is not practical to simulate the system installation provisions (e.g. enclosures, maintainer access, etc.) in the laboratory for all subsystems/equipment. In order to accurately verify the maintainability performance requirements of subsystems and equipment under development, a system maintainability demonstration is useful. This demonstration is used to assess maintainability critical areas, verify conformance of system installation with maintainability requirements and maintenance concept, and identify installation interface problems for correction and evaluate field installable software patches to demonstrate that the system can be patched and returned to operational status. This demonstration may be combined with the system BIT demonstration.

- *System BIT Demonstration* – The system-level BIT demonstration should be conducted with sufficient time before Government system testing in order to incorporate any corrective actions discovered as a result of this demonstration. The system-level BIT demonstration should be used to verify the adequacy of all BIT fault recording, reporting, and display functions for both the operator and the maintainer.

Faults should be inserted by use of breakout boxes that allow signal alteration, e.g., frequency and amplitude, voltage, and short/open conditions. For non-electronic systems that have high numbers of interface discretes, an adequate number of those discretes should be faulted. For electronic systems, the number of faults should be based upon the fault codes available for each system or subsystem to verify correct integration and unambiguous isolation to the failed equipment, function, or module. For systems that contain failure-declaring algorithms such as data computers, input signals should be distorted sufficiently to verify correct thresholds as well as the accuracy of the failure messages. Software manipulation of functions to simulate failures is encouraged. Software faults should adequately address the planned error messages and automated recovery for critical mission threads. Network loading and bit error rates should be varied and tested through the operational ranges. This demonstration may be combined with the maintainability demonstration.

- *System R&M Assessment* – During system testing it is essential to evaluate the R&M capabilities of the system to determine if there are any design problems that were not discovered during the laboratory testing and development work and to establish effective corrective actions to eliminate these problems. During all system tests, maintenance tasks should be conducted by maintenance personnel of the same type, number, and skill level to perform maintenance on the system during the operational phase in the field.

Each task should be carried out in accordance with the approved maintenance procedures for the specified maintenance concept, using the authorized documentation, test equipment, tools, and handling equipment designated for use with the system in the operational phase. All maintenance tasks should be monitored and all data related to each maintenance action should be recorded for analysis (via FRACAS and the R&M review board) against specified requirements. Any problems associated with prescribed skill levels, tools, manuals, automated test equipment (ATE), and allocated task times should be documented and effective corrective action taken and verified to eliminate these problems.

System Test FRACAS

The ultimate objective of a FRACAS is to devise corrective actions, which prevent failure recurrence and result in reliability growth, for incorporation into the system or equipment. The FRACAS should accommodate applicable scoring codes (based on the FDSC) for R&M-unique requirements scored by the Service R&M review boards. A FRACAS will be effective only if the reported failure data are complete and accurate. Key elements of an effective FRACAS for system testing are as follows:

- A central technical organization should be responsible for implementing and monitoring all R&M system testing.

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- All system failures (hardware and software) should be reported.
- All failures should be analyzed to sufficient depth to identify the root failure cause and necessary corrective actions.
- All failure analysis reports should be closed out within a specified period of time or rationale provided for any open failure analyses that extend beyond the closeout time.
- The FRACAS should accommodate vendor, prime, and system test data for all R&M and BIT parameters as well as providing reports on all parameters.
- Management should be automatically alerted to failures exceeding closeout criteria and ineffective corrective actions.
- Small subcontractors lacking facilities for in-depth failure analysis should arrange for the use of prime contractor, Government, or independent laboratory facilities to conduct such analyses.
- Criticality of failures should be prioritized in accordance with their individual impact on operational performance.

The contractor should develop and implement effective corrective actions to eliminate or minimize recurrence of all failure and BIT anomaly mechanisms and their effects. Corrective actions for all BIT anomalies and failures should meet the following criteria:

- Analytically or by test verified as an effective corrective action.
- Scheduled for incorporation into production equipment via configuration control procedures.

Service R&M Review Board

The contractor should monitor R&M parameters on all systems and equipment required to meet their specified requirements and the system detail specification. A Service R&M review board should be established to determine the relevancy of all maintenance actions, failures, maintenance man-hours expended, and BIT indications in accordance with agreed-upon policies, procedures, and FDSC. The contractor should be responsible for correcting all deficiencies identified in the equipment during the system test program and incorporating the necessary modifications into the development item for Government system test. The contractor should monitor the maintenance activity for the entire EMD test program.

SYSTEM TEST: DATA REQUIREMENTS

FRACAS reports should be delivered by the contractor, beginning with the first test, as required by the contract. R&M review board results should inform system requirements/TPMs and reported to program leadership, as applicable.

Maintainability and BIT demonstration reports should be delivered in accordance with the contract.

R&M test result assessments require the following data:

- *R&M review board report* – the R&M review board report presenting the following information:
 - Specification reference for the acceptance test requirement.
 - Growth curve including statistical parameters, decision criteria, and other analytical basis for test design.
 - Summary and flow diagram of test procedures followed in the demonstration/test.
 - Measurements recorded and test equipment employed.
 - Definition of failure, BIT evaluation criteria, definition of “no-test,” and other post-test exclusions consistent with the FDSC.
 - Unforeseen technical difficulties that occurred during test (if any).
 - Reference to chronological test log of all operations, failures, maintenance, and elapsed time occurring during test.
 - Analytical methods used in data analysis.
 - Recommended decision on the basis of analysis of test results.

SYSTEM TEST: REVIEW CRITERIA

- *Validity of Test* – The R&M demonstration and test have been conducted in accordance with procedures set forth in the approved test plan.
- *Authenticity of Test Results* – Test results have been analyzed and classified for R&M scoring in conformance to the test rules established in the approved test plan.
- *Degree of Conformance* – Test results satisfy the “accept” criteria established in the approved test plans. Reliability growth assessments show that reliability growth is on track to meet requirements.

3.3.4 Perform Government System Test



A Government system operational test is generally conducted on production-representative articles after successful completion of reliability growth tests and R&M demonstration and system testing. Government system test is conducted to determine whether the system or equipment is functioning in, and can be maintained in, a technically suitable manner. This test allows the Government, as the development agency, to measure the R&M program, to measure the contractor’s performance against the specified requirements, and to measure the program against the critical technical parameters (CTP) in the TEMP and growth planning curve in the SEP and TEMP. This test is critical to improve the chances of obtaining acceptable R&M results in operational test and to avoid surprises associated with problems that did not show up in laboratory or early system tests. The Government has primary responsibility for planning this testing, to

include the coordinated operational inputs of operational testers. Acquisition managers should enlist R&M experts as members of the Government test team.

GOVERNMENT SYSTEM TEST: PROCEDURE

Government system test consists of dedicated testing designed to measure reliability, maintainability, and BIT in the actual field environment in which the equipment will operate. Maintenance data collection, FRACAS, and R&M review boards should occur as in contractor system test. The results of Government system test determine the contractor's compliance with the specification requirements. If the results meet or exceed the specification and the CTPs in the TEMP, there should be low risk to proceeding, assuming the requirements have been established using appropriate requirement translation procedures. If the results fail to meet the CTPs the program may be at high risk of not meeting R&M thresholds during operational test.

Review the Government system test plans, procedures, and test results, to accomplish the following:

- *Test Plan* – Verify that required R&M measurements data are defined and integrated into the detailed Government system test plan and test procedures.
- *Test Report/R&M Review Board Results* – Verify that the Government test report conforms to requirements.
- *R&M Analysis* – Verify the test data from the Government system test is properly analyzed with respect to duty cycle and maintenance cycles and other special conditions that prevailed during the test, to yield an estimate of R&M under conditions consistent with those used in earlier analyses and demonstrations. Correlate the Government system test R&M assessments with the earlier assessments to identify causes underlying any significant differences.
- *Problem Definition* – Evaluate problems and critical areas identified during the Government system test, accounting for any differences noted in the R&M analysis. Investigate these problems in sufficient depth to determine the need for, and general nature of, corrective action.

GOVERNMENT SYSTEM TEST: DATA

R&M control at this point should include the following data:

- *Test Report* – the completed test report prepared by the Government test team.
- *Test Data* – test data maintained during the Government system test, with the following essential data entries:
 - Applicable elapsed life readings, BIT information, system failures, and maintenance events.
 - Identification of each instance of system malfunction requiring adjustment or repair.
 - Description of malfunction symptom, failure diagnosis, and repair action.

- Serial number and identification of unit to which failure was traced and for which the unit was replaced or repaired.
- Disposition of failed units, as to level of repair, and follow-up report of repair action taken.

GOVERNMENT SYSTEM TEST: REVIEW CRITERIA

- *Correlation of Test Conditions* – Government system test conditions are consistent with (or correlatable to) operational conditions defined in the system specification on which all previous R&M assessments have been based.
- *Conformance to Requirements* – R&M as measured under Government system test conditions conform to requirements specified for the same configuration under the specified conditions.

3.3.5 Review P&D R&M Test Plan/Input to TEMP



Results of the EMD test program, including R&M tests and demonstrations, system test, and any operational assessment/test experience, provide the best available basis for design of a proposed production R&M test program. This approach is encouraged to the extent practicable in the interest of economy, as well as to reduce unnecessary duplication in inspection and test functions.

P&D R&M TEST PLAN/TEMP: PROCEDURE

Evaluation of the contractor's proposed P&D R&M test plans should verify the adequacy of plans to accomplish the following test objectives:

- *Production Evaluation Tests* – Test plans should evaluate producibility of the Low-Rate Initial Production (LRIP) articles to control deficiencies and discrepancies, and to evaluate R&M degradation/growth potential associated with proposed design or production changes.
- *Production R&M Acceptance* – Acceptance tests should determine conformance to specified R&M criteria as a basis for acceptance of individual systems or subsystems and that acceptance tests will identify problems, latent defects, and marginal performance trends requiring corrective action. The R&M acceptance tests may be used as a basis for overall control of the production program (sometimes used as a basis for acceptance of individual production items, or inspection lots of production items, under limited environmental conditions).

The TEMP inputs described below should be integrated and updated with the inputs developed previously.

- *System R&M Demonstration* – Identify tests designed specifically for R&M verification. Specific reference should be made to the applicable sections of the contractor's plan for R&M testing.
- *Reliability Growth Planning* – Provide a test schedule and resources compatible with the schedule of major program milestones outlined in the production plan for both the LRIP and

Full-Rate Production (FRP) sub-phases. Describe the adequacy of system-level growth test provisions for achieving requirements. Update the reliability growth curve.

- *R&M Test Flow Diagram* – Include a network of all R&M test and test support activities planned for the production program related to key control points in the production flow.
- *T&E Integration of R&M Engineering Activities* – Identify individual tests keyed to the production schedule, with dates for submission of individual test plans for approval, TRRs, commencement of test, completion of test, and test report delivery. Describe the FRACAS to be implemented by the contractor, and describe the transition of responsibility of FRACAS to the Government if applicable, for recording, reporting, analysis, correction, and monitoring of design and production deficiencies, discrepancies, and problems revealed in P&D testing, at all levels.
- *R&M Measurements Requirements* – Identify tests into which R&M measurement requirements and test conditions have been integrated. Identify data and measurements to be derived from the tests described above along with the associated R&M decision criteria. Update FDSC as necessary.

P&D R&M TEST PLAN/TEMP: DATA

Control of R&M test planning for production requires the contractor data described below.

- *Production R&M Plans* – Contractor test plans and tentative procedures for performance of tests outlined above. Test plans should be in the format required by the contract.
- *Production Specifications* – Product baseline specifications, drawings, and production R&M test plans. These provide the basis for specific test requirements and decision criteria for individual items.

P&D R&M TEST PLAN/TEMP: REVIEW CRITERIA

- *Adequacy of Coverage* – All potential production control problems are covered by an appropriate production reliability monitoring and control procedure.
- *Adequacy of Procedure* – Each R&M inspection or test procedure in the proposed plan is substantiated by test data indicating its effectiveness as a production R&M control procedure.

3.4 PROCUREMENT

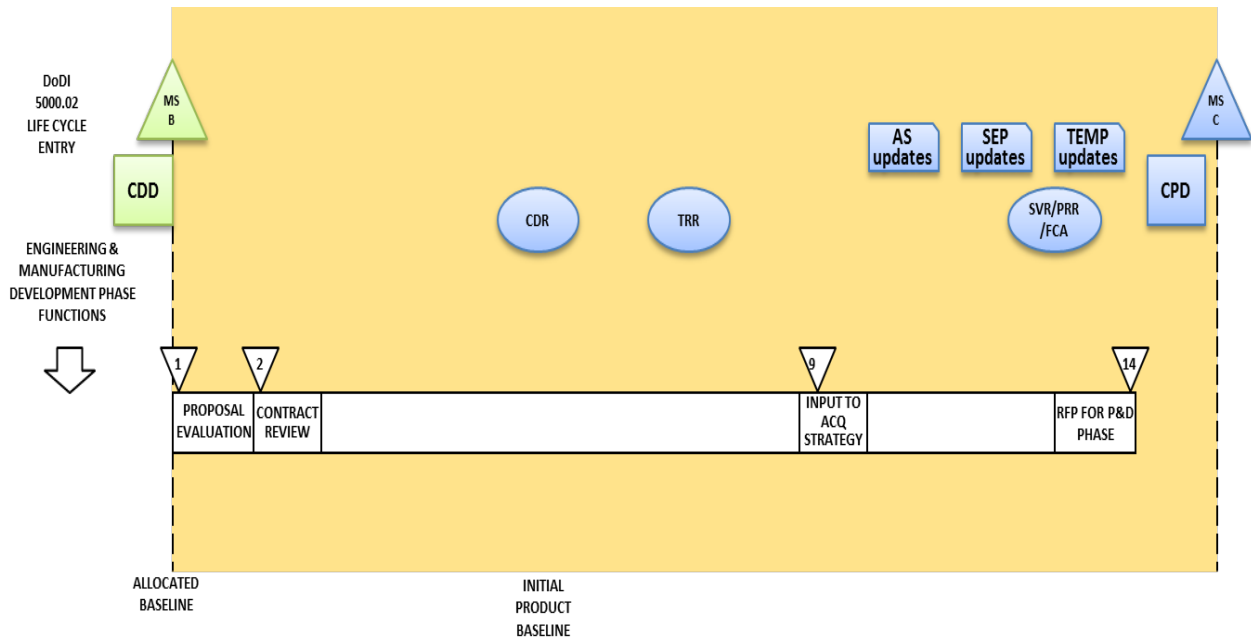


Table 3-5 lists the R&M activities applicable to the EMD phase Procurement functional area.

Table 3-5. R&M Procurement Activities – EMD Phase

R&M Activity	Description
1 Evaluate proposals	Evaluate R&M adequacy of EMD phase proposals.
2 Review EMD phase contract	Review contract R&M requirements.
9 Provide R&M input to Acquisition Strategy	Provide R&M-specific language for incorporation into the AS.
14 Prepare R&M input to RFP for P&D phase	Verify adequacy of R&M requirements and provisions in RFP for production.

3.4.1 Evaluate Proposals and Review EMD Phase Contract



The RFP and proposed contract SOW for EMD will normally have been prepared by the Government. These two documents, along with supporting exhibits (e.g., DD 1423s, product baseline specifications) constitute the bid package for EMD. Proposals received in response to the RFP are evaluated for conformance to requirements and guidelines set forth in the bid package, and the Government selects the best overall proposal as the basis for contract negotiation.

The most vital function to be performed by the Government in this transition from TMRR to EMD is the review of R&M provisions contained in proposal and contract documents prior to formal execution. Unless adequate provisions for R&M are specifically called out in the contract, there will be no basis for acceptance of a system that meets the R&M specification requirements under the terms of the contract, leaving the requirement possibly unfulfilled.

PROPOSALS AND CONTRACT REVIEW: PROCEDURE

Evaluate the prospective contractor's proposals and the resulting contract against the R&M criteria outlined below:

- *Program Management* – Verify that the RFP-specified R&M management activities are included in the proposal and are specified and clearly described in the contract. The contractor's proposal (as modified and finally accepted in negotiation) may be designated as one of the contract exhibits and specifically referenced in the contract. However, the proposal does not constitute a legally binding commitment by the contractor unless it is specifically referenced in and made part of the contract. Verify that the primary tasks listed below are clearly specified in the contract.
 - R&M program plan for EMD should be submitted by the contractor for Government review and approval prior to formal contract execution by the Government. The program plan should cover all R&M activities to be performed throughout EMD.
 - Program R&M reviews will be performed by the contractor at designated major decision points, and assessments to be submitted following each review.
- *Data Review and Control* – Verify that the following R&M activities are addressed in the contractor's proposal and are specified in the contract:
 - In-process review of data and procedures for disseminating data to other in-house teams who require the R&M data for their activities.
 - Preparation and submission of R&M data in accordance with contract DD 1423s.
- *Configuration and Change Control* – Verify that the following R&M activities are described in the proposal and are specified in the resulting contract:
 - Preparation of R&M specifications based on initial product baseline specifications for systems, subsystem, and equipment levels of engineering development.
 - Assessments of R&M impacts associated with Engineering Change Proposals (ECPs).
 - Review of R&M sections of the product baseline specifications for the proposed production system.
- *R&M Engineering* – Verify that the following R&M analysis and activities are described in the proposal and are specified in the contract as part of the systems engineering/design function:
 - Preparation and use of FMECA, SFMEA and R&M predictions.

