Reliability and Maintainability (R&M) Engineering Management Body of Knowledge

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Office of Systems Engineering and Architecture

Office of the Under Secretary of War
for Research and Engineering

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1 Introduction

1.1 Purpose and Scope

The purpose of reliability and maintainability (R&M) engineering 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, resulting in increased acquisition efficiency, higher success rates during the development process, successful operational testing, and improved operational readiness.

This document presents procedures for Department of War (DoW) program managers (PMs), project engineers, and R&M engineers to use to achieve and control R&M requirements for any DoW weapon system. Although the format follows the comprehensive Major Capability Acquisition (MCA) pathway, the tasks and activities could apply to any pathway. See Figures 1-1 and 1-4 to align efforts with the applicable MCA phase. These recommendations are derived from the DoD Instruction (DoDI) 5000.88, "Engineering of Defense Systems." Addenda to this document present recommendations for achieving R&M requirements for programs following other acquisition pathways defined in DoDI 5000.02, "Operation of the Adaptive Acquisition Framework [AAF]." DoDI 5000.02 and DoDI 5000.88 together form the basis for DoW acquisition policy and guidance. This document and its addenda identify the procedures necessary to achieve R&M requirements for all DoW acquisitions.

These procedures, when properly implemented, influence the design early, allowing 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. While it is imperative to rapidly field new advanced capabilities, R&M activities such as a Failure Modes and Effects Analysis will help improve readiness and minimize or eliminate failures.

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. R&M activities, which may include the use of digital twins, 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.

1.2 POLICY AND GUIDANCE

The R&M policy for DoW materiel is established in DoDI 5000.88. This instruction requires a comprehensive R&M engineering program for all defense systems, incorporating essential engineering management activities to guide their development. This responsibility requires PMs to implement a life cycle R&M engineering program as an integral part of the overall engineering process and the digital representation of the system being developed.

Given the extent to which software contributes to modern weapon systems, software reliability is critical. DoDI 5000.87, "Software Acquisition Pathway," requires PMs to include a strategy to assess software reliability, performance, suitability, interoperability, survivability, operational resilience, and operational effectiveness.

The Institute of Electrical and Electronics Engineers (IEEE) maintains a standard on Software Reliability (IEEE-1633) that proves beneficial to the practitioners. Software development testing, Government developmental testing, and operational testing will be integrated, streamlined, and automated to the maximum extent possible to accelerate delivery timelines based on risk strategies. Automated test scripts and test results will be made available to the test community so that critical verification functions (e.g., performance, reliability), and validation functions (e.g., effectiveness, suitability and survivability) can be assessed iteratively and incrementally.

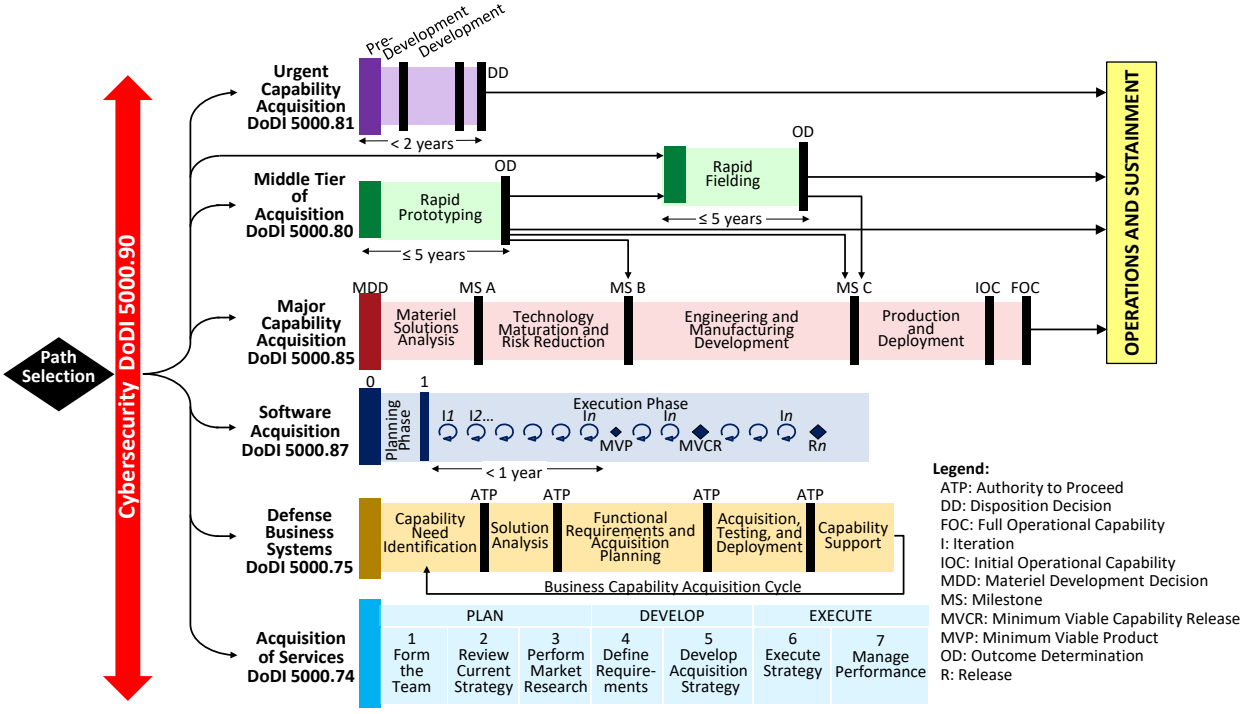
The following guidelines address key considerations for software reliability in DoW systems, including redundancy, failure analysis, and fault detection:

- **Software Reliability: Beyond Simple Redundancy.** Software reliability is not solely about replicating code. True software redundancy, used in critical systems, requires independent development by multiple contractors to mitigate common design flaws. However, this is very expensive and may not be as effective as rigorously testing and validating a single, well-designed codebase. Since software failures often stem from specification and design errors, redundant code can easily share the same vulnerabilities.
- **Software Failure Modes and Effects Analysis (FMEA)/Failure Modes, Effects, and Criticality Analysis (FMECA).** Avoid specifying "Software FMECA" in contracts. Applying hardware-centric FMECA principles to software is often unproductive and leads to arbitrary probability assignments. Instead, emphasize comprehensive specifications, fault-tolerant designs, and thorough testing. These proactive measures significantly reduce the risk of software failures far more effectively than attempting to quantify them in a FMECA. In short, FMECA is not an applicable tool for software assessment.
- **Detecting Hardware Faults: A Critical Software Responsibility.** A frequently overlooked failure mode is the software's failure to detect and respond to hardware, sensor, and communication failures. To address this, system specifications must explicitly require the

software to handle all critical failures of these elements appropriately. This ensures the software is designed to mitigate cascading failures and maintain system availability.