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- BIT design activities.
- Design trade-off R&M optimization studies.
- Use of design guidance in the selection and application of parts and materials, diagnostics design, the use of derating, and the application of redundancy, to achieve specified R&M.
- Performance of FRACAS based on test results and feedback data, for corrective action guidance.
- Evaluation of R&M characteristics of GFE/COTS and their interfaces.
- *Test and Evaluation* – Verify that the following R&M test and evaluation activities are described in the proposal and are specified in the EMD contract:
 - Preparation of detailed plans for the integrated test program, and detailed test plans for individual tests in the program.
 - Conduct of tests for design verification, environmental evaluation, and final demonstration acceptance.
 - Preparation and submission of test reports and data analysis in accordance with contract DD 1423s.
 - Preparation of the preliminary R&M test program plan for the proposed follow-on production phase.
- *Procurement* – Verify that the following R&M activities are described in the proposal and are specified in the EMD contract:
 - Implementation of an R&M program for control of in-house and subcontractor production operations.
 - Preparation and implementation of vendor/subcontract R&M controls.
 - Preparation of a production R&M plan for the proposed follow-on production phase.

PROPOSALS AND CONTRACT REVIEW: DATA

The following information is required for R&M at these points.

- *Contractor Proposals and Basis of Estimates (BOE)* – Complete technical proposals for EMD, including (but not limited to) R&M portions thereof, to verify that R&M are completely integrated into and diffused throughout the overall technical approach; and to verify that R&M were considered and treated as design parameters in the proposed systems engineering and design activities. BOEs to verify that cost of the R&M work effort is in accordance with the proposed R&M work scope.
- *RFP Data Package* – Initial RFP to which the proposals are responding, with the SOW, CDRL, and specifications that accompanied the RFP to provide the basis for proposal evaluation.

- *Proposal Evaluation Criteria* – R&M criteria related to requirements defined in the RFP, which facilitate quantitative assessment and relative ranking of competitive proposals on the basis of R&M adequacy and responsiveness to the RFP.
- *Contract Data Package* – SOW, data requirement addendums (DD 1423), Specification and other contractual documents to be (but not yet) formally executed by the Government following final cost negotiations.

PROPOSALS AND CONTRACT REVIEW: REVIEW CRITERIA

- The contract satisfies the criteria indicated in the proposal and contract review procedure.

3.4.2 Provide R&M Input to Acquisition Strategy



The Acquisition Strategy (AS) for the program should include a description of the R&M engineering activities essential for achieving and verifying the requirements. The AS also should specify how the sustainment key performance parameter (KPP) thresholds have been translated into R&M design and contract specifications. The [AS Outline](#) addresses the required R&M inputs for MDAPs.

INPUT TO AS: PROCEDURE

The R&M Input to AS will shape the R&M requirements for the P&D RFP.

- Identify the engineering activities to be stated in the RFP and required of the contractor to demonstrate the achievement of the R&M design requirements.
- Provide a table to specify how the sustainment KPP thresholds have been translated into R&M design and contract specifications.

INPUT TO AS: DATA REQUIREMENTS

Inputs shall be by integration into appropriate sections of the AS and updated as required.

INPUT TO AS: REVIEW CRITERIA

- *R&M Data* – The AS includes the R&M data outlined above.
- *Verification* – R&M data summarized in the AS are consistent with the validated data presented in the CDD/draft Capability Production Document (CPD) and RAM-C Report.

3.4.3 Prepare R&M Input to RFP for P&D Phase



The Government should prepare a draft RFP for the P&D phase for coordination well before the planned date for release of the RFP. This lead time is necessary to prepare and validate the SOW, exhibits, addendums, and production release data package for the proposed production contract. During this time, R&M activities, milestone schedules, and review criteria should be prepared. As the EMD phase nears completion, the production-representative article production and test experience gained by the Government and the development contractor will be useful to the Government

in preparing the proposed SOW and will support exhibits for the production phase contract. These documents then become the basis for the Service's RFP for production.

PREPARE RFP FOR P&D: PROCEDURE

Using Service policy as guidance for preparing the RFP, evaluate progress and final acceptability of the RFP for production from the points listed below:

- *Production R&M Program Planning* – Adequacy of Government-specified R&M program planning criteria should include a description of review criteria and control functions.
- *R&M Test Plans* – The RFP-specified R&M test and evaluation requirements should ensure detection and correction of problems in production operations. These requirements also should include statistical and technical adequacy of specified R&M acceptance test plans and acceptance criteria for individual end items or product lots of end items, as appropriate.
- *Data Requirements* – The R&M data requirements and data descriptions called for in the RFP are adequate.
- *R&M Change Review* – Provisions for formal change control and analysis of impact to R&M are stipulated in the RFP.

PREPARE RFP FOR P&D: DATA

Data required at this point includes the following:

- *Specifications* – System (product baseline) specification R&M requirements and demonstration acceptance criteria.
- *Proposed RFP SOW* – Description of appropriate R&M engineering activities, schedule, performance criteria, and demonstration requirements proposed for production.
- *Exhibits* – Applicable addendums and provisions to the contract (e.g. data item requirements, applicable R&M demonstration and test requirements and acceptance criteria).

PREPARE RFP FOR P&D: REVIEW CRITERIA

- *Adequacy of Requirements* – The proposed procurement package defines firm quantitative requirements for R&M consistent with requirements defined in approved initial product baseline specifications.
- *Provisions for Government Control* – The proposed procurement package clearly defines the provisions for in-process review and control of R&M at major milestones during production (i.e., FRP).

3.5 MILESTONE C REVIEW

R&M ASSESSMENT FOR MILESTONE

The transitional milestone between the EMD phase and P&D is one of the last opportunities to keep unsatisfactory system designs out of production. The primary criteria are:

- (1) Applicable R&M tests satisfy conformance to quantitative criteria.
- (2) Government system test and evaluation verifies the suitability of R&M technical characteristics for the intended application.

These tests provide the data for a comprehensive R&M assessment of the production-representative article design and provide the basis for a LRIP release decision. Demonstrated R&M characteristics are compared with specified requirements in product baseline specifications. The significance of any disparity between the two is evaluated. Reliability growth potential for solution of problems is estimated. Adequacy of R&M aspects of the proposed production data package is evaluated.

The final review of R&M achievements in the EMD phase (performed just prior to the scheduled milestone) is intended to verify fulfillment of specified requirements and to ensure that the production release data package is adequate for proceeding to production. The review should be primarily a verification of earlier in-process review findings, except for inconsistencies that may now become visible in an integrated, system-oriented, program-wide review.

3.5.1 Procedure

Assess the following R&M aspects of the EMD phase, and make recommendations of the proposed final design for P&D based on the following:

- *R&M Achievement* – Evaluate R&M achieved by the design in its final configuration, compared with specified requirements.
- *R&M Analyses and Trade-off Studies* – Evaluate results of the design analysis and R&M engineering trade-off studies involving consideration of safety, redundancy, failure-mode/effects, packaging, and environmental design features underlying the configuration selected for production.
- *R&M Allocations* – Verify that R&M requirements allocated to subsystem equipment levels correspond to requirements defined in end item development and production specifications. Evaluate the basis for production failure rate control criteria and verify compatibility with specified requirements.
- *Evaluation of Problems and Critical Areas* – Evaluate the criticality of R&M problems that remain uncorrected, and verify the feasibility of correcting them before (or after) release to P&D. Review critical component/part/material characteristics and R&M problems in GFE, CFE, and GFE/CFE interfaces that require special attention.
- *R&M Growth* – Compare predicted R&M growth (available through correction of remaining

deficiencies) with specified requirements. Evaluate the cost and schedule requirements related to R&M growth.

- *R&M Test Plans* – Evaluate the adequacy and compatibility of R&M demonstration and test requirements defined in specifications.
- *R&M Contract Requirements* – Evaluate the adequacy of overall contractor conformance to R&M program requirements as specified in the contract.
- *Other Reliability/Maintainability Considerations* – Verify engineering considerations and analyses underlying the performance monitoring and failure diagnosis features of the design, e.g., BIT and support equipment.

R&M Data Requirements – Evaluate the adequacy of R&M data submitted by the contractor in accordance with CDRL items appended to the contract.

The following data is generally required at this review point:

- *R&M Analysis Reports* – Final EMD phase R&M analysis reports.
- *System Specifications* – Updated product baseline specifications.
- *Integrated Test Plans* – Proposed integrated test plan for R&M in the P&D phase.
- *R&M Program Plans* – Contractor-proposed R&M plans for the P&D phase.
- *Proposed Contract Work Statement* – Activities for achievement, monitoring, and control of R&M in the P&D phase.
- *Data Requirements Exhibit* – R&M contract data requirements and corresponding DIDs.
- *Program Documentation* – Program documentation such as the SEP, TEMP, and AS.

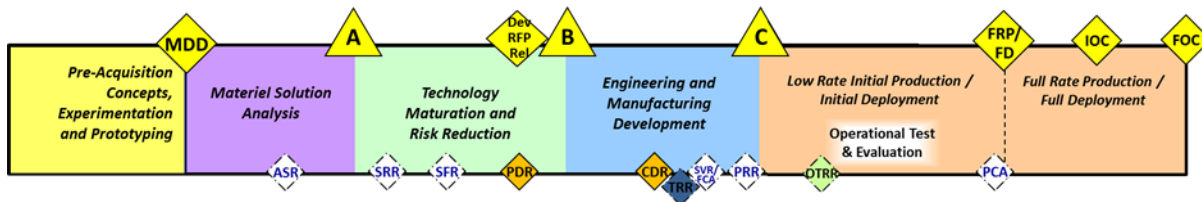
3.5.2 R&M Recommendation

On the basis of the review, make recommendations (with justification) for disposition of the program by one of the following alternatives:

- *Proceed into P&D* – Production-representative article has demonstrated conformance to specified R&M requirements and has been determined suitable by Government system test, with minor exceptions, if any. The production release data package has been verified adequate with minor, if any, exceptions. Approve the production-representative article design and development data package for release to production, conditional on initiating ECPs to correct design deficiencies, and correcting documentation inadequacies.
- *Extend the EMD phase to correct deficiencies* – Production-representative article design fails by significant margin to satisfy R&M requirements; or the documentation package is seriously inadequate. The design and data package should be corrected and verified by test, including a reevaluation of the design documentation.

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4. R&M in the Production and Deployment Phase



Objectives of the Production and Deployment Phase

The Production and Deployment (P&D) phase translates the production-representative article into a production system for delivery to the field. Manufacturing processes and tooling, inspection and test procedures, and management control techniques are designed for economical production consistent with delivery schedule requirements. The Government is responsible in the P&D phase to ensure conformance to specified R&M requirements and delivery of operationally suitable equipment to the field.

For Full-Rate Production (FRP), the Low-Rate Initial Production (LRIP) period is often used to evaluate the contractor's processes, tooling, inspection and test procedures, and basic capability to reproduce the production-representative article design without degradation of performance and R&M characteristics achieved in the production-representative article design. As applicable, LRIP units are submitted to tests comparable to the environmental, demonstration, and operational tests performed in the EMD phase. Results of these tests are used to measure performance and R&M characteristics of the LRIP units, and to detect, diagnose, and correct causes of any degradation in these inherent design characteristics. For some systems, e.g., space assets and mission-critical one-of-a-kind ground assets, extensive environmental and operational tests of production items are not feasible until the items are deployed. In these instances, the program usually arrives at confidence in R&M through analytical and test rigor during design, vendor selection and control practices, comprehensive technical reviews, and other R&M techniques described throughout this guide.

Objectives of the P&D phase include the following:

- Consistently manufacture and deliver to the field the equipment and systems that not only meet the operational thresholds but also ensure there is no unacceptable degradation of design characteristics that would present a risk to meeting the operational thresholds due to activities in the P&D phase.
- Deliver, concurrent with system delivery, the technical data, support equipment, and operating and maintenance manuals and instructions required for system operation and maintenance in the field.
- Provide the required quantities, of specific quality and in correct proportions, of maintenance spares, repair parts, contractor-augmented support, and trained personnel to achieve and sustain operational thresholds.

4. R&M IN THE PRODUCTION AND DEPLOYMENT PHASE

- Maintain surveillance of deployed and operational systems through the Service maintenance data collection system and other continued closed-loop Failure Reporting, Analysis, and Corrective Action Systems (FRACAS) to correct problems identified in the operational environment.

R&M Activities in the Production and Deployment Phase

R&M activities essential to P&D processes are identified in Figure 4-1. Table 4-1 lists these activities in the approximate chronological order in which they occur in the P&D phase.

During the P&D phase, the R&M engineer, as part of the program systems engineering team, should:

- Verify initial production control of R&M through test and inspection, production data analysis, and supplemental tests.
- Verify R&M characteristics, maintenance concept, repair policies, and maintenance procedures by test and evaluation.
- Identify R&M and Built-in Test (BIT) improvement opportunities via FRACAS and field data assessment.
- Review Engineering Change Proposals (ECPs), operational mission/deployment changes, and variations for impact on R&M.
- Update R&M predictions; Failure Mode, Effects, and Criticality Analysis (FMECA); and other analyses based on field results and apply them to the models previously developed to assess impacts on spares, manpower, missions, and logistics.
- Verify that Parts Management Program requirements for limiting reliability risk and “lessons learned” are used during all design change efforts including change proposals, substitutions, product improvement efforts, or any other hardware change effort

R&M engineering validates that achieved R&M levels are retained through production, deployment, and operations, and it includes the essential activities to identify, analyze, and correct deficiencies.

4. R&M IN THE PRODUCTION AND DEPLOYMENT PHASE

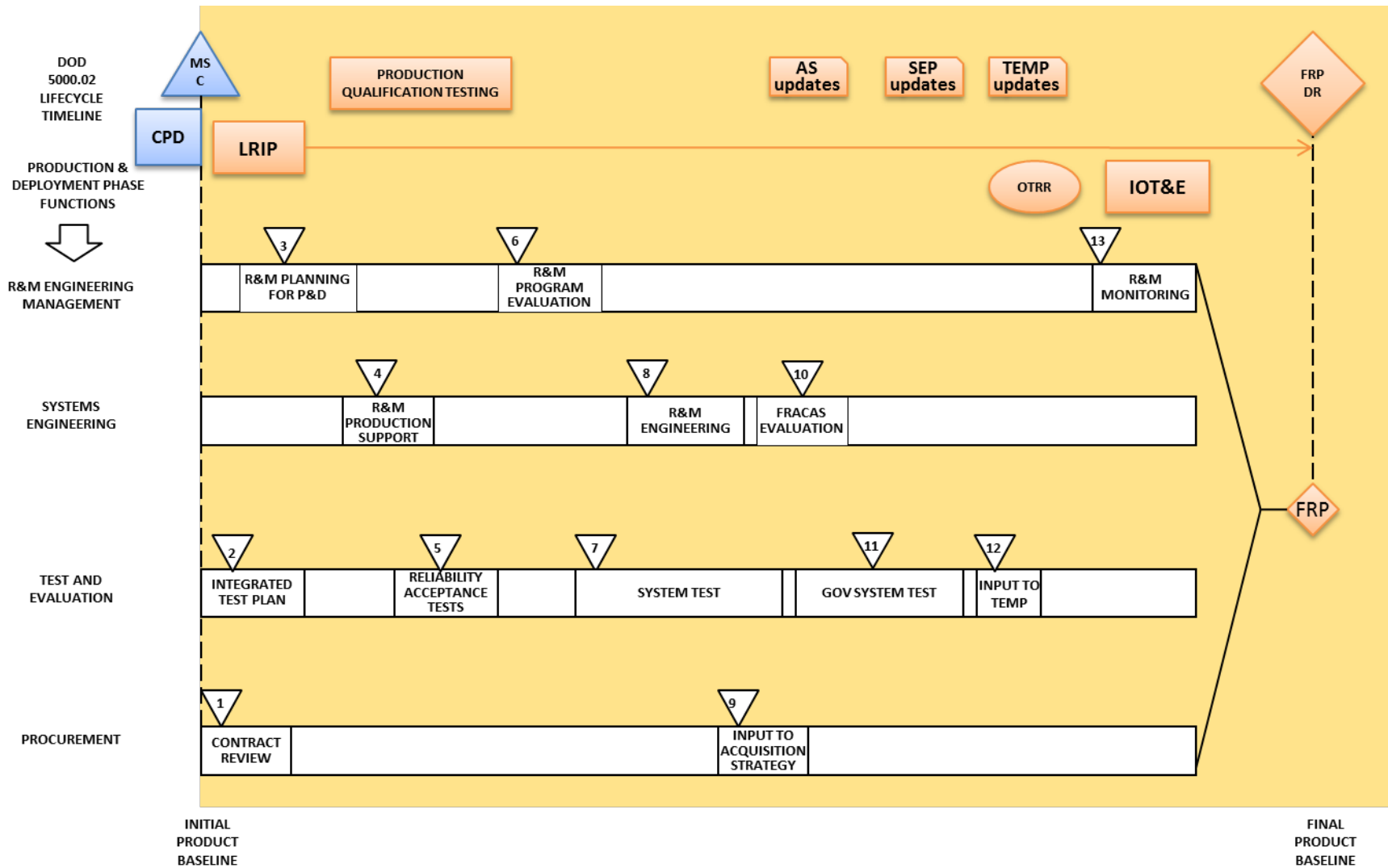


Figure 4-1. P&D Phase R&M Activities by Functional Area

4. R&M IN THE PRODUCTION AND DEPLOYMENT PHASE

Table 4-1. R&M Activities in the P&D Phase

R&M Activities	Functional Area	Paragraph
1 Review P&D phase contract	Procurement	4.4.1
2 Review Integrated Test Plan	Test and Evaluation	4.3.1
3 Review R&M Planning for P&D phase	R&M Engineering Management	4.1.1
4 Provide R&M production support	Systems Engineering	4.2.1
5 Perform Production Reliability Acceptance Test	Test and Evaluation	4.3.2
6 Evaluate R&M Program	R&M Engineering Management	4.1.2
7 Perform System Test	Test and Evaluation	4.3.3
8 Perform R&M engineering	Systems Engineering	4.2.2
9 Provide R&M Input to Acquisition Strategy	Procurement	4.4.2
10 Evaluate FRACAS	Systems Engineering	4.2.3
11 Perform Government System Test	Test and Evaluation	4.3.3
12 Provide R&M input to TEMP	Test and Evaluation	4.3.4
13 Monitor R&M in production	R&M Engineering Management	4.1.3