- **Effective Software FMEA: Focused and Timely.** Conducting a software FMEA on 100% of the functions is impractical. Focus the FMEA on critical areas where design changes are feasible and beneficial. The goal is to influence the software design early in the development process, preventing the FMEA from becoming a post-coding exercise of little value. Use of a Common Development Environment (CDE) can aid in identifying failures spanning the system. In short, a narrowly focused FMEA in the design phase has greater impacts than a system-wide FMEA conducted post design.

The AAF (Figure 1-1) of DoDI 5000.02 supports DoD Directive (DoDD) 5000.01, "Defense Acquisition System (DAS)," with the objective of delivering effective, suitable, survivable, sustainable, and affordable solutions to the end user in a timely manner. To achieve those objectives, Milestone Decision Authorities (MDAs), other Decision Authorities (DAs), and PMs have broad authority to plan and manage their programs consistent with sound business practice. The AAF acquisition pathways provide opportunities for MDAs/DAs and PMs to develop acquisition strategies and employ acquisition processes that match the characteristics of the capability being acquired.



Source: DoDI 5000.02

Figure 1-1. DoW Adaptive Acquisition Framework

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 life

cycle 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 the DoW, will ensure timely performance of the activities necessary to achieve the requirements and the acquisition of adequate data to judge the acceptability of R&M achievement at major milestones. The outcome delivers as rapidly as feasible, reliable, maintainable**,** and safe advanced capability to the warfighter.

1.3 R&M Principles

1.3.1 R&M Parameters

In this guidance, *reliability* and *maintainability* are defined as follows:

- **Reliability:** The probability that a product, system, or service will perform its intended function(s) under stated conditions without failure for a specified period of time.
- **Maintainability:** The probability that an item can be retained in, or restored to, a specified condition when maintenance is performed by personnel having specified skill levels, using prescribed procedures and resources, at each prescribed level of maintenance and repair.

R&M parameters are important characteristics used in measuring the operational suitability and effectiveness of DoW 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. If failures do occur, they fail in a safe mode of operation and are restored to full operation as quickly as possible.

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. The RAM-C Report Outline Guidance describes this relationship and the associated trade-off process.

1.3.2 R&M and Relationship to Other Disciplines

Several technical concepts are closely related to and support, or are supported by, R&M. One is Product Support, one of the functional areas covered in this document. Dependability is another concept needed to achieve R&M and meet readiness requirements. (R&M MIL-HDBK-338B)

Dependability is the collective term describing the continued and safe operation of any simple or complex item. R&M (including testability and Built in Tests (BIT)) are key factors in influencing dependability. BITs can be of value to maintainability in Systems Engineering because they embed diagnostic and fault-detection capabilities directly into the system's hardware and software. Well-designed BIT can reduce downtime and maintenance costs and improve operational readiness.

Other factors influencing the dependability performance of any item are availability, maintenance, and safety. Dependability has a direct impact on mission success, sustainability and life cycle cost. For most items, reliability and maintainability are the key performance characteristics of interest as they have a direct impact on mission success and life cycle cost. The logistic and maintenance strategy of the item are mainly external. However, they can have significant impact on its availability performance, as it reflects the ability to provide the necessary resources to implement optimized maintenance procedures developed and refined throughout the life cycle of the item.

The levels of R&M and availability and hence dependability that are achieved by an item are very dependent on the conditions under which that item is used (i.e., Mission or Usage or Life Profile). Therefore, when specifying requirements for R&M or any of the dependability characteristics, it is necessary to define the:

- Conditions of:
  - Storage
  - Transportation
  - Installation
- Anticipated maintenance policy

- The geographic areas in which that maintenance will be undertaken
- The skill levels of the persons performing maintenance.

The human impact also needs to be considered, and items should be designed to minimize the chances of human errors impacting on R&M and hence dependability performance. Maintenance-induced failures are just one example of how human error can affect the reliability of an item, increase maintenance requirements, and reduce dependability.

DoDI 5000.88 emphasizes integrating R&M engineering into the design and development of defense systems from the outset, and throughout their life cycle. Per MIL-HDBK-338B, R&M are important contributions to system effectiveness since they are significant factors in consideration of the availability and dependability parameters. Therefore, it follows that the purpose of R&M engineering is to influence system design with the goal of increasing mission capability and availability, and hence dependability, while decreasing logistics burden and cost over a system's life cycle. This Body of Knowledge presents comprehensive guidance on R&M activities and supporting information. It can assist the DoW community in understanding how R&M engineering is properly planned and used throughout the DoW acquisition life cycle to reduce cost and schedule risks by preventing or identifying R&M deficiencies early in development.

The specialty engineering disciplines are also closely related to and support, or in turn are supported by, R&M, Along with R&M Engineering, specialty engineering capabilities such as human systems integration (HSI) (DoDI 5000.95), manufacturing and quality (M&Q) engineering, and system safety engineering (SSE) are considered and applied throughout the life cycle of DoW systems. DoW engineers apply knowledge from the specialty engineering disciplines at concept definition, early in design, and continuing through sustainment, to balance total system cost, schedule, and performance. In addition, value engineering achieves essential functions at the lowest life cycle cost consistent with required performance, quality, reliability, and safety specialty engineering Policy, guidance, and technical references are available at the SE&A Specialty Engineering web page. The disciplines are summarized as follows:

- **System Safety.** System Safety is an important element of acquisition programs that provides a standard, generic method for the identifying, classifying, and mitigating hazards. Several DoDIs and a Military Standard establish policy and procedures for system safety:
  - (MIL-STD) DoDI 5000.88, Section 3.6.e., requires the program to use the Systems Engineering Plan (SEP) to document a strategy for the System Safety Engineering program in accordance with MIL-STD-882.
  - MIL-STD-882 reinforces integration of other functional disciplines into systems engineering to improve the consistency of hazard management practices across programs.