4.1 R&M ENGINEERING MANAGEMENT

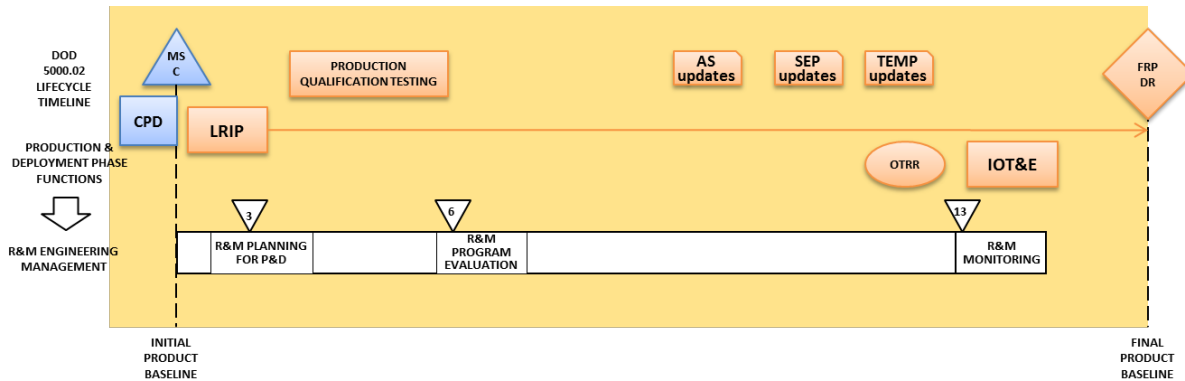





Table 4-2 lists the R&M activities applicable to the P&D phase R&M Engineering Management functional area:

Table 4-2. R&M Engineering Management Activities – P&D Phase

R&M Activity	Description
 Review R&M Planning for P&D phase	Review and update Government R&M program planning for the P&D phase. Review and evaluate contractor’s R&M program plans and procedures for the P&D phase.
 Evaluate R&M Program	Evaluate effectiveness of the implemented program in P&D to refine R&M procedures.
 Monitor R&M in production	Manage and control R&M status, trends, and problems in production items.

4.1.1 Review R&M Planning for P&D Phase



Effectiveness of the R&M program is reassessed and continually refined through monitoring, management, and control procedures, using results of acceptance tests, demonstrations and tests, operational evaluation, and field data reported through Service maintenance data collection systems. Production inspection, engineering, and quality control activities have an impact on R&M and should be taken into account when planning the R&M P&D program so that quality practices are in place to ensure inherent defects are not induced into the products being manufactured.

The Government planning and the contractor’s plan for R&M should be reviewed to verify adequacy to accomplish the objectives. The contractor should then use the implemented plan, as the basis for monitoring and control of the P&D R&M program.

P&D R&M PLANNING: PROCEDURE

The Government and contractor R&M planning prepared for the P&D phase should be reviewed and updated to reflect any changes that may have been approved during contract negotiations.

R&M planning should address, as a minimum:

- *LRIP Schedule* – Review the Integrated Master Schedule (IMS) of LRIP R&M activities and data requirements to evaluate production processes and to verify the adequacy of proposed test procedures for R&M.
- *Production Schedule* – Review the schedule of monitoring points for production, to include the following significant points for R&M involvement in the production flow:
 - Incoming parts and materials inspection.
 - In-process assembly and workmanship inspection.
 - Subsystem and system functional tests.
 - Burn-in tests (e.g., environmental stress screening, highly accelerated screens).
 - Acceptance tests.
 - Configuration and change reviews.
- *Production Procedures* – Evaluate procedures and measurement data associated with the production flow, to include:
 - Effectiveness of root cause analyses of deficiencies and corrective action procedures.
 - Statistical analysis, trend analysis, and control limits related to key reliability product characteristics. These controls in turn minimize inherent production defects that would otherwise affect field reliability performance.
- *Parts and Materials Selection and Control* – Evaluate procedures (if not done during the EMD phase) for the selection and control of parts and materials procured for use in the production line, in accordance with the approved parts or materials specifications and drawings, including the quality assurance provisions, Government-Industry Data Exchange Program (GIDEP) participation, and provisioning for feedback of failure and discrepancy information between suppliers, subcontractors, prime contractors, and the Government.
- *Workmanship Control* – Evaluate procedures, practices, and internal standards for control of workmanship, including provisions for maintaining necessary inspection and test records for correlation analysis with subsequent production test data.
- *R&M Analysis* – Review accumulation and analysis of data from key sources, burn-in or environmental stress screening tests, production acceptance tests, R&M demonstration, operational evaluation, and field reports useful for assessment of R&M. Assess the contractor's process for detection, analyses, and correction of non-conformances induced during the manufacturing operations. Ensure the material review board, failure review board, FRACAS, and

R&M review boards are effectively identifying and correcting deficiencies in a timely manner that would otherwise impact reliability.

- *Production Test Program* – Review the description of the P&D test program, showing the translation and integration of R&M requirements and criteria into tests.
- *Acceptance Tests* – As applicable, determine the reliability acceptance test requirements. Perform periodic assessments of the test results during production.
- *Failure Data Feedback* – Review the FRACAS for recurrence control and fix effectiveness, including use of data reported by the Service maintenance data collection system. Review planning for conduct of failure review boards, material review boards, and R&M review boards, as applicable.
- *Change Control* – Review the description of change control procedures for R&M impacts and verification of all proposed changes.

P&D R&M PLANNING: DATA

The following data is needed at this point:

- *R&M Plans* – Government planning and contractor’s R&M plans for P&D covering the provisions above.
- *R&M Procedures* – Contractor’s R&M procedures related specifically to production control of R&M covered above.

P&D R&M PLANNING: REVIEW CRITERIA

- *Contract Conformance* – The planning is up to date, executable, and conforms to the contractually specified requirements.
- *Descriptive Adequacy* – Activities and their outputs are described clearly and in sufficient detail in the Integrated Master Plan (IMP), Work Breakdown Structure, and other program planning documents to disclose their exact purpose and the procedures to be used in their execution.
- *Documentation Adequacy* – Procedures are in place to ensure inherent defects are not introduced into the products being manufactured.

4.1.2 Evaluate R&M Program



R&M planning is the essential first step to R&M engineering in P&D. The next step is application of the planning in the LRIP period. The FRP review at the end of the P&D phase is the point at which overall effectiveness of the contractor’s R&M procedures can be quantitatively evaluated. This review coincides with the LRIP model configuration audit and conformance evaluation and results in the basis for deciding whether to initiate FRP. Other program reviews should be scheduled when accrued changes significantly alter the configuration of the system, to verify that R&M procedures are keeping pace with production changes and that the accrued system changes are reflected in updates to previously performed R&M analyses (e.g., predictions, FMECA, SFMEA).

4. R&M IN THE PRODUCTION AND DEPLOYMENT PHASE

R&M in-process review of test results as they accrue, Government evaluation of contractor effectiveness in management and control of manufacturing operations; and coordination of configuration, logistics, and maintenance data preparation.

R&M PROGRAM EVALUATION: CONTROL PROCEDURE

Perform the following review functions on a continuing basis throughout the P&D phase:

- *In-Process Review* – Identify critical R&M data and perform in-process reviews to verify conformance to production test procedures. Verify that interim results of production inspection and test are reported immediately when serious R&M problems are detected.
- *Utilization of Production Data* – Evaluate the extent to which the contractor is applying reliability and quality data (i.e., yield data, non-conformance/quality trend data, rework and repair data, quality assessments) derived from production inspection and test procedures to the management and control of those manufacturing operations that significantly affect R&M of the production item. This evaluation lets the R&M engineer ascertain how well the product quality levels are being controlled to ensure reliability will not be affected, or to begin the corrective action process for controlling production processes, training operators, improving tooling, etc. The contractor's problem-identification system should interface with the FRACAS for R&M use for the failure review board and R&M review boards.

Evaluate the effectiveness of the collection and analysis of failure data from all sources in the production program and for the identification and solution of problems. Ensure that previous R&M analyses are updated to reflect changes to the system design resulting from failure data from all sources.

Evaluate the following R&M significant factors::

- *Acceptance* – Verify that the LRIP item meets established product baseline acceptance criteria in the proposed acceptance test.
- *R&M Demonstration* – For demonstration(s) performed on the production representative article, verify that the LRIP item conforms to functional baseline requirements for R&M.
- *Test Correlation* – Evaluate and initiate corrective actions for any discrepancies identified between acceptance and demonstration procedures.
- *Incoming Materials Inspection* – Verify that part failure rates, failure modes, and maintenance action rates are specified requirements for incoming inspection and tests.
- *Production Inspection* – Verify that R&M criteria have been defined and integrated into quality inspection and test procedures for control of workmanship, fabrication, assembly, processing, and other manufacturing operations.
- *Change Control* – Verify that ECPs, waivers, and deviations have been adequately evaluated by analysis and test for R&M impacts as a normal step in the change review procedure.

4. R&M IN THE PRODUCTION AND DEPLOYMENT PHASE

- *Production Problems* – Review R&M-degrading production problems, inspection deficiencies, and manufacturing discrepancies to ensure adequate corrective and recurrence control measures.
- *Production Monitoring and Control* – Verify that the FRACAS and statistical control techniques used to monitor and control production to prevent R&M degradation provide an adequate data set for controlling R&M in FRP.

R&M PROGRAM EVALUATION: DATA

R&M data applicable to this function can be defined, in general, on the basis of R&M activities assigned to the contractor, including those for which in-process reviews have been designated; for example:

- *Government Planning and Contractor/Subcontractor/Supplier R&M Program Plans* – The contractor is responsible for flowing P&D requirements to subcontractors and suppliers, but the Government should ensure that the process for doing so is appropriate.
- *FRACAS Reports* – As conducted in previous phases, FRACAS support should continue with all production systems.
- *Product Baseline Data* – Specifications, drawings, parts lists, technical order, manuals, training materials, and test procedures applicable to the LRIP design, updated to reflect approved ECPs incorporated in the design.
- *Acceptance Test Plan/Report* – Equipment or system acceptance test plans and report of LRIP items submitted to acceptance test. This report should describe the test plan, test procedure, test conditions, and success/failure criteria applicable to the test and should present an analysis of test results in terms of failure rates, failure modes, failure causes, maintenance action rates, and a growth curve with an estimate of reliability. Raw test data should be appended to the report.
- *R&M Demonstration Plan/Reports* – Test plans and reports for individual R&M demonstrations and tests, to include the contents outlined above, plus an evaluation of conformance to requirements and an analysis of any observed difference in R&M estimates between production-representative article demonstration and acceptance test results.
- *R&M Field Surveillance* – Field data surveillance analysis to provide an evaluation of current production R&M status, problems, corrective action requirements, and growth.

R&M PROGRAM EVALUATION: REVIEW CRITERIA

- *R&M Conformance* – The LRIP design (when tested under the identical conditions used in EMD phase production-representative article R&M demonstration) demonstrates R&M equal to or exceeding that demonstrated by the EMD production-representative article.
- *R&M Acceptance* – LRIP items satisfy the R&M acceptance criteria for each of the specified acceptance tests.
- *Test Correlation* – Acceptance test results are highly correlated with results of demonstration and other tests on the same items to ensure that the acceptance tests prevent the introduction of unsatisfactory non-conforming items to the field.

- *R&M in Quality Procedures* – Quality control procedures demonstrate capability to identify and control impending R&M degradation in all aspects of the manufacturing process and, as a self-checking feature, provide continuous monitoring of the outgoing production R&M levels as evidenced by the following:
 - LRIP items submitted to R&M tests disclose no critical weaknesses or incipient problems due to either the design or the production processes and reveal no evidence of faulty workmanship standards or control criteria.
 - LRIP items tested in accordance with specified procedures verify that no compatibility problems exist in checkout and field maintenance equipment, Government-furnished equipment (GFE) components and interfaces, fabrication and assembly tolerances and performance stability requirements, and subassembly-to-assembly test correlation.
 - Root causes of problems have been identified by failure analysis and can be brought under control, in accordance with the contract, before FRP. Corrective actions have been successfully tested and implemented to show effectiveness.

4.1.3 Monitor R&M in Production



Experience gained in the LRIP period is applied to the correction and refinement of plans and procedures for FRP. Periodic program reviews, as described in 4.1.2, should be scheduled to revalidate R&M controls whenever a major design modification is introduced. In addition, continuous R&M monitoring programs should be initiated for surveillance purposes, and should be used for individual item acceptance. The surveillance programs provide a running analysis of R&M and a trend analysis of test results at critical points in the manufacturing process or production flow. Failures observed during production alert management to a condition that may require management intervention to correct production deficiencies.

PRODUCTION R&M MONITORING: PROCEDURE

The Government should monitor R&M status and manage the overall R&M program on a continuous, cumulative basis, to accomplish the following:

- *R&M Achievement* – Verify from demonstrations, tests, and field data analysis that the R&M of items accepted for field delivery conform to specified requirements.
- *Problem Status* – Verify effectiveness of contractor responsiveness in the correction of problems (including updates to previous R&M analyses), control of discrepancies, and actions taken on other deficiencies, both to achieve R&M uniformity item-to-item and R&M stability lot-to-lot, and to achieve growth available through the correction of identified problems.
- *Production Decision* – Apply corrective action, as provided in the contract, to the production program if it becomes evident that R&M requirements will not be met.

PRODUCTION R&M MONITORING: DATA

Monitoring and management of R&M is facilitated by a production R&M monitoring report, prepared and submitted by the contractor on a scheduled basis as required by the contract.

- *R&M Monitoring*– A detailed summary submitted on a monthly, lot-to-lot, or other scheduled basis, as required by the contract, should present the following analyses:
 - Reliability of current production system (or current lot, or current month’s production) acceptance test results, compared with previous production or moving average of previous production, and compared with specified reliability acceptance requirements.
 - Current assessment of R&M surveillance test results (as actually measured under the specified test conditions), compared with previous production and specified operational thresholds.
 - Current assessment of field experience, based on an analysis of operational data from production items already delivered.
 - R&M problem analysis, differentiating between production problems and design problems, with a description of current status of proposed changes or other corrective action.
 - R&M trend analysis, comparing observed R&M against R&M potential available with the introduction of proposed changes.
 - Maintainability rates of production systems that were observed during demonstration or test.
 - Correlation analysis between R&M observed in reliability acceptance test and field use, with an explanation of any disparity noted between results.
 - Report of contractor actions and recommendations based on the contractor’s interpretation of the analyses.

PRODUCTION R&M MONITORING: REVIEW CRITERIA

- Results of production monitoring should be used to determine the adequacy of the production operation as a whole, not the acceptability of individual items or production lots. Indication of a condition that could jeopardize outgoing R&M levels provides sufficient basis to correct deficiencies underlying the observed trend.

4.2 SYSTEMS ENGINEERING

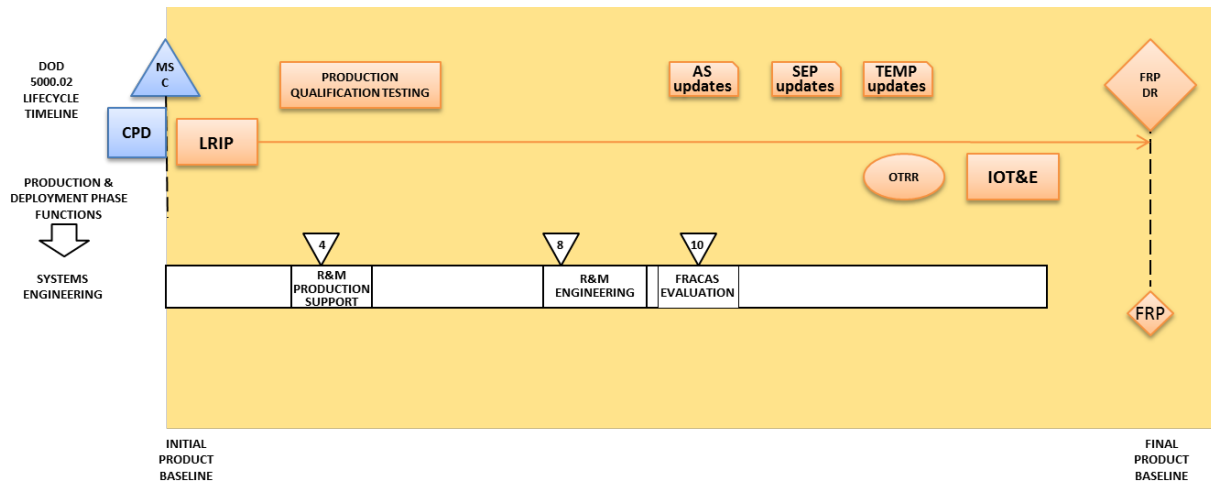





Table 4-3 lists the primary R&M activities for the Systems Engineering functional area in the P&D phase.

Table 4-3. R&M Systems Engineering Activities – P&D Phase

R&M Activity	Description
 Provide R&M Production Support	Review contractor’s production engineering R&M activities to evaluate effectiveness of parts and materials R&M, production process evaluation, and environmental survey.
 Perform R&M engineering	Review contractor’s R&M engineering activities to evaluate analyses and measurement, reliability growth, field use environment, effectiveness of use of ECP evaluation, and problem investigation and production improvements.
 Evaluate FRACAS	Evaluate the effectiveness of continuing failure data collection, analysis, and feedback procedures for detecting and correcting production and field discrepancies, design deficiencies, and R&M program problems.

4.2.1 Provide R&M Production Support



During the LRIP period of the P&D phase, the contractor should establish and evaluate production methods and controls, parts and materials application requirements and test procedures, to ensure that final items will be capable of meeting reliability requirements. The contractor is responsible for flowing requirements as necessary to subcontractors and suppliers. The Government should review the process of flowing the appropriate requirements. R&M, as ultimately observed in the field, can only approach the inherent levels achieved in design to the extent that R&M factors associated with production can be controlled.

4. R&M IN THE PRODUCTION AND DEPLOYMENT PHASE

The contractor's R&M engineering activities in support of production should evaluate R&M-sensitive manufacturing operations during the LRIP period. This evaluation should ensure producibility of the item in conformance to approved production release documentation and demonstrate the adequacy of production processes and controls to be employed in the P&D phase. Production R&M engineering should be applied on a continuing basis in the production period to evaluate the R&M impact of proposed changes in production and design processes.

R&M PRODUCTION SUPPORT: PROCEDURE

Review the contractor's consideration and use of R&M engineering in the areas described below.

- *R&M Controls* – Define and integrate R&M requirements at inspection and test points and criteria in the production sequence for the item. Verify that critical R&M-dependent operations are identified and adequately controlled.
- *Workmanship Standards* – Evaluate workmanship standards for critical fabrication and assembly operations in relation to known sources of R&M degradation.
 - Rework – Evaluate the effects of production rework (of rejected items) on potential failures due to latent defects, as determined by the contractor through FMECA and appropriate R&M evaluation of LRIP units.
 - Identify production processes that affect the ability of maintainers in the field to remove and reinstall components. For example, conduct wiring integrating testing with maintenance procedures as defined for the user.
 - Software maturity – Evaluate the defect find versus fix rate to ensure the software baseline is stable for the production system.
- *Parts, Components, and Materials Control* – Evaluate the compatibility among specified characteristics of parts, components, materials, and equipment application requirements. Verify that essential characteristics (including failure rate and removal rate in specified failure modes) are adequately defined in quantitative terms for the known critical applications in the design, by an evaluation of application in the LRIP item. This verification should have been accomplished initially in development, but should be verified in the LRIP period to revalidate the approved lists of parts, components, and materials. Verify that results of this evaluation are used to select suppliers, prepare purchase requests, and design incoming inspection tests to ensure parts and materials meet the required failure rate. R&M-dependent data should include the following:
 - Quantitative definition of part, component, and material characteristics essential to system performance and R&M.
 - Specification values and test conditions for procurement description and acceptance inspection.
 - Verification that GFE parts and components designated for incorporation in the production model are applied in accordance with their respective specifications.

R&M PRODUCTION SUPPORT: DATA

Review the following contractor data for R&M engineering support:

- *Production Engineering Data* – Results of initial and updated engineering analyses, and the following specific R&M analyses:
 - Assessment of R&M degradation potential in manufacturing methods, processes, and fabrication and assembly operation, adopted for production, which should be brought under control to ensure homogeneous production in the system.
 - R&M requirements in inspection, test, and control criteria related to parts, materials, fabrication, assembly, workmanship, and manufacturing operations required to reproduce the R&M achieved in the production-representative article design.
 - Assessment of R&M degradation from software changes to correct discrepancies or for security changes. Assessments should focus on CSCIs with large numbers of discrepancies or late discovery defects (defects not found in unit or integration tests). These may indicate changes needed in the architecture or testing.
 - Effect of repeated cycles of rework on items rejected as a result of inspection and test.
 - Correlation analysis between R&M in-process inspection and test procedures, and production acceptance test results.
- *Production Specifications* – Documented procedures, standards, qualification or acceptance criteria, statistical analysis methods, and control charts used at significant points in the production flow that can show control of R&M.

R&M PRODUCTION SUPPORT: REVIEW CRITERIA

- Results of analyses have been used in the design of manufacturing methods, standards, R&M procedures, and acceptance criteria employed in production.
- Testing of LRIP items has demonstrated the effectiveness of R&M engineering support, verifying that R&M degradation controls are adequate to ensure consistent reproduction to the specified requirements.

4.2.2 Perform R&M Engineering



R&M engineering support in the P&D phase is essentially an extension of R&M engineering activities applied in the EMD phase. For example, during the production period, engineering changes will become necessary either to correct deficiencies or to modernize the design consistent with changing requirements. These changes should progress through the same iterative design-evaluation-redesign cycle described in the EMD phase chapter to verify that R&M characteristics of the production item are not degraded. R&M design guidelines and support procedures are also applicable in the P&D phase.

R&M ENGINEERING: PROCEDURE

Prepare and periodically review and update R&M requirements defined in production specifications, or review contractor proposed changes, as outlined below.

- *Requirements Definition* – Verify that quantitative R&M design requirements are compatible with those defined in the product baseline specification. If they are not compatible, determine which requires correction and take appropriate action.
- *Test Requirements* – Ensure that applicable R&M demonstration and test criteria are clearly specified for LRIP item and FRP item R&M acceptance and demonstration.
- *Test Conditions* – Verify that production acceptance test conditions and failure-rate/failure mode/maintenance action rate criteria for production acceptance of individual units or production lots of units, as applicable, are consistent with the test requirements above.
- *Inspection Requirements* – Verify that R&M requirements for production inspection and test are specified for those elements and interfaces that have a degradation effect on R&M.

Each proposed change to the product baseline should be evaluated to determine its effect on R&M characteristics of the design. The contractor should provide for this evaluation as an essential part of the change review procedure. The R&M review associated with change control procedures both at the contractor and the Government can then determine the significance of the impact on system reliability, maintainability, equipment failure rates, failure modes, and maintenance action rates and interactions on other interfacing GFE or contractor-furnished equipment (CFE) items, to prevent the introduction of an unknown degree of reliability or maintainability degradation. Review each proposed change and/or ECP to accomplish the following on a continuing basis:

- *R&M Impacts* – Verify that the R&M impacts of the proposed change are adequately evaluated (i.e., updates to previously performed R&M analyses) and the analysis is properly validated.
- *Trade-off Study* – Verify that the R&M impacts are acceptable from a total system viewpoint, as determined from trade-off study results with other parameters that would benefit from the change.

In conjunction with other functional teams, support the Functional Configuration Audit (FCA) and Physical Configuration Audit (PCA) on the LRIP item, to accomplish the following:

- *R&M Conformance Evaluation* – Review the functional and physical configuration of the item, to verify the configuration conforms to R&M and BIT requirements defined in product baseline specifications, as follows:
 - R&M, including fault detection, fault isolation, and false alarm rates, as measured by the approved demonstration/test, equals or exceeds the contractually specified requirement.
 - Test conditions, procedures, performance requirements, success/failure criteria, and analytical procedures applied in the R&M demonstration and tests conform to those prescribed by the specification and called out in the contract.
 - Failure rates and maintenance action rates observed in production acceptance tests are within the acceptance limits specified by the R&M acceptance test.

4. R&M IN THE PRODUCTION AND DEPLOYMENT PHASE

- Test conditions, procedures, performance, and accept/reject criteria used in R&M acceptance tests conform to those prescribed by the production specification and called out in the contract.
- *Initial Test and Evaluation / Follow-On Test and Evaluation* – Evaluate results of initial and follow-on tests to verify R&M suitability of the LRIP item design and to identify any specification inadequacies that account for observed R&M deficiencies.
 - Interface Compatibility – Evaluate compatibility of R&M-sensitive interfaces between the LRIP item design and GFE or other items of CFE (including test equipment, support equipment, and packaging) to verify conformance to requirements defined in interface control drawings and specifications.
 - Problem Evaluation – Verify that R&M problems are identified, diagnosed, and adequately described relative to root cause, effect, and corrective action requirements. Evaluate R&M requirement conformance potential based on successful correction of these problems, and evaluate the technical feasibility of correction through ECPs, contract changes, or contractor-introduced corrective action measures, as appropriate.

Evaluate the contractor's application of R&M engineering principles and procedures in analysis and solution of field-reported problems, pursuit of system improvement objectives, investigation of cost-saving design alternatives, and review of change proposals, involving the following:

- *Requirements Analysis* – Verify contractor understanding of current R&M and BIT requirements at system and equipment levels, by functional mode and mission profile.
- *R&M Allocation* – Verify the contractor's reassessment of allocated requirements and the validity of the basis for proposed reallocations in product baseline specifications. If the reallocations are not possible, determine which ones require correction and take appropriate action.
- *R&M Analyses* – Verify that R&M predictions, FMECA, and other analyses are updated based on field results and have been applied to the models previously developed to assess impacts on spares, manpower, missions, and logistics.
- *Failure Diagnosis* – Evaluate contractor failure diagnosis activity in terms of depth of investigation, impacts on other functional areas, and use of results for problem solving.
- *Environmental Analysis* – Verify currency and adequacy of the design environment (thermal, shock, and vibration) under field use conditions including field results of packaging design (e.g. handling, storage, and transportation requirements).
- *Computational and Network Loading Analysis* – Verify currency and adequacy of the planned operational loading (computational, network and Bit Error Rates) under field use conditions including field results.
- *Problem Control* – Evaluate the contractor's detailed technical knowledge of the nature and significance of outstanding R&M problems, the required corrective action, and the improvement that could be expected if the corrective actions were implemented.

R&M ENGINEERING: DATA

Data required for review of contractor R&M engineering includes primarily the results of analyses and evaluations. Contractor data required at this review point may include the following:

- *Production Specifications* – Most recent applicable version of product baseline specifications, drawings, and parts specifications.
- *Production R&M Engineering Reports* – R&M analyses of current product baseline configuration test results, demonstrations and tests, and field data, to include the following:
 - R&M allocation reassessments and reallocations.
 - FRACAS and R&M review board reports and results, including progress on the updated reliability growth curve(s).
 - BIT (Hardware and Software) detection, isolation, and false alarm data.
 - FMECA, SFMEA updates.
 - Critical parts evaluation.
 - Test and support equipment compatibility analysis.
 - Production acceptance test correlation analysis, in relation to demonstration and test results, field experience, and failure mode analysis.
- *Changes/ECPs* – Approved changes already incorporated in the design and not yet integrated into the specifications and drawings.
 - R&M Impacts – R&M of the system with and without the change, based on analysis and test data, to include:
 - Failure mode pattern in the equipment with and without the change.
 - Maintenance procedures, including BIT detection and isolation, of equipment with and without the change.

R&M ENGINEERING: REVIEW CRITERIA

- *Activity Performance* – Activity Results – Currency – Specifications, upon completion of review for updating, reflect the effect of all approved changes applicable to the particular production item.
- *Consistency of Requirements* – Quantitative R&M requirements for R&M acceptance are compatible with R&M demonstration and test requirements specified for production surveillance, and both are consistent with R&M specification requirements.
- *Compatibility of Test Conditions* – Test conditions for R&M acceptance are compatible with test conditions specified for R&M demonstration.
- *Adequacy of Analysis* – ECP R&M impacts are based on realistic analysis and results of verification tests.

- Trades performed when ECPs degrade R&M that result in acceptable improvement in other areas.
- R&M Conformance – The LRIP item design has demonstrated its conformance to R&M requirements under the contractually specified demonstration and test conditions.
- Reliability Acceptance – The LRIP item design has satisfied the R&M criteria for acceptance in the applicable production specification.
- Operational Suitability – Results of operational tests and evaluation have disclosed no serious R&M deficiencies that would require extensive corrective action.

4.2.3 Evaluate FRACAS



The Government and contractor should continue the closed-loop FRACAS established in previous phases for recording all failures, discrepancies, and malfunctions that occur at any point in the program, during all testing from equipment to system level. The FRACAS should incorporate data from operational data collection systems. For systems with a major software interface and separate Software Support Activity (SSA), the help desk and problem reporting system should be integrated into the FRACAS system.

The FRACAS should provide for recording accumulated operating time and cycles and the prevailing environmental conditions for all subassemblies, units, and completed items on which functional or operational tests are performed. Formal procedures for statistical analysis, engineering interpretation, and presentation of failure data should be established to facilitate application in the assignment of corrective actions and early detection of failure trends.

FRACAS EVALUATION: PROCEDURE

Review the FRACAS to verify or evaluate the procedures described below.

- *Failure Reporting* – Verify that failure reports are prepared for each failure (including BIT detection or isolation failures) that occurs. Complete and accurate reporting is required, to provide a valid basis for failure analysis and evaluation of inspection, process, and procedural controls that caused (or permitted) the failure.
- *Failure Classification* – Verify that failures are classified according to the severity of the failure and are consistent with the Failure Definition and Scoring Criteria (FDSC).
- *Failure Analysis* – Evaluate the procedures for failure analysis for all failures. Through the Government R&M review board and contractor’s failure review board, provide added assurance that the reporting, analysis, and corrective actions taken on identified failures will be controlled. The failure analysis should accomplish the following:
 - Determine the mode of failure.
 - Determine the root cause of failure.
 - Prescribe the necessary corrective action.

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- Identify and rank problem areas according to the seriousness of the threat to reliability, using the FMECA as a reference. Rank problem areas according to the seriousness of the threat to safety and performance jointly with relevant subject matter experts.
- *Follow-up Procedures* – Evaluate effectiveness of follow-up procedures. It is essential that the contractor follow up on the status of all R&M and BIT problems. The contractor should summarize corrective action completed, in process, and contemplated.
- *Application Effectiveness* – Evaluate effectiveness of recurrence controls and corrective actions for discrepancies and failures identified in the preceding steps.

FRACAS EVALUATION: DATA

Review of the FRACAS, in operation, requires access to the following data:

- *Failure Reporting System Procedures* – Documented procedures and basis for the reporting system, including:
 - Data entry requirements, codes, and instructions for completion.
 - Data processing procedure for storage, retrieval, and analysis.
 - Terms, definitions, and mathematical models, consistent with the FDSC, by which data are translated into R&M parameters.
 - Statistical analysis procedure.
 - Engineering evaluation procedure.
 - Corrective action assignment and follow-up procedure.
 - Reassessment procedure to verify effectiveness of the system as a data feedback system.
- *Failure Reports* – Selected samples of individual failure reports.
- *Failure Analysis Reports* – Failure analysis reports that translate the accumulated failure reports into information useful to evaluate R&M and BIT status, measure growth, identify problems, and assign corrective action.
- *Failure Evaluation Report* – Reports of corrective actions taken, verified, and introduced into the production item or forwarded as an ECP for approval.

FRACAS EVALUATION: REVIEW CRITERIA

- *Reporting Adequacy* – The FRACAS provides for reporting all data needed for identification, traceability, R&M and BIT measurements, and failure mode analysis, as outlined above.
- *Feedback and Application* – The system provides rapid feedback of analysis results to those responsible for engineering investigation and corrective action determination.
- *Follow-up* – The system provides a formal means to analyze corrective action implementation and effectiveness.