- DoDD 5000.01 requires the establishment of a safety and risk management program to ensure program cost, schedule, and performance objectives are achieved, and to communicate the process for managing program uncertainty and safety risks that must be eliminated, controlled, or can be accepted.

Reliability is concerned with all system failures. System safety focuses on a subset of system failures, those related to the purpose of system safety: "protecting personnel from accidental death, injury, or occupational illness; mitigating risk of civilian harm; and safeguarding defense systems, infrastructure, and property from accidental destruction, or damage while executing its mission requirements of national defense.0F1" Many of the system safety analyses are related to R&M analyses. For example, the Environmental Hazard Analysis (EHA), System-of-Systems (SoS) Hazard Analysis, and Functional Hazard Analysis (FHA), all conducted as part of System Safety, can provide data to the FMEA and Fault Tree Analysis (FTA) conducted as part of reliability engineering and the Maintenance Task Analysis (MTA) conducted as part of maintainability engineering. In turn, the R&M analyses can provide data to the System Safety Analyses. The FMECA uses a bottom-up inductive analytical technique that facilitates identification of potential problems in the design or process by examining detail-level fault propagation. Product reliability defects present a risk to product safety margin when failure results in loss of redundancy or higher than expected failure rates.

- **Quality.** Quality within the DoW is address in two important areas:
  - Quality Assurance (QA): a broad and organizational-wide system for managing and improving quality. QA focuses on the entire quality system including suppliers and ultimate consumers of the product or service and includes all activities designed to produce products and services of appropriate quality. QA planning begins well before production or before a project is even started
  - Quality Control (QC): a subset of QA and refers to the activities used during production that are designed to verify that the product meets the customer's requirement. QC focuses on the process of producing the product with the intent of eliminating problems that might result in defects. QC begins as the product is being produced.
  - Quality has sometimes been defined as a product's performance at a point in time (e.g., at final inspection), whereas reliability is the product's performance over time. Certainly, the quality of a product, the assurance that production does not degrade the designed-in levels of performance, is critical to a product meeting the user's reliability requirement during operational service. Quality is also addressed in this document as part of the R&M Engineering Management functional area for the P&D phase. Manufacturing issues that escape the quality process manifest themselves as failures in the field.

[1] MIL-STD-882, Foreword, paragraph 3.

- **Human Factors Engineering.** Human factors engineering includes a wide range of major design considerations that include:
  - Ergonomics. the science of designing products, equipment, and workspaces to fit the physical and cognitive capabilities of users, aiming to enhance efficiency, safety, and well-being.
  - Anthropometrics. the study of human body measurements, specifically focusing on size, proportions, and composition. These measurements are used to understand human variation, assess health, and optimize the design of products, equipment, and environments.
  - Psychology. the scientific study of the mind and behavior, that investigates how individuals perceive, process information, and behave, as well as the factors that influence these processes. It helps designers understand user behavior, needs, and motivations, which in turn allows them to create more user-friendly and effective products
  - The Effects of Physical Environments on Humans. The physical environment significantly impacts operator performance and well-being. Factors like lighting, temperature, noise, and ventilation can influence productivity, stress levels, and overall health.
  - Human Information Processing. The study of the human as a sensor and the allocation of tasks between humans and other parts of systems (computers).

  These areas are closely related to and are a consideration in designing displays and controls and maintenance procedures and equipment. Displays and controls that reduce the probability of an operator error increases mission reliability. Equipment and procedures that are consistent with human anatomical, information processing and sensory capabilities minimize maintenance errors and reduce maintenance times. Understanding the environment in which a system must be operated and maintained, and the effect of this environment on human performance, helps to design a system that is reliable, maintainable, and supportable.
- **Value Engineering (VE).** VE is an organized, systematic technique that analyzes the functions of systems, equipment, facilities, services, and supplies to ensure they achieve their essential functions at the lowest life cycle cost (LCC) consistent with required performance, reliability, quality, and safety. DoDI 4245.14, Diminishing Manufacturing Sources and Material Shortages Management," implements Section 1711 of Title 41, United States Code (41 USC 1711), and Office of Management and Budget (OMB) Circular No. A-131 by establishing policy, assigning responsibilities, and defining authorities for the effective administration of the DoW VE Program.

Questions to address in a VE assessment include:

- Can some other architecture perform the same function more effectively or at less cost with equal effectiveness?
- Is there a more effective hardware/software mix?
- Are user requirements too restrictive/excessive?
- Can a commercial product or a custom product or modifications to existing products provide better value?
- Are any test procedures, operations, or steps unnecessary?
- Are there alternatives (products, requirements, procedures, or methods)?
- Is there a more efficient way to accomplish a function or process?
- What's the most efficient pace for developing and fielding new capability?
- Are there opportunities to add value associated with hardware development of procurement?

A contractor VE program will assist the Government in value assessments and can be voluntary or required by contract. However, requiring organization should validate and assess the feasibility of requiring contractors to have a VE program.

The following language may be included in a contract to establish A Value Management Program that defines VE actions:

The contractor shall establish and maintain a Value Management Program in order to apply Value Engineering/Value Analysis techniques to continuously review and analyze systems, projects, equipment, facilities, services, and supplies for the purpose of achieving the essential functions at the lowest life cycle cost consistent with required levels of performance, reliability, quality, or safety. Value improvement solutions shall be considered for formal submission of Value Engineering Change Proposals (VECPs) to reduce Government contract costs. The contractor may use SD-24 and FAR 52.248 as additional guidance for value management and VECPs.

FAR Part 48 prescribes policies and procedures for using and administering value engineering techniques in contracts. FAR Part 52.248-1 encourages contractors to propose changes in the form of VECPs that can reduce the life cycle costs of projects while maintaining performance and quality standards.

Regarding FAR VE guidance:

- *Contract Thresholds:* The requirement to include the 52.248-1 in contracts is based on the simplified acquisition threshold. FAR 52.248-1 may also be included in contracts of lesser value. Refence FAR 48.2 for exceptions to clause inclusion.