4.3 TEST AND EVALUATION

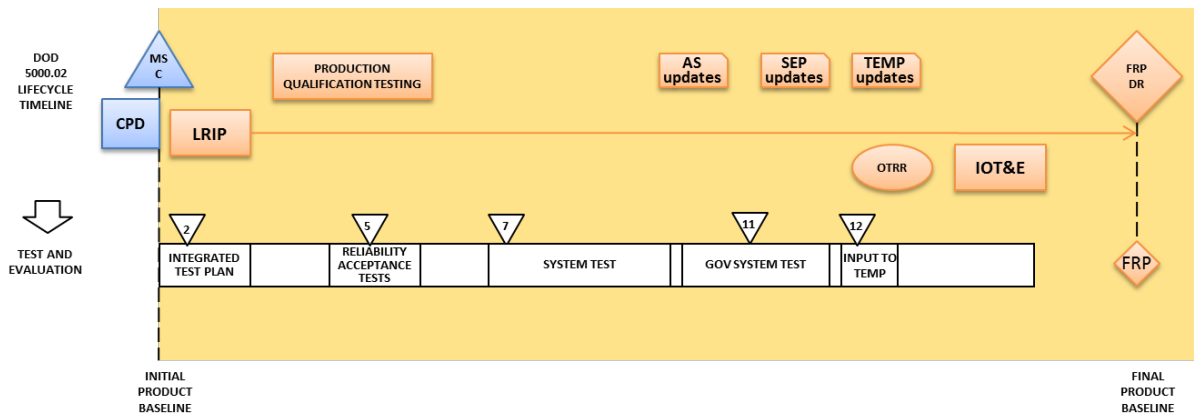


Table 4-4 lists the primary R&M activities associated with the Test and Evaluation functional area in the P&D phase.

Table 4-4. R&M T&E Activities – P&D Phase

R&M Activity	Description
2 Review Integrated Test Plan	Review the contractor's updated integrated test plan for the P&D program, using applicable documents referenced in the P&D contract.
5 Perform Production Reliability Acceptance Test	Evaluate R&M status and problems of production reliability acceptance tests.
7 Perform System Test	Evaluate R&M status and problems of system test.
11 Perform Government System Test	Evaluate R&M performance of Government system test results.
12 Provide R&M Input to TEMP	Update the TEMP for follow-on tests.

4.3.1 Review Integrated Test Plan



The contractor's overall test program for the P&D phase is usually a composite of several categories of tests:

- Acceptance tests for incoming parts, materials, and supply items.
- Quality inspection and functional tests in the production flow.
- Production and production change evaluation tests in the production assembly.
- Pre-installation and post-installation operability tests.

- Final assembly tests
- Government acceptance tests.
- Initial and Follow-on tests and evaluation (Service conducted).

All of these test categories have a common objective to evaluate and control the attributes and deficiencies of the product ultimately to be delivered to the field. The Government wants evidence that the system will satisfy field operational thresholds for R&M as reflected in the requirements document, as demonstrated by the approved production-representative article design and progressively translated into the product baseline requirements specified in the P&D contract.

REVIEW INTEGRATED TEST PLAN: PROCEDURE

Review the contractor's integrated test program plan for P&D, to verify adequacy of R&M test provisions in individual test plans. The contractor is responsible for ensuring the adequacy of its subcontractor and supplier test programs; however, the Government should review the processes and procedures for doing so. Evaluate the following aspects of the test program:

- *Test Program and Schedule* – Verify that the test program (as documented in the IMP, IMS, and other program documentation) includes a network of all test and test support activities planned for the program related to key points in the production flow. The plan should include a description of the following:
 - Identification of tests into which R&M measurement requirements and test conditions have been integrated.
 - Identification of tests designed specifically for R&M evaluation or demonstration.
- *Test Descriptions* – Verify that the test program describes the following types of tests. Individual tests within each of these categories will be prepared as test plans following the outline below, when required by contract:
 - *Parts and Materials Tests* – To evaluate and control failure rate characteristics and latent R&M defects in parts and materials used in production of the item, in the procurement of maintenance spares, and in the qualification and control of suppliers for these parts and materials.
 - *Production Conformance Tests* – To evaluate producibility of the approved production design, to evaluate and control deficiencies and discrepancies in the production control system itself, and to evaluate R&M degradation/enhancement potential associated with proposed design or production changes. This could include highly accelerated stress screening, or other environmental stress screening.
 - *Production Reliability Acceptance Tests* – To determine equipment conformance to specified failure-rate/failure-mode/maintenance action rate criteria as a basis for acceptance and to identify problems, latent defects, and marginal performance trends requiring corrective action. Production reliability acceptance testing (PRAT) can be accomplished in either of two ways, depending on the size, complexity, and quantity of production items. First, formal

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reliability demonstrations for large, complex systems, or second, failure-rate acceptance for small items produced in large quantities, backed up by reliability demonstration on a sampling basis for overall control of the production program.

- R&M System Demonstration and Test – To evaluate system conformance to specified requirements and identify R&M problems and latent defects under the simulated environmental conditions applicable to the deployed system, as a basis for overall control of the program. This test could be continued reliability growth using Test Analyze And Fix (TAAF) methods from the EMD phase, Reliability Demonstration and Test, Maintainability and BIT Demonstrations (M-Demo), or other R&M system demonstrations and tests.
- *Test Plan Outlines* – Verify that each type of production test identified above appropriately addresses the specific items to be tested, stating the test objectives, and describing the following:
 - Test conditions, test procedures, test duration, environmental conditions, parameter measurements, and time elements to be recorded.
 - Factors to be evaluated, analytical procedures to be employed, and decision criteria, where applicable. Include action to be taken in the event of a reject decision.
 - Specific R&M measurements data required and provisions included in the individual test plan for acquiring these data.
- *Individual Test Plans* – Review and approve individual test plans prepared and submitted by the contractor in accordance with contract requirements and the approved test outlines above. The Government should verify, on an individual basis, that these detailed test plans satisfy R&M measurements and data requirements for the specific test objectives defined in the contract and are sufficient in the particular areas of test design.
- *Individual Test Reports* – Review individual test reports prepared and submitted by the contractor on completion of individual tests to verify conformance to detailed test plans as approved above and to evaluate consistency with data requirements defined in the contract.

REVIEW INTEGRATED TEST PLAN: DATA`

Review of the contractor-integrated test plan and individual detailed test plans requires the following data, as applicable, submitted in the overall integrated test plan and subsequently expanded in detail in the individual detailed test plans.

- *Purpose of Test* – Purpose and justification for each test in the production test program and point in the production flow at which test results are required for accept/reject decision, engineering evaluation, or R&M control.
- *Specific Test Objectives* – Identification of the particular type of test to be performed.
- *Engineering Requirements* – Explicit definition of the following engineering considerations:
 - Environmental stress spectrum to which the test item is to be subjected, e.g., thermal vibration, shock, humidity.

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- Operational stress spectrum to which the test item is to be subjected, e.g., software operations.
- Interfacing systems with which the test item is to be tested.
- Test item operating duty cycles and environmental exposure cycles.
- Test time requirements for R&M measurement.
- Success/failure criteria in terms of performance limits on essential parameters.
- *Statistical Criteria* – Test parameters established by statistical constraints may include data analysis methods, Consumer and Producer Risks, test sensitivity, number of test items required, test duration, and sample selection process.
- *Measurement Data* – Data required for description of test conditions and test results.
- *Facilities and Support Requirements* – Physical facilities and personnel required to conduct individual tests (Government, industrial, or contractor-furnished).
- *Test Procedure* – Detailed procedures for conducting individual tests.
- *Data Analysis Methods* – Planned use of each item of data, with a sample analysis to verify adequacy of both the procedure and the data elements.

REVIEW INTEGRATED TEST PLAN: REVIEW CRITERIA AND DECISION ALTERNATIVES

- *Adequacy of Test Program Plan* – The contractor’s integrated test program plan includes provisions for performance of R&M tests of the types described above in accordance with the schedule of inspection and test points in the production flow, as defined in the contract.
- *Adequacy of Individual Test Plans* – The contractor’s integrated test plan and plans for individual tests conform to data requirements outlined above.

4.3.2 Perform Production Reliability Acceptance Test



Production reliability acceptance testing can be accomplished in either of two ways, depending on the size, complexity, and quantity of production items: (1) formal reliability demonstrations for large, complex systems or (2) failure-rate acceptance for small items produced in large quantities, backed up by reliability demonstration on a sampling basis for overall control of the production program. Failure rate acceptance is practicable when equipment reliability requirements can be translated into failure-rate/failure-mode criteria for the design of fixed-time acceptance tests. The Government should therefore review the production acceptance plan and the R&M demonstration plans at the same time.

PRODUCTION RELIABILITY ACCEPTANCE TESTS: PROCEDURE

Perform a review of acceptance test plans, procedures, and test results, to make the following determinations:

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- *Acceptance Provisions* – The contractor’s acceptance test design should show its basis in terms of failure-rate/failure-mode equivalency over the test time period planned for the test to the specified reliability requirements established for the demonstration or test. The step-by-step review procedure should be followed, to evaluate conformance to the following provisions:
 - Specific test objectives and parameters to be measured.
 - Test conditions and environmental factors.
 - Test duration and operational cycling.
 - Statistical criteria, consumer and producer risks, sampling plan, reliability discrimination ratio.
 - Measurement data, instrumentation, accuracy.
 - Test procedures.
 - Mathematical models and data analysis.
 - Accept/reject criteria.
- *Test Monitoring* – Monitor contractor performance of the approved acceptance test and authenticate the test results.
- *Review of Acceptance Test Results* – Ascertain that the production item or lot conforms to specified failure-rate/failure-mode criteria established in the approved test plan, and make accept/reject decision.
- *Test Correlation Analysis* – Compare cumulative analysis of acceptance test results with R&M demonstration and test results to evaluate discrepancies, and require contractor adjustment of acceptance test criteria to minimize the disparity.

PRODUCTION RELIABILITY ACCEPTANCE TESTS: DATA

Review of production reliability acceptance tests and test results, as a basis both for approving the test and for making the critical decision to accept or reject the item under test, requires the following contractor data:

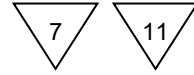
- *Acceptance Test Plan* – Test plan and procedures showing the conditions, measurements, analysis, and accept/reject criteria related to the reliability requirements.
- *Product Baseline Specification* – R&M requirements and acceptance test provisions as contractually called for in the specification.
- *Acceptance Test Report* – Acceptance test results to include performance measurements and failure data, failure diagnosis to root cause, and data analysis to substantiate accept or reject decision.

PRODUCTION RELIABILITY ACCEPTANCE TESTS: REVIEW CRITERIA

- *Conformance to Test Plan* – The acceptance tests are conducted in conformance to the approved acceptance test plan, and data recorded during the test are authenticated.

- *Conformance to Requirements* – Results of the acceptance test fall in the “accept” region of the test plan.

4.3.3 Perform System Test and Government System Test



R&M demonstration and test plans, whether for production surveillance and control or for production acceptance of large, complex equipment and systems, should be reviewed by the Government for conformance to test requirements and acceptance criteria specified in the contract. Results of the approved demonstrations and tests are used as specified, either to determine acceptability of individual systems or production lots or for overall control of the production program. Procedures, data requirements, and review criteria and decision alternatives are as described in the EMD phase chapter. The “System Test” is generally performed by the contractor with Government involvement, and the “Government System Test” is performed independently by the Government for formal verification testing.

SYSTEM TEST: CONTROL PROCEDURE

Review R&M demonstration and test plans and test results to accomplish the following:

- *Test Plan Review* – Review and approve the demonstration and test plans following the same review procedures described above and in the EMD phase, to include the appropriate reference to specific test provisions and environmental conditions.
- *Test Monitoring* – Monitor performance of all R&M demonstrations and tests performed for acceptance. Monitor those performed for production surveillance on a sampling basis.
- *Conformance Evaluation* – Verify contractor analysis of data and, on the basis of the analysis, evaluate the degree of conformance to specified R&M requirements.
- *Test Correlation Analysis* – Compare cumulative results of acceptance test with cumulative reliability observed on demonstrations and tests for the same production lots. Evaluate significance of any disparity and assign corrective action to the contractor.
- *Evaluation of Contractor Test Data Utilization* – Review contractor R&M assessments on the basis of demonstration and test results and evaluate contractor effectiveness in performance of the following:
 - Correlation analysis of demonstration and test results, with data from acceptance tests, failure reports, and other sources, to identify major deficiencies in the acceptance test and demonstration/test in relation to field experience.
 - Analysis of critical failure modes and effects on system R&M, with a description of failure root causes and corrective action requirements.
 - Analysis of problems that account for system failures in the field environment that have not been detected in the R&M test program and/or were not identified in previous R&M analyses (unanticipated failures), with a description of corrective action requirements.

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- Application of the foregoing analyses in engineering investigation, corrective action development, and change proposal preparation.
- Application of analysis by maintenance and logistics support activities to correct problems traceable to these activities.
- Application of analysis in the procurement and production control activities for the improvement of production processes, manufacturing operations, supplier controls, and inspection and test procedures, as applicable.
- Application of analysis to the improvement of production reliability acceptance tests.

SYSTEM TEST: DATA

Assessment of R&M demonstration and test results requires the following contractor data:

- *R&M Specifications* – Product baseline R&M requirements, acceptance test provisions and criteria, and demonstration and test requirements.
- *R&M Demonstration Plans* – R&M demonstration and test plan, test conditions, test procedures, and acceptance criteria for production surveillance or item acceptance, as applicable.
- *Demonstration/Test Report* – Individual demonstration and test reports including test data, data analysis, R&M computations, and correlation analysis with acceptance test data and field data.

SYSTEM TEST: REVIEW CRITERIA

- *Adequacy of Test Plan* – The R&M demonstration and test plans, as approved by the Government, satisfy contractually specified test requirements.
- *Adherence to Test Plan* – The demonstration and test have been conducted in conformance to the approved test plan; if conducted for acceptance purposes, the test has been witnessed and authenticated by the designated Government representative.
- *Conformance to Specified Requirements* – Results of the R&M demonstration and tests fall in the “accept” region of the test plan, whether the test is used for acceptance or for production surveillance.

4.3.4 Provide R&M Input to TEMP



Update the Test and Evaluation Master Plan (TEMP) for the Operations and Support (O&S) phase and any follow-on tests.

INPUT TO TEMP: PROCEDURE

The program should develop or update the TEMP with the following:

- *System R&M Demonstration* – Identify tests designed specifically for R&M evaluation or demonstration. Include a specific reference to the applicable sections of the contractor’s plan for R&M testing.

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- *Reliability Growth Planning* – Provide a test schedule and resources compatible with the schedule of major program milestones. Describe the adequacy of system-level and appropriate subsystem growth test provisions for achieving requirements. Update the reliability growth curve.
- *R&M Test Flow Diagram* – Include a network of all R&M test and test support activities planned for the program.
- *T&E Integration of R&M Engineering Activities* – Identify individual tests keyed to the schedule with dates for submission of individual test plans for approval, test readiness reviews, commencement of test, completion of test, and test report delivery. Describe the FRACAS to be implemented, and transition of responsibility of FRACAS to the Government if applicable, for recording, reporting, analysis, correction, and monitoring of design and production deficiencies, discrepancies, and problems revealed in O&S testing, at all levels.
- *R&M Measurements Requirements* – Identify tests into which R&M measurement requirements and test conditions have been integrated. Identify data and measurements to be derived from the tests described above along with the R&M decision criteria. Update FDSC as necessary to align with Service-specific scoring criteria.

INPUT TO TEMP: DATA

R&M test planning requires the following data:

- *R&M Plans* – Test plans and tentative procedures for performance of tests outlined above.
- *Specifications* – Product baseline specifications for items covered in the R&M test plans. These specifications provide the basis for test requirements and the criteria for accept/reject decision of individual items.

INPUT TO TEMP: REVIEW CRITERIA

- *Adequacy of Coverage* – All areas that by development experience are projected as potential problems are covered by an appropriate R&M test and monitoring.
- *Adequacy of Procedure* – The proposed plan includes test data to substantiate the effectiveness of each R&M procedure outlined above.

4.4 PROCUREMENT

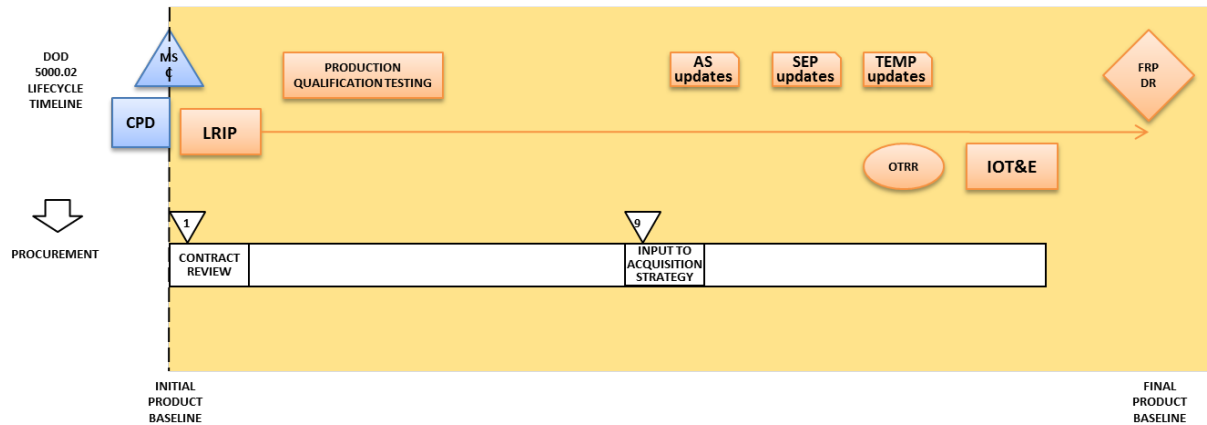




Table 4-5 lists the primary R&M activities associated with the Procurement functional area in the P&D phase.

Table 4-5. R&M Procurement Activity – P&D Phase

R&M Activity	Description
 Review P&D phase contract	Review the P&D phase contract R&M requirements.
 Provide R&M Input Acquisition Strategy	Provide R&M input for incorporation into the Acq Strat.

4.4.1 Review P&D Phase Contract



R&M activities in the P&D procurement functional area are generally the same and equally as important as those described in the preceding TMRR and EMD phases. When the P&D phase is the direct follow-on to a newly completed EMD phase, the contract statement of work (SOW) will generally have been prepared in accordance with instructions and requirements specified in the EMD phase contract.

The Government should review and approve the R&M provisions contained in the P&D proposal and contract documents before formal execution and signature by the Government.

CONTRACT REVIEW: PROCEDURE

Using the contractor’s proposal as a reference, review the proposed P&D contract against the criteria outlined below.

4. R&M IN THE PRODUCTION AND DEPLOYMENT PHASE

- *R&M Management* – Verify that R&M management procedures related to those activities described in this document are specified and clearly described in the contract. Essential features of the contractor’s proposal should be specifically referenced in the contract.
 - Verify that the contractor’s R&M planning conforms to requirements defined in the RFP, covering all R&M engineering activities to be performed throughout the P&D phase.
 - Verify that the contract requires in-process review of R&M data and establishes procedures for dissemination of data to other functional areas or stakeholders, in accordance with applicable contract DD 1423s.
 - Verify that the contractor will prepare and maintain current R&M specifications in product baseline specifications at system, subsystem, and equipment levels.
- *R&M Engineering Activities* – Verify that the following R&M engineering and analysis are specified in the contract as part of the systems engineering function:
 - Perform failure analysis, to failure root cause, and identify R&M problems based on test results and feedback data for corrective action guidance.
 - Perform analysis of R&M impacts and verification of ECPs.
 - Review waivers and deviations for impact on R&M.
- *Product Support Activities* – Verify that the R&M activities in the contract support logistics planning:
 - Provide validated failure-rate, failure-mode and demand data derived from test and field experience for maintenance and logistics support activities.
 - Verify adequacy of maintenance instructions and procedures manuals to maintain the system without reliability or maintainability degradation.
- *Test and Evaluation Activities* – Verify that the appropriate R&M activities are in the contract:
 - Prepare the overall production test program plan and detailed test plans for individual tests in the program.
 - Conduct tests for required parts and materials evaluation, production acceptance, and R&M demonstration.

CONTRACT REVIEW: DATA

The following data are required for review of the P&D contract:

- *RFP* – The technical data package on which the contract is to be based, including production specifications, R&M requirements, data requirements, acceptance and demonstration/test requirements, and configuration control requirements.
- *Contractor Proposal* – The contractor’s proposal, including P&D R&M plans and procedures.
- *Contract* – The proposed contract, including R&M requirements, test plans, data requirements, and ECP R&M review process.

CONTRACT REVIEW: REVIEW CRITERIA

- The contract satisfies the criteria indicated in the procedure and data requirements above.

4.4.2 Provide R&M Input to Acquisition Strategy



The Acquisition Strategy (Acq Strat) should include a description of the essential activities for achieving the R&M requirements. The Acq Strat should include the JCIDS R&M thresholds and production specification requirements. R&M engineering activities in the following O&S phase primarily are focused on assessing operational data to determine the adequacy of R&M and BIT characteristics, maintenance features and procedures, and provisioning plans, and identifying problem areas for correction through ongoing closed-loop FRACAS and field data assessment. These identified problem areas for correction then require activities for the continuation of the iterative design-evaluate-redesign-reevaluate practiced in previous phases.

INPUT TO AS: PROCEDURE

The [Acq Strat Outline](#) contains the following:

- Identify the activities to be stated in the RFP (if one will exist for O&S) and required of the contractor to demonstrate the achievement of the R&M requirements.
- Provide a table to specify how the sustainment KPP thresholds have been translated into R&M production specification requirements.

INPUT TO ACQ STRAT: DATA

Inputs should be by integration into appropriate sections of the Acq Strat and updated as required.

INPUT TO ACQ STRAT: REVIEW CRITERIA

- *R&M Data* – The Acq Strat includes the R&M data outlined above.
- *Verification* – R&M data summarized in the Acq Strat are consistent with the validated data presented in the requirements document, RAM-C Report, and contract specifications.

4.5 FULL-RATE PRODUCTION DECISION REVIEW

R&M ASSESSMENT FOR REVIEW

The FRP decision review is the critical transition point in the life cycle at which ownership of the system shifts from the acquisition project team to the field. R&M suitability of the production system should first be demonstrated by test, then verified by operational test and evaluation and evaluated for field use. When it is determined through this chain of events that the production system will satisfy field requirements, and P&D phase exit criteria are met, review objectives are satisfied.

R&M assessment is conducted at this review to evaluate the degree of conformance to specified requirements, both to assess current R&M status of the production design and to identify and define the sources of R&M problems for which corrective actions should be provided. Assessments should consist of an independent analysis of the design, using failure data and growth curves accruing from production tests and field operational experience.

4.5.1 Procedure

Review of R&M achievement and program effectiveness in the P&D phase provides the basis for the FRP decision and to provide confirmation that R&M deficiencies and discrepancies observed in LRIP are under control and that these controls are adequate to ensure consistent R&M.

- *R&M Assessment* – Verify the adequacy of implemented R&M activities relative to the specified R&M requirement or criteria. Identify any inconsistencies or deficiencies noted in the review.
- *R&M Impact Assessments* – Evaluate the seriousness of noted deficiencies in terms of impact on R&M and prepare an assessment report on which to base the approval/disapproval recommendation.

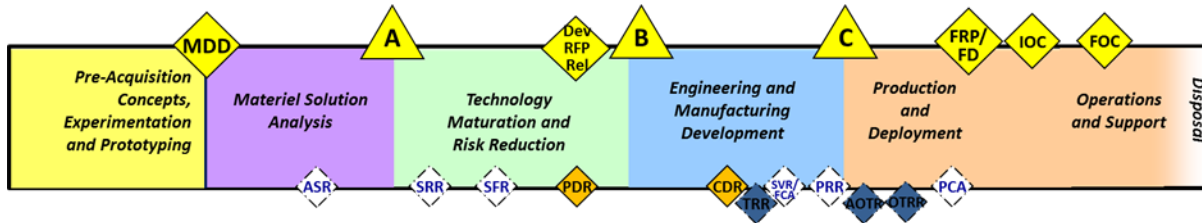
4.5.2 R&M Recommendation

On the basis of the review, make specific recommendations, with justification, for disposition of the program by one of the following alternatives:

- *Proceed into FRP and O&S phase* – LRIP items have demonstrated conformance to specified R&M requirements and have been deemed operationally suitable with only minor exceptions. Approve the LRIP item for FRP, conditional on correction of production discrepancies and R&M inadequacies.
- *Continue with P&D* – LRIP item fails by a significant margin to satisfy acceptance or demonstration and test requirements. Correct the LRIP discrepancies and verify thru demonstration and/or test. This page intentionally blank.

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5. R&M in the Operations and Support Phase



Objectives of the Operations and Support Phase

The Full-Rate Production (FRP) decision in the system life cycle marks the successful completion of engineering and manufacturing verification and ensures that the system will be reproduced in a manner to ensure conformance to specified requirements and delivery of an operationally suitable system to the field.

The Operations and Support (O&S) phase of a system begins with its introduction to service use and ends with its retirement from use. The period of useful service can range from a few years to several decades depending on the practicability and desirability of updating the design and support structure to satisfy changing requirements or to incorporate improvements made possible by technological advances.

Typically, a system begins its introductory period of service use under the surveillance and with the augmented support of the production contractor. During this period, the production contractor is required, by reference to appropriate contract tasks, to identify and investigate inherent design and manufacturing process-related problems and to submit recommendations for their correction. Corrections or improvements are then introduced as engineering changes in follow-on production systems and may be retrofitted on those systems already deployed.

Following completion of a successful introductory period, the Government monitors the system's effectiveness and logistics support by analyzing reports from Service maintenance data collection systems and other reporting systems. Problems are identified, corrected, and monitored on a continuing basis throughout the useful life of the system.

Objectives of the O&S phase are:

- In the field, the system consistently experiences the operational features and characteristics (including R&M) it achieved in development and maintained under control throughout production.
- Operational and maintenance documentation, training programs, spare and repair parts provisioning plans, and other features of the implemented logistics support plan are adequate to support the system in the field environment.

R&M activities in the Operations and Support Phase

The R&M program activities during the O&S phase will differ from the development activities implemented during the preceding acquisition phases but should not vary appreciably from those

5. R&M IN THE OPERATIONS AND SUPPORT PHASE

production and sustainment activities implemented during the P&D phase. The activities may vary significantly between systems selected for improvement depending on the complexity of the systems and the degree of research and development effort required.

The R&M program should be tailored to the needs of the particular program to provide the program manager with the degree of control needed to assure the specified surveillance of the system (including continuous analysis of software changes), failure analysis, and improvement efforts. If the system selected for improvement is still being procured under contract, the R&M program in the contract should cover the requirements of approved material or non-material changes to the system being procured. If the R&M program of record does not cover, or is not adequate for, the selected modifications, the required R&M program should be made a part of the configuration change (i.e., Engineering Change Proposal (ECP)), or non-material change (i.e., inspection, training) process or its equivalent.

Primary R&M activities to be performed during the O&S phase are identified in Figure 5-1 and Table 5-1. The activities should reflect the continuation of the iterative design-evaluate-redesign-reevaluate doctrine practiced in previous phases.

5. R&M IN THE OPERATIONS AND SUPPORT PHASE

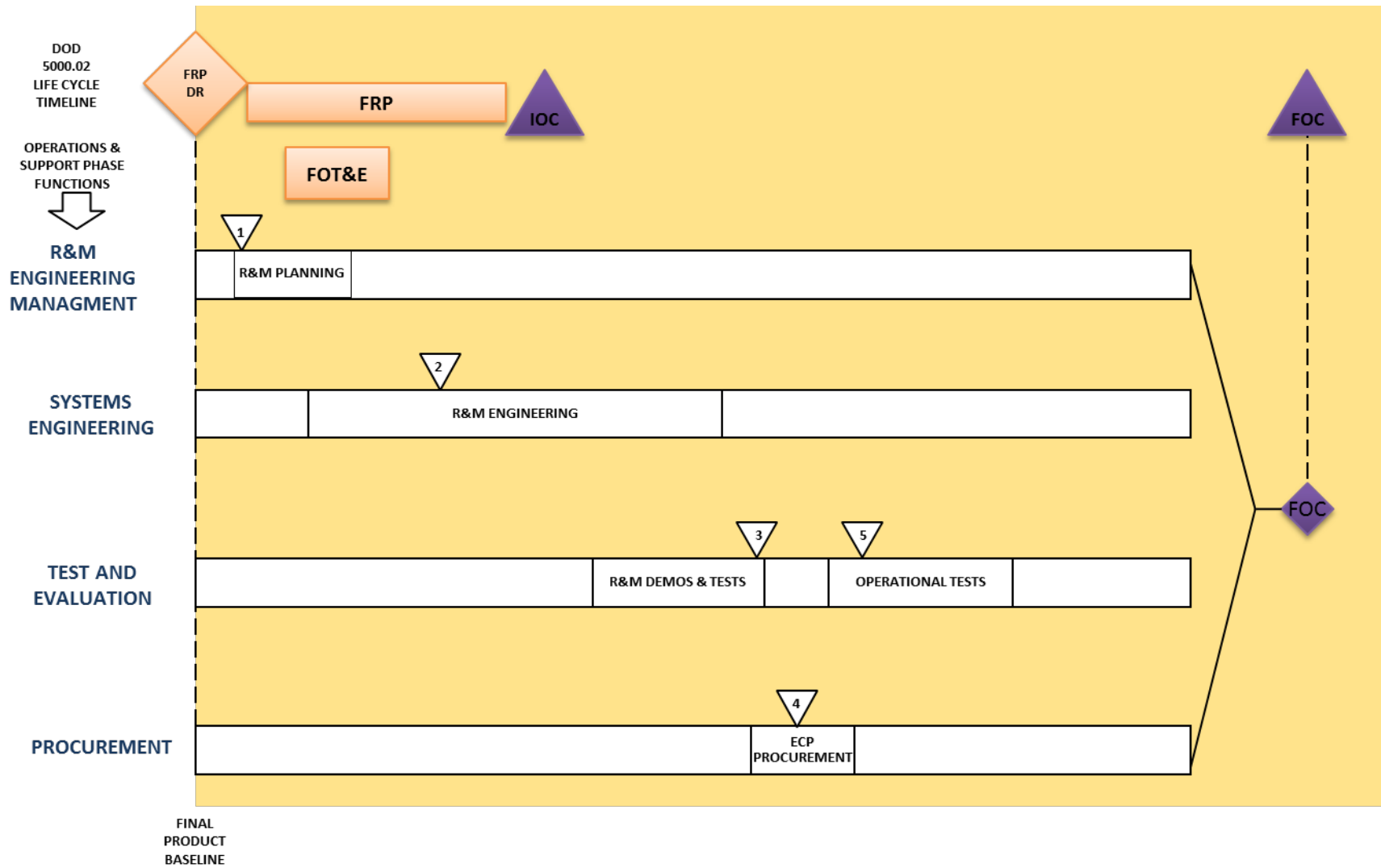


Figure 5-1. O&S Phase R&M Activities by Functional Area

Table 5-1. R&M Activities in the O&S Phase

R&M Activity	Functional Area	Paragraph	Page
1 Develop R&M planning	R&M Engineering Management	5.1.1	177
2 Perform R&M engineering	Systems Engineering	5.2.1	183
3 Conduct R&M demonstrations and tests	Test and Evaluation	5.3.1	186
4 Support ECP procurement	Procurement	5.4.1	191
5 Support Service operational tests	Test and Evaluation	5.3.2	188

5.1. R&M ENGINEERING MANAGEMENT

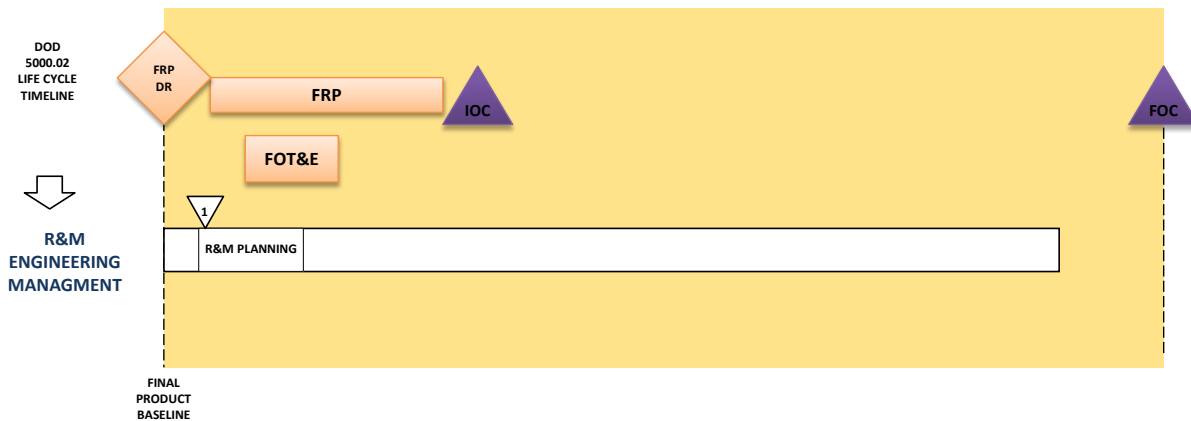



Table 5-2 lists the primary R&M activity associated with the R&M Engineering Management functional area in the O&S phase.

Table 5-2. R&M Engineering Management Activity – O&S Phase

R&M Activity	Description
 R&M Planning	Implement an R&M assessment and analysis program for the O&S phase to ensure quick response to the indicated need for R&M improvement and corrective actions.

5.1.1. Develop R&M Planning



As the system gains operational experience, the need for improvements will become apparent to the Service, to the production contractor, and to the program office. Many of these improvement needs will be traceable to design problems and manufacturing discrepancies; others will be attributable to the need for “modernization” consistent with changing operational requirements or obsolescence. In anticipation of these impending needs, the Government should provide for systematic evaluation of potential improvement requirements and introduction of changes as necessary into the system, beginning immediately upon its delivery and introduction to the field.

During the O&S phase, delivered articles should be monitored to ensure that R&M parameters are not degraded as a result of maintenance, storage, transportation, spares and repair parts, and operational usage. If operational results indicate the system is deficient in fulfilling its intended capability; that it is being used in an environment other than that for which it was originally designed, tested, and approved for service; or that R&M performance is degrading unacceptably over time, the Government should develop and administer growth and retrofit plans.