- *Contract Types:* The VE clause may be used in contract types such as incentive, fixed price, and cost reimbursement.
- *VE Approach:* The contracting officer includes either Alternate I, Alternate II, or a combination of I and II to inform the contractor of Government agency expectations. Alternate I is the incentive clause and Alternate II is the requirements clause. Alternate II requires a program that may or may result in viable VECPs.
- *VECP Requirement:* The VECP must generate net acquisitions savings and must change the instant contract to implement. Reference 52.248-1 (b) (2) for restrictions to the type of change.

1.3.3 R&M Activities by Functional Area

Programs that did not implement an R&M program often found during Initial Operational Test and Evaluation (IOT&E) that their weapon systems did 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,[2] 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.

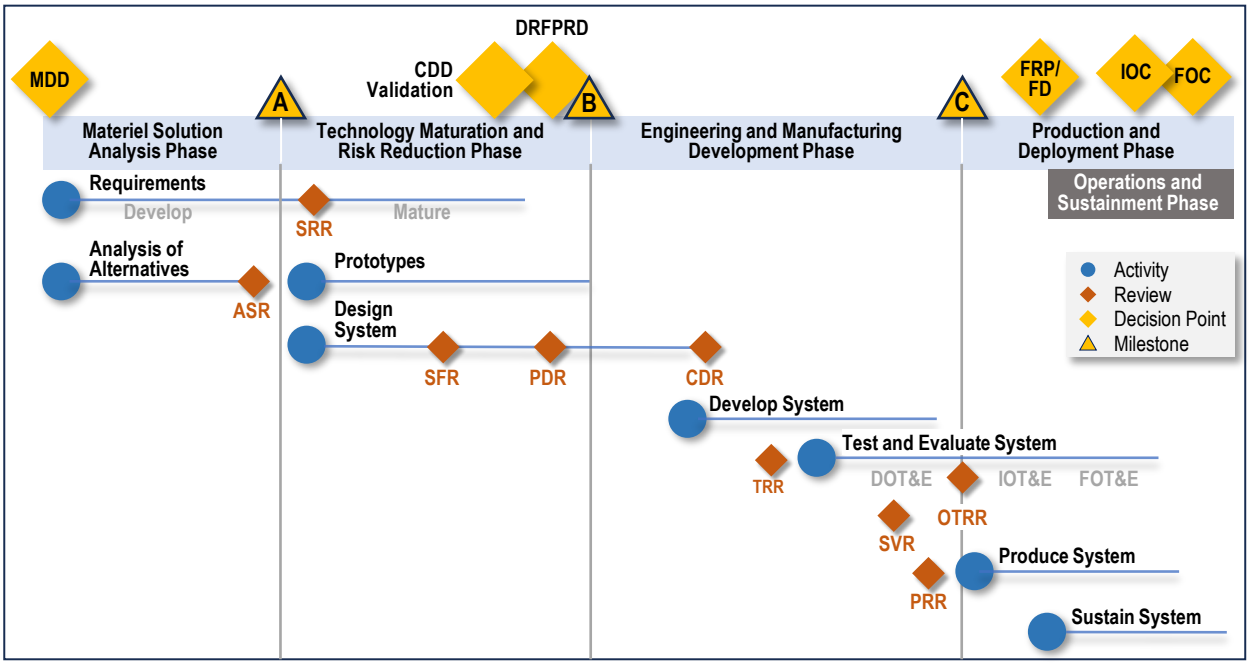
[2] See the Systems Engineering Guidebook, February 2022 for details on technical reviews.

- **Product Support:** pertaining to the functions required to field and maintain the readiness and operational capability of all systems, subsystems, and components, including all functions related to system readiness.

1.4 How To Use The Body of Knowledge

1.4.1 Determine the Life Cycle Phase

Determine the acquisition life cycle phase (Figure 1-2) to which the design of each item or equipment has progressed, keeping in mind that activities in previous phases may still be relevant or required in order to proceed.



Source: https://aaf.dau.edu/aaf/mca/.

ASR: Alternative Systems Review; CDD: Capability Development Document; CDR: Critical Design Review; DOT&E: Director, Operational Test and Evaluation; DRFPRD: Development Request for Proposal Release Decision; FOC: Full operational Capability; FOT&E: Follow-On Test and Evaluation; FRP/FD – Full-Rate Production/Field Deployment; IOC: Initial Operational Capability; IOT&E: Initial Operational Test and Evaluation; LRIP: Low-Rate Initial Production; OTRR: Operational Test Readiness Review; PDR: Preliminary Design Review; PRR: Production Readiness Review; SFR: System Functional Review; SRR: System Requirements Review; SVR: System Verification Review; TRR: Test Readiness Review

Figure 1-2. Major Phases of Defense Acquisition Life Cycle for the MCA Pathway

1.4.2 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 (SE)
- Test and Evaluation (T&E)
- Procurement
- Product Support (PS)

Table 1-1 details the Reliability and Maintainability (R&M) functional areas, their corresponding engineering activities (based on R&M requirements outlined in DoDI 5000.88), and the life cycle phase(s) in which those activities should occur. Table 1-1 outlines high-level phase activities; however, programs often have unique requirements (e.g., specific FMECA update schedules, continued testing during P&D and O&S phases), so practitioners must understand their program's needs.