R&M PLANNING: PROCEDURE

R&M planning for the O&S phase should include the following:

- *R&M Assessment* – Assess R&M by monitoring field data through the Service maintenance data collection systems and other reporting systems. Enter the data into the continuing Failure Reporting, Analysis, and Corrective Action System (FRACAS) and provide the data to the failure review board and R&M review board processes implemented in previous life cycle phases. The assessment may include the addition of an aging and surveillance program, warranty evaluations, changes to the IT infrastructure (e.g., operating system, storage, compute, network, 3rd party applications) and other processes applicable to the sustainment of the system. Determine the degree of conformance under field-use conditions to requirements document operational thresholds, including:
 - R&M measurements under operational-use conditions. Accurate and complete data is essential to the proper measurement of field R&M, and subsequent analyses and decisions. Data reporting systems should be periodically reviewed to ensure that the correct data is being recorded and analyzed.
 - Description of problem areas that account for the disparity between observed and specified R&M.
 - Evaluation of operational need for reliability or maintainability improvement, to justify an improvement program of the required scope.
 - Periodic reassessment of R&M status to verify effectiveness of applicable improvements.
- *R&M Analyses* – Plan the following analyses based on the field data collected and results of the assessment process:
 - Engineering Analyses – To identify problems, evaluate corrective action potential and trade-off considerations, evaluate impacts of software changes and patches, assess growth potential, and establish an improvement cycle based on relative priorities, risk, cost-effectiveness (see bullet below), and feasibility. Ensure that R&M priority rankings and objectives are aligned with the overall program needs and objectives. Plan to update previous analyses (i.e., block diagrams; predictions; Failure Mode, Effects, and Criticality Analysis (FMECA), Software Failure Mode Effect Analysis) to reflect any design or process changes made or to reflect any previously unaccounted-for or undocumented failure modes that have occurred in the field.
 - Cost Analysis/Business Case Analysis – Evaluate the life cycle cost (both recurring and non-recurring costs) impact of proposed improvements, process changes, operational changes, and use of advanced inspection or data analysis techniques. Use the business case/cost analysis to support the best option(s) for improving R&M.
 - FRACAS/Failure Management Strategy – Determine the failure root cause/effects and define corrective action requirements for proposed changes.

5. R&M IN THE OPERATIONS AND SUPPORT PHASE

- Assignment of Corrective Action – Develop the necessary changes to fulfill the specified corrective action requirements. This step includes identifying/implementing corrective action(s) and verifying the failure mode was eliminated or managed as expected.
- R&M Demonstrations – Verify the effectiveness of proposed changes, as applicable, as prerequisite to the review and approval of a proposed change. When feasible, look for the opportunity to test critical or rarely occurring failure modes to ensure the support mechanisms are prepared and capable.
- Maintenance and Logistics Analysis – Evaluate the impact of proposed changes on maintenance procedures, test equipment, provisioning plans, and other product support areas.
- Help Desk and Administration Support Evaluation – Evaluate the performance and adequacy of the response to system failures and opportunities to improve via training, documentation or software changes.
- Deployment and Installation Evaluation – Evaluate software deployment methods and installation procedure for area to improve effectiveness.
- Spares and Replacement Evaluation – Evaluate the conformance of spares and replacement parts to applicable procurement specifications.
- Change Documentation – Update configuration and technical documentation consistent with approved changes.
- Change Implementation – Provide for the procurement and introduction of approved changes, both in current production and for retrofit into items already delivered and deployed.

R&M PLANNING: DATA

Assessment and analysis of R&M in fielded systems depends primarily on the collection and analysis of accurate and complete operational data. Whether improvements are to be undertaken by the program office, the current production contractor, a designated Government office, or an independent engineering contractor, the same data requirements apply and should accompany the contract. The following principal items are required for R&M assessment, analysis, and improvement.

- *R&M Assessment Reports* – Reports of current status derived from the Service maintenance data collection systems and other data sources covering the period of interest, to include:
 - System/mission reliability.
 - System maintainability.
 - Failure-rate/root cause failure mode.
 - Operational availability.

5. R&M IN THE OPERATIONS AND SUPPORT PHASE

- Description of system configuration, use conditions, environmental factors, and failure definition, under which the data was accumulated and for which the R&M analyses are valid.
- Conformance and suitability evaluation to include comparison of current measured field experience with specified operational thresholds and previous assessments, to evaluate change since the earlier assessments.
- Problem definition, to provide the basis for detailed engineering investigation and corrective action assignment, including criticality analysis for each of the dominant failure modes and relative ranking of problems in total impact on system R&M.
- Tentative estimate of R&M improvement/growth available by correcting problems.
- Maintenance and logistics analysis for each proposed solution, and the implications of non-redesign activities.
- Detailed analyses underlying the data outlined previously to include block diagrams, mathematical models, allocations, parameter definitions, and description of verification methods used to evaluate quality of data and realism of analytical results.
- Recommendations for corrective action, further investigation, and subsequent reassessment.
- Raw data tabulation from Service maintenance data collection systems and other data sources.
- R&M improvement planning: plans, procedures, and assignment of responsibility for implementing the necessary materiel or non-materiel solution, including (as applicable) engineering, fabrication, verification testing, production, change control, installation, training, documentation and assessment tasks to achieve the desired degree of improvement in the fielded system.
- *R&M Analysis* – Analysis pertinent to the investigation and solution of problems identified in the assessment reports described previously, to include the following:
 - Technical description of the problem or problems under investigation.
 - FRACAS reports detailing the failure diagnosis of parts and materials recovered from field failures, and engineering analyses identifying the specific root cause and consequence of failure.
 - Description of source of problem, e.g., production tolerance, parts quality, maintenance damage.
- *Change Documentation (i.e., ECPs)* – Technical description of corrective action alternatives, including trade-off analysis supporting selection of the specific materiel or non-materiel change, to include:
 - Detailed materiel (design) or non-materiel disclosure of the proposed change.

5. R&M IN THE OPERATIONS AND SUPPORT PHASE

- Verification of R&M improvement or impact to be attributed to the change, based on analysis and test data.
- Description of configuration documentation changes (e.g., specifications, drawings) to be made upon approval and implementation of the change.
- *Test Report* – Description of test procedures and test results applicable to problem investigation, parts evaluation, and R&M demonstration and test.
- *Logistics Analysis Reports* – Description of maintenance plan changes, logistics, and provisioning changes, to be initiated as a result of approved changes.
- *Procurement Documentation* – Production release data adequate for procurement and implementation of approved changes.

R&M PLANNING: REVIEW CRITERIA

- *Adequacy of R&M Program Planning* – The planning provides a systematic procedure for identifying, investigating, and remedying R&M problems and for R&M involvement in developing, verifying, and implementing approved changes both in the fielded systems and in current production items.
- *Accessibility of Data* – The Government has rights to access/use the data and information down to failure root cause from contractors, subcontractors, and suppliers, as appropriate to the contract.

5.2. SYSTEMS ENGINEERING

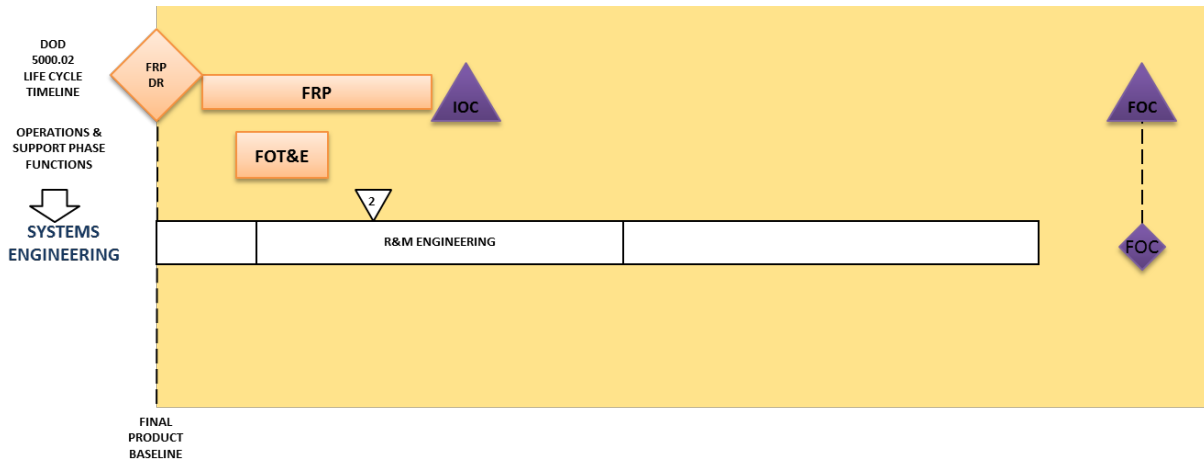



Table 5-3 lists the primary R&M activities associated with the activities for the Systems Engineering functional area in the O&S phase.

Table 5-3. R&M Systems Engineering Activities – O&S Phase

R&M Activity	Description
 Perform R&M engineering	Conduct R&M activities, including: change preparation, review, and implementation; problem investigation, evaluation, and corrective actions; R&M performance and effectiveness assessments; aging and surveillance effectiveness assessments; maintenance data analyses; FRACAS and R&M review boards.

5.2.1. Perform R&M Engineering



R&M engineering during the O&S phase is concerned with: continuing the FRACAS and R&M review board activities to assess R&M status in the field; support of contractor and Government activities engaged in the development, evaluation, and implementation of engineering changes potentially affecting R&M; and the update of previously performed R&M analyses based on these changes to reflect new system configurations.

Procedures outlined for evaluation of proposed materiel or non-materiel changes in the P&D phase are applicable in the O&S phase, with the exception that provisions should be made for the users to participate in the review of proposed changes and for service tests to verify R&M improvement achieved by the implemented changes. Users should also report the status of ongoing non-materiel system changes.

Operational support baseline specifications, drawings, and associated lists must be kept current as approved changes are implemented in the system. These documents provide the basis for the logistics support program and for future reprocurement. The program should modify the specified requirements and verification criteria in these documents before introducing change actions.

Specific R&M engineering activities in the system improvement or modernization cycle should be explicitly defined in the contract statement of work (SOW) (if applicable) that implements the improvements.

PERFORM R&M ENGINEERING: PROCEDURE

Through the FRACAS and R&M review board process implemented in previous life cycle phases, the review of R&M engineering progress and effectiveness should address the following:

- *Problem Verification* – Review assessment reports, production data, field complaints, and other data sources to verify the existence of problems or deficiencies as reported. Evaluate and validate the following analyses to provide the basis for engineering action:
 - Current observed R&M of the system and its major subsystems, and comparison to the expected/designed/allocated performance.
 - Correlation analysis between production failure experience, field data analysis, and other sources of data.
 - General description of problem areas, in terms of symptoms, failure modes, consequences, and apparent causes (e.g., design, manufacturing, human factors).
 - Relative ranking of problems according to impact on system performance, availability, and cost.
 - Estimation of improvement potential, through elimination/reduction/management of failure modes, by correction of individual problems.
- *Failed Parts Analysis* – Analyze part failures and removals in systems and major subsystems during corrective maintenance to determine the failure mode, failure cause, and underlying failure mechanism.

- *Analysis of Failed Software Components* – Analyze restarts of system, applications, and processes occurring during operations to determine failure modes, failure causes and underlying failure mechanisms.
- *Design Analysis* – Analyze high failure-rate components and major units, including software to determine the failure mode, failure cause, and underlying failure mechanism.
- *Configuration and Packaging Analysis* – Correlate system failure rate and FMECA with physical and virtual configuration, location, packaging, deployment and installation to assess R&M improvement potential by reconfiguration. In some instances, improvements can be achieved by relocating environmentally sensitive components or by repackaging if the environment is determined to be the failure-inducing factor to be controlled.
- *Design Study and Trade-off Analysis* – Analyze alternative methods identified for achieving the R&M improvement and verify improvement potential of each, using prediction analysis and verification methods. Evaluate relative life cycle costs/business case analysis, technical risks, and advantages of each possible solution and select the approach that is optimum for the detail design. Consider the following possible alternatives in each case:
 - Repackaging and physical configuration changes.
 - Alternative deployment and installation changes.
 - Alternative choice of parts with only minor design change.
 - Additional automation for failure recovery.
 - Alternative design approach with major change in detail design.
 - Updated trouble shooting procedures.
 - Additional test points and monitoring.
 - Alternative maintenance concept employing diagnostics and prognostics for early detection of impending failures to allow correction by scheduled preventive maintenance.
 - Software design changes as an alternative to hardware design changes.
- *R&M Impacts* – Verify R&M analyses (e.g., prediction, FMECA, SFMEA) related to the proposed engineering change to accompany the change proposal.
- *R&M Analyses Update* – Ensure that R&M analyses reflect the latest failure data/information from the field. An ECP may not be required, but previous R&M analyses should be updated (e.g., current failure rates in the FMECA or failures that occur whose root cause is not design-related, failure modes or mechanisms not previously documented).
- *R&M Evaluation* – Through the use of appropriate environmental tests and R&M demonstrations and tests, evaluate the change in status the system should achieve by implementing the approved changes. Verify whether test results have been applied by the designers to refine the design of the proposed change.

PERFORM R&M ENGINEERING: DATA

Monitoring coordination and control of R&M engineering activities in the O&S phase requires the following data, which should be specified in contracts issued for system improvement or modernization:

- *R&M Data* – Reports based on Service maintenance data collection and software discrepancy reports.
- *R&M Engineering Analyses* – Reports of R&M investigations and analyses.
- *Test Reports* – Reports of service tests (e.g., Follow-on Operational Test and Evaluation (FOT&E)), investigative tests, and change verification tests.

PERFORM R&M ENGINEERING: REVIEW CRITERIA

- *Adequacy of Assessments* – The assessment of R&M field data is based on accurate and complete field data.
- *Acceptability of Changes* – Proposed changes do not induce undesirable side effects in reliability, maintainability, logistics or other system performance parameters beyond the limits established by the trade-off study that substantiated the change.
- *Accessibility of Data* – The Government has rights to access/use data and information down to failure root cause from contractors, subcontractors, and suppliers, as appropriate to the contract.

5.3. TEST AND EVALUATION

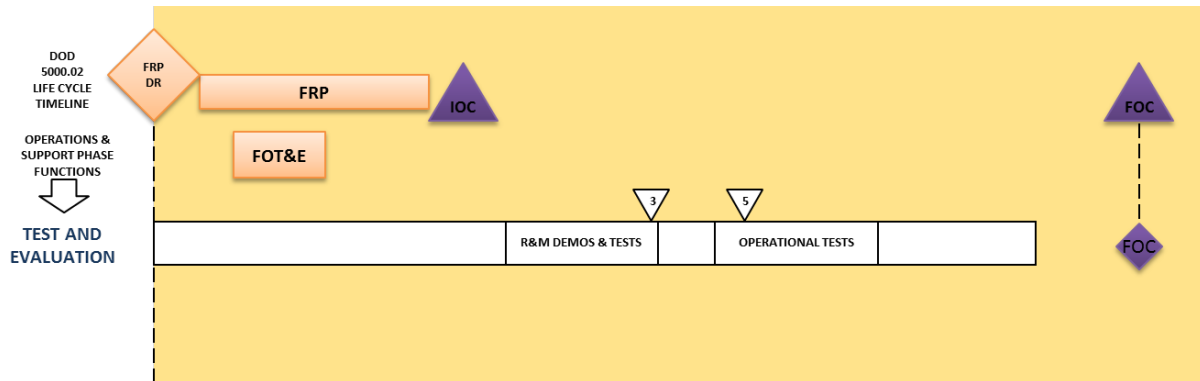




Table 5-4 lists the primary T&E R&M activities in the O&S phase.

Table 5-4. R&M T&E Activities – O&S Phase

R&M Activity	Description
 Conduct R&M demonstrations and tests	Review R&M verification plans and results as a basis for determining acceptability of changes, as defined by the program TEMP, for production and implementation in fielded systems.
 Support Service operational tests	Conduct limited operational verification of changes as a basis for approving field-wide implementation.

R&M verification plays two important roles in the O&S phase, investigation and definition of reported problems, and verification of solutions. When specified in the Test and Evaluation Master Plan (TEMP) and contract, the latter becomes the Government’s acceptance test for proposed changes and modifications. These tests are the same as the demonstrations and tests described in previous chapters, which should be referred to for additional background. In addition, major changes should be submitted to limited Service operational tests (e.g., FOT&E) to determine suitability for field-wide implementation.

5.3.1. Conduct R&M Demonstrations and Tests



R&M demonstrations and tests in the O&S phase identify precisely the nature and cause of problems, reveal failure modes and effects, indicate a direct course of corrective action or modification to overcome the problem, and demonstrate the success of the proposed solution. These demonstrations and tests should be described and specified in the TEMP.

Individual test plans should be subject to approval by the program office. The program office should review test results to evaluate and verify the interpretation of the problem for which the change is to be developed.

The program office also should review and approve demonstration plans. These demos are used to show conformance to improvement requirements specified for major changes as a condition for Government acceptance. Demonstration, testing, and redesigning individual changes before implementation in the field can save the program time as this may eliminate the need for future revisions of implemented changes. Previous R&M analyses (e.g., FMECA) should be updated based on the results of the demonstrations and tests.

Just as in the EMD and P&D phases, R&M demonstrations and tests for major changes should be witnessed and authenticated by the designated Government representative. Results of the demonstrations and tests can then be used to determine acceptability of the proposed change for production and implementation in fielded systems, subject to verification in the Service operational test (e.g., FOT&E).

R&M DEMONSTRATIONS & TESTS: PROCEDURE

Define test requirements for investigation of R&M problems, evaluation of solution requirements, and demonstration of solution effectiveness. Review results of these tests to verify the adequacy of test data and data analysis for the decisions they indicate. Initiate the necessary R&M measures including the following to ensure adequate testing of proposed changes before design approval.

- *Define Test Requirements* – Define the requirements for R&M verification in the TEMP, and contract for system improvement, production refinement, or operational system development, as applicable. The verification requirements should cover the following:
 - Basic investigative procedures to be employed for simulating the conditions and reproducing the failure experience observed in the field as reported by the Service maintenance data collection system and software problem reports.
 - Parts and materials evaluation test procedures to evaluate failure rates, failure modes, and failure causes underlying those problems that appear to be traceable to faulty parts or marginal applications of parts in the system.
 - Test procedures for evaluating and defining problems traceable to instability, erratic performance, interface variation, performance degradation, or “could-not-duplicate” failures.
 - Test procedure for evaluating system recovery from software failures.
 - Demonstration procedures to verify achievement of R&M improvement specified for major changes or groups of individual small changes.
 - Individual test report requirements to be documented.
- *Review Demonstration and Test Plans and Results* – Review individual R&M demonstration and test plans prepared by the contractor or Government activity responsible for development and production of engineering changes. Verify that R&M demonstrations and tests are conducted in conformance to approved plans and that results clearly substantiate either an accept or reject decision with respect to specified R&M requirements for the particular change under test.

R&M DEMONSTRATIONS & TESTS: DATA

Review of R&M demonstration and test plans and procedures and individual test results require the following data:

- *Test Plans* – Overall O&S R&M tests are described in the TEMP. Applicable test plans are provided.
- *Test Reports* – Individual test reports for each problem investigation and R&M demonstration and test.

R&M DEMONSTRATIONS & TESTS: REVIEW CRITERIA

- *Adequacy of Data* – Individual tests yield the quantity and validity of data called for in the test plan and have satisfied engineering and statistical criteria for data analysis.
- *Accessibility of Data* – The Government has rights to access/use data and information down to failure root cause from contractors, subcontractors, and suppliers, as appropriate to the contract.
- *Conformance to Test Plan* – Tests have been conducted in accordance with the applicable TEMP and approved test plan(s).

5.3.2. Support Service Operational Tests

5

Service tests may be conducted in the form of FOT&E, operational evaluations, design verification tests, or controlled field surveillance tests, as described in the TEMP. Field surveillance tests have the advantage of being economical and realistic because existing systems and personnel are used to conduct the test. When the proposed change is classified as a critical change of major proportions, it may be more practical to conduct a formal operational evaluation to determine suitability for field-wide implementation. In either case, some form of service operational test of changes is considered essential prior to field-wide implementation.

SERVICE TESTS: PROCEDURE

Requirements and procedures for evaluating the R&M of major changes include the following:

- *Selection of Test System* – Selection of a fielded system for use as a test system should be influenced by the system having a good record for failure reporting in the Service maintenance data collection system, and a typical mission profile and operating and maintenance conditions.
- *Outline the Test Plan* – Describe the test to be conducted in the following terms:
 - Description of change to be evaluated, including its purpose and importance to operational suitability of the system.
 - Purpose of the test and specific objectives in terms of parameter measurements and comparative analyses.
 - Engineering requirements and statistical criteria.

5. R&M IN THE OPERATIONS AND SUPPORT PHASE

- Data recording requirements with instructions for recording performance characteristics of the system, attributed to the change, observed during operational periods.
- Measurement requirements in terms of performance characteristics to be monitored and recorded, frequency of readings, malfunction symptoms, failure description, time and cycle readings at failure, and time required for repair and checkout.
- Test procedure documenting changes to routine operating and maintenance procedures currently in use on the unmodified system.
- R&M data analysis methods for specified mission profiles, modes of operation, and levels of performance.
- *Monitor the Test* – Establish direct liaison between the test personnel to monitor the progress of the service evaluation and to modify the test plan as experience dictates.
- *Analyze Test Results* – Analyze the accrued test data and assess the changes in system R&M that can be attributable to the change. Evaluate the change in relation to specified improvement objectives. Determine overall suitability of the change for field-wide implementation.

SERVICE TESTS: DATA

The following are required for the design, conduct, and analysis of service tests to evaluate the suitability of the change:

- *System R&M Assessment* – R&M assessments of the pre-change system based on Service maintenance data collection system reports, for selection of the test system and to establish the reference benchmark for measurement of change effectiveness.
- *Engineering Data* – Description of the change to be evaluated in terms of functional configuration, performance characteristics, and effect on operation, maintenance, and procedures.
- *Test Report* – Results of R&M demonstrations and tests to include analyses, failure modes and effects evaluation, failure diagnosis, and R&M measurements under demonstration and test conditions.

SERVICE TESTS: REVIEW CRITERIA

- *R&M Conformance* – With the change installed, the test system R&M performance conforms to TEMP requirements and other requirements specified for the change.
- *Accessibility of Data* – The Government has the rights to access/use data and information down to failure root cause from contractors, subcontractors and suppliers, as appropriate to the contract.

5. R&M IN THE OPERATIONS AND SUPPORT PHASE

- *Operational Suitability* – The change as installed in the test system has demonstrated its operational suitability under the conditions of operation and maintenance applicable to the system.

5.4. PROCUREMENT

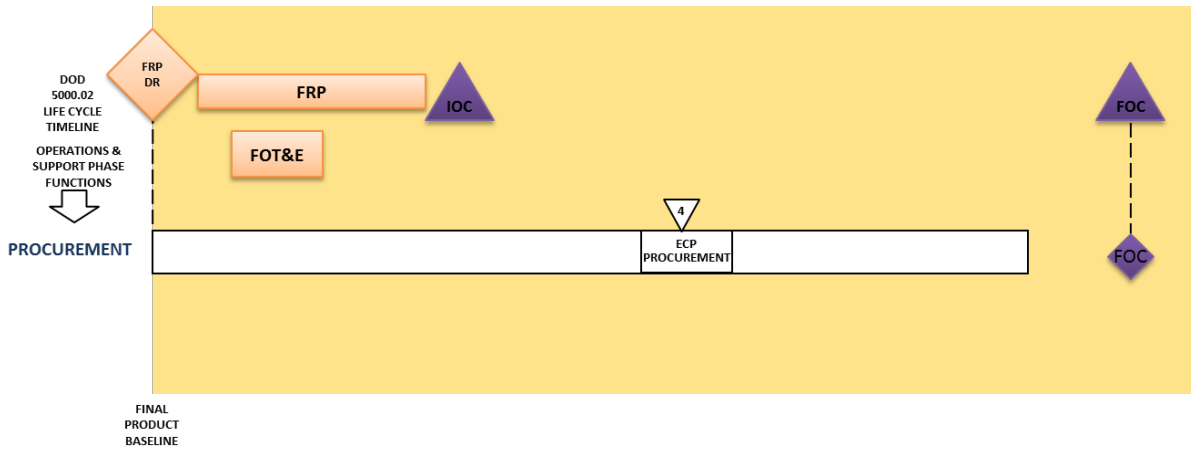



Table 5-5 lists the primary procurement R&M engineering activities in the O&S phase.

Table 5-5. R&M Procurement Activities – O&S Phase

R&M Activity	Description
 Support ECP Procurement	Develop procurement documentation for ECPs.

5.4.1. Support ECP Procurement

Whether program improvements are to be executed by participating Government activities, independent contractors, or the prime system contractor, a definitive procurement package must be prepared as the formal basis for change acquisition and implementation. R&M provisions and requirements in the change procurement package are essentially the same as those outlined in EMD and P&D phase contracts. The Government should prepare R&M requirements and provisions for change procurement documentation consistent with objectives of the improvement or modernization program.

Engineering changes required for operational improvement or “modernization” of a fielded system may involve major modifications of existing equipment and component designs or complete redesign and replacement of existing elements. Others may involve only minor design changes, parts replacement, or slight reconfiguration of existing elements. Changes at either of these extremes can have a serious impact on system R&M if provisions are not included in the contract by which the changes are to be developed and subsequently implemented in the field.

ECP PROCUREMENT: PROCEDURE

Following the procedures outlined in previous chapters, integrate the following R&M requirements in the change procurement contract.

- *Description of Problem* – Prepare technical data including current R&M assessments based on Service maintenance data collection system reports, current test and demonstration reports, and other test data that would familiarize the contractor with the nature of the problem and the scope of the R&M improvement program.
- *Specification Package* – Integrate R&M requirements and test criteria into the product baseline specification and drawings for the current configuration. These requirements should be based on and define the design trade space available based on performance, availability, and cost.
- *R&M Requirements* – Define R&M improvement requirements in quantitative terms and relate to specific problems and corrective actions for which changes are to be developed.
- *Contract SOW* – Describe the specific tasks to be performed under the contract with provisions for in-process review by the Government.
- *Test Requirements* – Outline the change demonstration and test requirements for proof of conformance to specified requirements and Government acceptance (for guidance, describe the Service tests to be conducted, if applicable).
- *Data Requirements* – Describe contractor data requirements essential for R&M monitoring and control. The Government must have rights to access/use data and information down to failure root cause from contractors, subcontractors, and suppliers, as appropriate to the contract.

ECP PROCUREMENT: DATA

Documentation of R&M requirements and provisions in change procurement requests and contracts requires the following reference data:

- *R&M Planning* – Plans that contribute the basis for R&M assessment and analysis in the O&S phase.
- *Data Requirements* – Description on the DD 1423 of data items required.
- *R&M Engineering Analyses* – Description of the problem or area for improvement, and assessment of R&M improvement to be realized through appropriate corrective action.
- *Test Planning* – Description of R&M verification plans and plans for Service T&E.

ECP PROCUREMENT: REVIEW CRITERIA

- *R&M Requirements* – Quantitative requirements are specified both for the change and for the system with the change installed.

5. R&M IN THE OPERATIONS AND SUPPORT PHASE

- *Demonstration and Test Requirements* – Demonstration and test requirements and acceptance criteria are specified and are consistent with the quantitative requirements defined above.
- *Control Provisions* – Specific activities and data requirements for change review, Service maintenance data collection system data analysis, and R&M assessments are called out in the contract.

5.5. IN-SERVICE REVIEWS

R&M ASSESSMENT

Effectiveness of R&M improvements can be determined best by periodic reassessment of operational R&M measured under service use conditions. The Government should perform or assign responsibility for performance of these periodic assessments. On the basis of these periodic assessments, the Government can evaluate growth achieved by improvement programs, non-material changes, and improved data collection, reevaluate the known remaining problem areas as yet uncorrected, and identify any new problems for investigation.

5.5.1. Procedure

Using Service maintenance data collection system data and data from depots, laboratories, and other sources of field experience, evaluate the effectiveness of the R&M improvements as described below.

- *System Assessments* – Evaluate R&M of systems relative to current configuration status, to make the following determinations:
 - Observed R&M compared with specified mission and operational mode thresholds.
 - Observed R&M compared with previous assessments and applicable growth curve(s).
 - Estimated reliability growth and maintainability improvements attributable to specific improvement changes introduced since the preceding assessment, compared with established improvement objectives.
- *Subsystem Evaluations* – Evaluate R&M at subsystem and component levels (including spares and replacement parts), to determine:
 - Failure rate and failure modes of individual elements of the system.
 - Problem areas within these elements ranked according to relative impact on system R&M.
 - Impact on O&S costs.
- *Maintainability Assessment* – Derive maintainability parameters related to each failure/failure mode identified above to provide the basis for downtime computation used in the problem ranking procedure.
- *Effectiveness of Improvement Actions* – Evaluate relative degree of improvements (or degradation) attributable to individual corrective actions as changes in the following categories, to provide the basis for decisions:
 - Manufacturing discrepancies and production control deficiencies that have allowed latent defects or incipient failures to creep undetected into the field. Responsibility for these improvement actions would have been assigned to the production contractor or Government, as appropriate.

- Design deficiencies that escaped detection in earlier demonstration and operational test, but which now appear as major threats to operational suitability of the item. Responsibility for these improvement actions would have been assigned to a design activity (not necessarily the original development or production contractor) determined best qualified in the particular area of design.
- Deficiencies due to other than design problems, e.g., changing operational requirements, inadequate maintenance instructions, faulty test equipment, poor quality spares and replacement parts, lack of adequate data infrastructure, improper training. Responsibility for improvement actions would have been assigned as above to the best qualified source.

Program review and R&M reassessments require the following data:

- *R&M Assessment Data* – Data and analysis from the evaluation outlined previously, with block diagrams, mathematical models, allocations, assumptions, analytical procedures, and raw data summary for the current assessment and preceding assessments.
- *R&M Improvement Plans* – Plans and procedures as outlined, which identify the milestones and growth objectives for each program reassessment.
- *Technical Baseline Data* – Specifications, drawings, and technical manuals pertaining to the system under surveillance, to include:
 - Baseline specifications and drawings.
 - Change (i.e., ECP) descriptions and configuration list for each system or piece of equipment indicating change implementation status.
- *Material and Engineering Review Data* – Results of problem investigation, change design and verification test, and parts and materials failure diagnosis pertaining to problems corrected or in the process of correction.

5.5.2. R&M Recommendation

Approval of R&M improvement progress at each program review point is contingent on satisfying the following criteria:

- *R&M Improvement* – Changes introduced specifically for improvement purposes have achieved the degree of overall improvement specified for the changes.
- *Degradation Control* – Changes introduced for reasons other than R&M improvement have been evaluated for their impact on R&M and must not have induced degradation in excess of that considered permissible in the trade-off decision that approved the change.

Failure to satisfy these criteria should result in a tightening of management controls over the improvement program and the changes introduced.

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ACRONYMS

Acq Strat	Acquisition Strategy
ACTD	advanced concept technology demonstration
ADM	Acquisition Decision Memorandum
AoA	Analysis of Alternatives
AS	Acquisition Strategy
ASR	Alternative System Review
ATE	automated test equipment
BIT	Built-in Test
CDD	Capability Development Document
CDR	Critical Design Review
CDRL	Contract Data Requirements List
CFE	contractor-furnished equipment
COTS	commercial off-the-shelf
CPD	Capability Production Document
CTP	critical technical parameter
DAES	Defense Acquisition Executive Summary
DAG	Defense Acquisition Guidebook
DASD(SE)	Deputy Assistant Secretary of Defense for Systems Engineering
DID	Data Item Description
DMU	Digital Mockup
DoD	Department of Defense
DoDI	DoD Instruction
DRMP	Design Reference Mission Profile
DT&E	developmental test and evaluation
ECP	Engineering Change Proposal
EMD	Engineering and Manufacturing Development (phase)
FDSC	Failure Definition and Scoring Criteria
FMECA	Failure Mode, Effects, and Criticality Analysis
FOT&E	Follow-on Operational Test and Evaluation
FRACAS	Failure Reporting and Corrective Action System
FRP	Full-Rate Production
GFE	government-furnished equipment

ACRONYMS

HALT	Highly Accelerated Life Test
ICD	Initial Capabilities Document
IMP	Integrated Master Plan
IMS	Integrated Master Schedule
IOT&E	Initial Operational Test and Evaluation
IPT	Integrated Product Team
JCIDS	Joint Capabilities Integration and Development System
KPP	key performance parameter
LRIP	Low-Rate Initial Production
MDAP	Major Defense Acquisition Program
MDD	Materiel Development Decision
MSA	Materiel Solution Analysis (phase)
MTTR	mean time to repair
O&S	Operations and Support (phase)
OTA	Operational Test Agency
OTRR	Operational Test Readiness Review
P&D	Production and Deployment (phase)
PDR	Preliminary Design Review
PM	program manager
PR	Procurement Request
R&M	reliability and maintainability
RAM-C	Reliability, Availability, Maintainability, and Cost
RDGT	Reliability Development Growth Test
RDP	Release Decision Point
RFI	request for information
RFP	request for proposal
RGC	reliability growth curve
SEP	Systems Engineering Plan
SFR	System Functional Review
SOW	statement of work
SRR	System Readiness Review
SRR	System Requirements Review
T&E	test and evaluation

ACRONYMS

TEMP	Test and Evaluation Master Plan
TMRR	Technology Maturation and Risk Reduction (phase)
TPM	Technical Performance Measure
TRR	Test Readiness Review
USD(AT&L)	Under Secretary of Defense for Acquisition, Technology, and Logistics
WBS	Work Breakdown Structure

**Department of Defense Reliability and Maintainability Engineering Management
Body of Knowledge**

Deputy Assistant Secretary of Defense
Systems Engineering
3030 Defense Pentagon
3C167
Washington, DC 20301-3030
www.acq.osd.mil/se