Table 1-1. 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	Estimate R&M to determine 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 BIT 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	●	●	●	●	

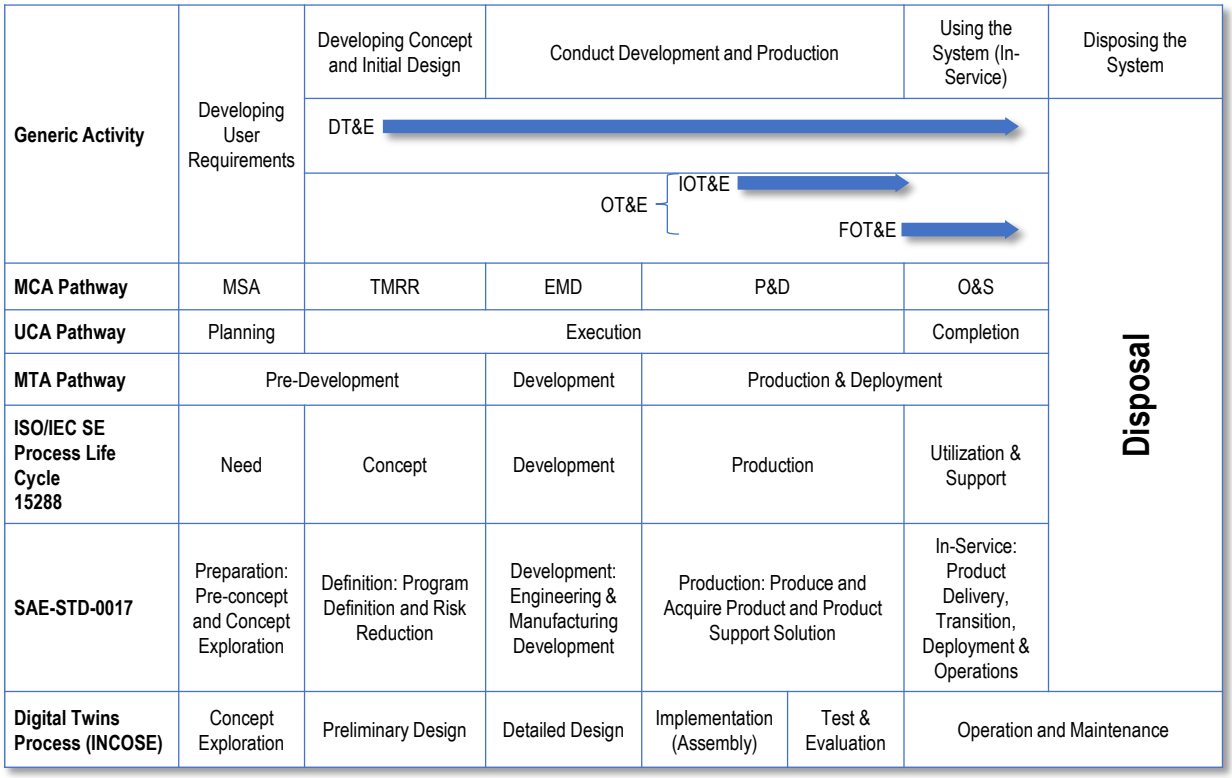
Functional Area	R&M Engineering Activities	MSA	TMRR	EMD	P&D	O&S
Procurement	Describe in the Acquisition Strategy the activities, processes and R&M requirements to be stated in the RFP. Describe how R&M values in the CDD. have been translated into design and contract requirements	•	•	•	•	
Procurement	Translate CDD R&M values into design and contract requirements	•	•	•		
Product Support (PS)	Apply R&M engineering activities to provide data and insights crucial for PS teams to effectively assist users. R&M information such as common failure modes, maintenance procedures, and spare parts availability is essential for PS.	•	•	•	•	•

CDD: Capability Development Document; CDR: Critical Design Review; DAES: Defense Acquisition Executive Summary; FMEA: Failure Mode and Effects Analysis; 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 Proposal; SEP: Systems Engineering Plan; SRR: System Requirements Review; TEMP: Test and Evaluation Master Plan

1.4.3 The BoK and the AAF Pathways

As originally developed, the BoK focuses on the MCA pathway and the life cycle phases of the pathway. To provide sample contractual language for the MCA, Urgent Capability Acquisition (UCA), Middle Tier Acquisition (MTA), and Software acquisition pathways, addenda to the BoK have been developed. The phases for these pathways, and in commercial standardization organizations and technical references, are defined differently. Figure 1-3 helps put the definitions of the MCA, UCA, and MTA pathways and other phase definitions in context.[3]

[3] The phases of the Software Acquisition pathway are unique and not shown in the figure. See DoDI 5000.87, "Software Acquisition Pathway," for details on the phases of the pathway.



EMD: Engineering and Manufacturing Development; INCOSE: International Council on Systems Engineering; IEC: International Electrotechnical Commission; ISO: International Organization for Standardization; MSA: Materiel Solution Analysis; O&S: Operations and Support; P&D: Production and Deployment; SAE: Society of Automotive Engineers; SE: Systems Engineering; TMRR: Technology Maturity and Risk Reduction

Figure 1-3. Phases of Acquisition as Defined by Different Sources

The addenda to the BoK, published by the Office of Systems Engineering and Architecture are:

- R&M Engineering Tailoring Guidance and Sample Contract Language for the Major Capability Acquisition (MCA) Pathway
- R&M Engineering Contract Language for the Middle Tier of Acquisition (MTA) Pathway
- R&M Engineering Contract Language for the Urgent Capability Acquisition (UCA) Pathway
- R&M Engineering Guidance for the Software Acquisition Pathway

Given that this BoK provides the timing and planning of R&M Engineering and Product Support activities throughout the life cycle of an MCA program, Figure 1-3 may also be used as a guide to determine the timing of activities for non-MCA programs. For example, for an MTA program in pre-development, review the activities planned for the MSA and TMRR phases. Then refer to the MTA addendum for guidance on placing the activities on contract.

1.5 Digital Engineering

Digital engineering (DE) (DoDI 5000.97) is an integrated digital approach using authoritative sources of system data and models as a continuum throughout the development and life of a

system. Digital engineering updates traditional systems engineering practices to take advantage of computational technology, modeling, analytics, and data sciences.

Through increased computing speed, storage capacity, and processing capabilities, DE has empowered a shift from the traditional design-build-test methodology to a model-analyze-build methodology. This approach can enable DoW programs to prototype, experiment, and test decisions and solutions in a virtual environment before they are delivered to the warfighter.

R&M engineers and practitioners tasked with integrating DE practices within their programs should create and contribute to these requirements:

- R&M considerations shall be a foundational elements of the program's Digital Engineering (DE) implementation. R&M has a role in defining the DE environment, processes, and tools to ensure they adequately support R&M analyses, design decisions, and verification activities.
- The system modeling language models and data developed for this program must comprehensively capture R&M requirements.
- Functional dependencies modeled in system modeling language must accurately reflect the system's architecture as represented in Reliability Block Diagrams (RBDs) and other reliability analysis tools.
- All data used in reliability analysis, including mathematical formulas, statistical distributions, failure rates, repair times, and operational profiles, must be accurate, validated, and properly documented within the DE environment.
- All personnel must have the necessary skills and knowledge to effectively use the DE environment for R&M activities.
- Data validation and certification are explicitly required, placing a higher burden on ensuring the accuracy of the information used in the DE environment.

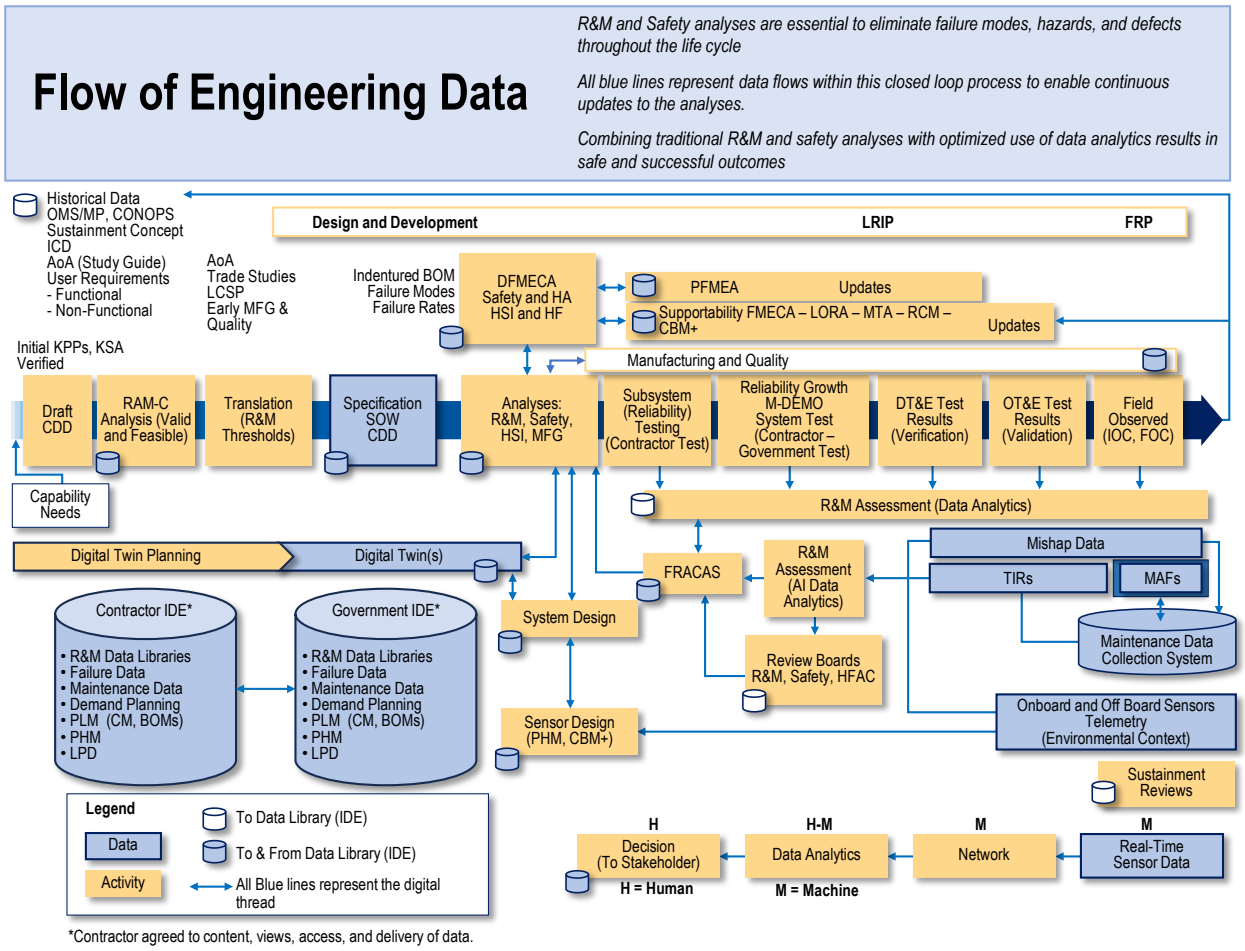
Digital methodologies include the following:

- Technological innovations in DE and digital product support
- ASOT, e.g., digital thread
- Formalized use of modeling, e.g., digital twin
- Use of a digital infrastructure (Product Lifecycle Management (PLM) or equivalent system)

The DoW R&M community has recognized the importance of integrating DE into R&M practices. To ensure modernized warfighting capabilities are reliable, maintainable, and supportable, engineering data in a DE data-centric environment must flow in approximate chronological order (Figure 1-4).

1.5.1 Digital Engineering Terms

- *Digital Engineering Ecosystem:* The interconnected infrastructure, environment, and methodology (process, methods, and tools) used to store, access, analyze, and visualize evolving systems' data and models to address the needs of the stakeholders. End-to-end digital enterprise.
- *Digital Artifact:* An artifact produced within, or generated from, the digital engineering ecosystem. These artifacts provide data for alternative views to visualize, communicate, and deliver data, information, and knowledge to stakeholders.
- *Digital System Model:* A digital representation of a defense system, generated by all stakeholders, that integrates the authoritative technical data and associated artifacts, which defines all aspects of the system for the specific activities throughout the system life cycle.
- *Authoritative Source of Truth (ASOT):* An entity such as a person, governing body, or system that applies expert judgment and rules to proclaim a digital artifact is valid and originates from a legitimate source.
- *Digital Thread:* An extensible, configurable and component enterprise-level analytical framework that seamlessly expedites the controlled interplay of authoritative technical data, software, information, and knowledge in the enterprise data-information-knowledge systems, based on the Digital System Model template, to inform decision makers throughout a system's life cycle by providing the capability to access, integrate and transform disparate data into actionable information.
- *Digital Twin:* An integrated multi-physics, multiscale, probabilistic simulation of an as-built system, enabled by Digital Thread, using the best available models, sensor information, and input data to mirror and predict activities/performance over the life of its corresponding physical twin. See the left side of Figure 1-4: The contractor and Government integrated date environment (IDE) for the key inputs and outputs to the digital twin.



Source: Adapted from DAU Course ENG 900, Lesson 5.1

Figure 1-4. Flow of Engineering and Support Data within a Digital Environment

1.5.2 Practical Considerations in Implementing Digital Engineering

Practical considerations in implementing DE include:

- Programs should consider leveraging existing capabilities within the DoW and industry. Start-up and maintenance costs for digital tools and processes can be high.
- Planning is important for integration of tools and sharing of data among engineering, production, sustainment, and program management. Legacy tools and obsolete data formats often hinder integration efforts.
- When acquiring, developing, and implementing digital technologies, it is imperative that all stakeholders have trust in the systems. Without trust, these technologies will not be employed effectively and there will be no support for their continued use and adoption.
- Data for DoW will be VAULTIS so that consumers can:
  - Locate the needed data (**V**isible)

- Retrieve the data (data is **A**ccessible)
- Find data descriptions to recognize the content, context, and applicability (**U**nderstandable)
- Exploit complementary data elements through innate relationships (**L**inked)
- Be confident in all aspects of data for decision-making (**T**rustworthy)
- Have a common representation and comprehension of data with producers (**I**nteroperable)
- Know that data is protected from unauthorized use and manipulation (**S**ecure)

1.6 Artificial Intelligence

The DoW is developing AI capabilities, computer systems that can do tasks that normally require human intellect. By leveraging generative AI models, which can use vast datasets to train algorithms and generate products efficiently, the Department aims to enhance warfighting, engineering, and other areas. AI has the potential to facilitate R&M engineering in many ways, including predictive maintenance, more accurate R&M estimates, analysis of accelerated reliability test results, and so forth. By providing better R&M estimates, more accurate estimates of spares and other support elements can be made.

Note: It is critical to validate AI algorithms to ensure accuracy; unvalidated algorithms can produce misleading results.

1.6.1 AI and Machine Learning

While artificial intelligence encompasses the idea of a machine that can mimic human intelligence, machine learning (ML) does not. ML aims to teach a machine how to perform a specific task and provide accurate results by identifying patterns. ML is a subset of the broader category of AI.

Put in context, artificial intelligence refers to the general ability of computers to emulate human thought and perform tasks in real-world environments, while ML refers to the technologies and algorithms that enable systems to identify patterns, make decisions, and improve themselves through experience and data.

Computer programmers and software developers enable computers to analyze data and solve problems, essentially creating AI systems, by applying tools such as:

- Machine learning

- Deep learning (a method in AI that teaches computers to process data in a way that is inspired by the human brain)
- Neural networks (a type of ML process, called deep learning, that uses interconnected nodes or neurons in a layered structure that resembles the human brain)
- Computer vision (a field of AI that enables computers and systems to derive meaningful information from digital images, videos, and other visual inputs, and take actions or make recommendations based on that information. If AI enables computers to think, computer vision enables them to see, observe and understand.)
- Natural language processing (refers to the branch of computer science, more specifically, the branch of AI, concerned with giving computers the ability to understand text and spoken words in much the same way human beings can)

Following are a few examples of how AI can assist in R&M engineering.

- *AI and Predictive Maintenance.* Predictive maintenance is Condition-Based Maintenance Plus (CBM+) (see DoDI 4151.22). CBM+ is maintenance based on the evidence of need" for maintenance. Evidence may indicate
  - An immediate event (Legacy maintenance)
  - An impending event based on Reliability-Centered Maintenance (RCM) and CBM
  - An event further on the horizon (CBM+/preventive maintenance)

  CBM+ relies on the ability to analyze all relevant data sets to discover the "evidence" using AI, ML, algorithms and advanced analytics, digital twins, physics of failure, and digital simulation. CBM+ populates these data sets with data from digital source collectors, usage data, maintenance and supply data and operational context. RCM (DoDM 4151.25) forms the foundation; its component analysis, R&M data design, FMECA data (obtained from R&M engineering), and maintenance plans inform candidate components for CBM+.

- *AI and R&M Engineering Models.* R&M engineering models and spreadsheets can be built and automated to run using AI algorithms designed to pull in data from known data sources and then formatting that data for input to R&M models. Digital engineering is driving the engineering community toward automated data collection and models linked through a digital engineering ecosystem. Automating those models to run on a continuous basis or creating a digital twin that can run throughout the life cycle and be used to improve the reliability and maintainability of systems.
- *Root Cause and Failure Trend Analysis.* AI algorithms can be used to analyze open-source operational data identifying root cause of failure and generate failure trends reports. Modern causal inferential techniques can also study historical observational failure and maintenance

data to conclude proximate and root causes of failure with much lower false positives and false negatives.

- *AI and Failure Reporting, Analysis, and Corrective Actions System (FRACAS).* AI algorithms can be used to analyze sensor data or maintenance and repair records and automate inputs to the FRACAS.
- *AI in Causal Analysis.* Modern causal inferential techniques including causal search, causal estimation, causal reasoning, and counterfactual reasoning enable AI to go beyond foundations built on statistical correlation and patterns to reasoned cause-effects in data (e.g., causal footprints).

1.6.2 Relationship of Artificial Intelligence to Digital Engineering

In a digital engineering ecosystem, the digital twin and digital thread[4] yield large amounts of data. Program engineers can use AI models to analyze the data rapidly to provide insight and make predictions. The results can help the program optimize product design, improve manufacturing processes, and reduce maintenance costs. Following is a fictitious example of how the digital twin and digital thread can be used in the development and operation of an aircraft.

> *The program develops the aircraft digital twin, a virtual model of the physical aircraft. The program continuously updates the digital twin with real-time data from sensors embedded in the physical aircraft. That data may include information such as engine performance, fuel consumption, or temperature.*
>
> *The program captures all data generated during the life cycle of the aircraft (the aircraft digital thread) and stores the data in a central location. During design and early operational testing, the program uses the digital twin to analyze test data (including reliability) of prototypes and early production models at both the subsystem and aircraft level. In production, the program uses the digital twin to track the history of the aircraft including maintenance activities and onboard sensor data installed on the physical system.*
>
> *The program uses AI models to analyze large amounts of data from test or field operation to help identify patterns that indicate potential failures or performance issues. Examples of types of data appropriate for AI analysis include engine vibration, fuel consumption, or temperature. The program uses the results to address potential problems proactively, reducing the risk of downtime or costly repairs.*

[4]Together, the digital twin and digital thread create an extensible, configurable, and component enterprise-level analytical framework that seamlessly expedites the controlled interplay of authoritative technical data, software, information, and knowledge in the enterprise knowledge systems. The common data source supports decision makers throughout the system life cycle by providing the capability to access, integrate, and transform disparate data into actionable information.

For more information on applying AI in R&M engineering, see "Summary of the 2018 Department of Defense Artificial Intelligence Strategy: Harnessing AI to Advance Our Security and Prosperity" (DoD 2019) and other published sources.

1.7 R&M AND PRODUCT SUPPORT

R&M engineering is important in developing supportable systems. A program executing an effective R&M engineering program, integrated with Product Support (PS), that includes the fundamentals of R&M design, manufacturing, and management will develop a reliable and maintainable system.

As the DoW moves forward in an increasingly challenging environment with constrained budgets, aging weapon systems, and a growing proliferation of threats around the globe, attention to PS is paramount and life cycle management (LCM) needs to focus on designing for supportability and sustainment. Product Support is a key component of weapon system development, implementation, and management. Success depends on balancing the competing priorities of capability, flexibility, and affordability.

PS, a key LCM enabler, is the package of support functions required to field and maintain the readiness and operational capability of all systems, (covered[5] or non-covered) subsystems, and components, including all functions related to covered system readiness. The package of product support functions related to weapon system readiness (and which can be performed by both public and private entities) includes the tasks that are associated with the 12 Integrated Product Support (IPS) Elements. These elements, as well as the IPS elements interrelationship with the others, should be considered during the development, implementation, and subsequent revalidation of the product support strategy.

In support of the DoD Digital Engineering (DE) Strategy, DoDI 5000.88, and DoDI 5000.91, "Product Support Management for the Adaptive Acquisition Framework," Product Support Managers (PSMs) should collaborate with Systems Engineering (SE) in developing and implementing the program's Digital Engineering Implementation Plan (Appendix E to the Systems Engineering Plan), including identifying product support activities enabled by DE (i.e., digital product support (DPS)) and documenting those activities in the Life Cycle Sustainment Plan (LCSP). Integrated DE with DPS will assist in building a more lethal force that will improve a Commander's ability to rapidly aggregate and deploy forces worldwide, and support those forces over vast distances, in contested environments.

[5] A covered system is a Major Defense Acquisition Program (MDAP) or Middle Tier of Acquisition Rapid Prototyping or Rapid Fielding program meeting the MDAP funding threshold (10 USC 4324, previously 2337).

Integrating R&M and PS through a single authoritative source will help ensure that modernized weapon systems are maintainable when they fail, supportable with the logistics infrastructure established, and replenished based on accurate demand rates and estimates. DoDI 5000.88, Engineering of Defense Systems, justifies the need to provide digital artifacts, for R&M activities and products such as the Failure mode, effects, and criticality analysis and a FRACAS maintained through design, development, test, production, and sustainment.

In addition, the DoW R&M community has recognized the importance of instantiating Digital Engineering (DE) into R&M practices. To ensure modernized warfighting capabilities are reliable, maintainable, and supportable, data in a DE data-centric environment must flow between Integrated DE and DPS. Introduction to Product Support

R&M engineering is key to developing supportable systems. A program executing an effective R&M engineering program, integrated with PS, that includes the fundamentals of R&M design, manufacturing, and management will develop a reliable, maintainable, and supported system.

1.7.1 Product Support Management

PS is critical to achieving and sustaining warfighter readiness and lethality and must begin at program inception to ensure effective and affordable readiness outcomes. PS management is the organization and coordination of life cycle activities, products, processes, and data required to achieve defined program supportability cost, schedule, and performance objectives. Product Support management includes planning, cost estimating and budgeting, developing, implementing, and managing an effective Product Support Strategy (PSS) that addresses all 12 IPS elements to accomplish materiel and system readiness for systems covered by 10 USC 4324 Life-Cycle Management and Product Support (covered systems), major systems, subsystems, components, and embedded software.

PS management is developing and implementing strategies to ensure supportability is considered throughout the system life cycle. This objective is accomplished by balancing the performance outcomes of reliability, availability, maintainability, and reduced total ownership costs. The scope of PS management planning and execution includes the enterprise-level integration of all 12 IPS elements throughout the lifecycle commensurate with the roles and responsibilities of the PSM position created under 10 USC 4324.

PS also involves selecting PS integrators (PSIs) and PS providers (PSPs) to execute the PSS, IAW the PS arrangements. The Product Support Manager Guidebook is a tool for PMs, PSMs, and Lead Life Cycle Logisticians (LCLs) serving in the role of PSM for any ACAT and non ACAT level program, their support staffs, and others in acquisition and sustainment organizations as they develop and implement product support strategies for new programs and major modifications to legacy programs.

Product support is scoped by the IPS elements, which provide a structured and integrated framework for managing PS. They are considered during the development of the PSS and continuously assessed throughout a system's life cycle and include:

- Product Support Management
- Supply Support
- Sustaining Engineering
- Maintenance Planning and Management
- Design Interface
- Support Equipment (SE)
- Manpower and Personnel
- IT Systems Continuous Support
- Facilities and Infrastructure
- Packaging, Handling, Storage and Transportation
- Technical Data
- Training and Training Support

The Integrated Product Support (IPS) Elements Guidebook has detailed descriptions of the ILS elements.

1.7.2 The PSS and the Life Cycle Sustainment Plan

A PSS is the overarching strategy to meet sustainment requirements. The PSM will document the initial PSS within the acquisition strategy at program inception, and in the LCSP, at Milestone A or an equivalent decision event for covered systems[6] pursuant to 10 USC 4324. The LCSP is the detailed PS plan, including sustainment metrics, risks, costs, and analyses used to deliver the performance-based best value strategy covering the IPS elements.

The LCSP is the primary program management reference governing operations and support planning and execution from program inception to disposal. An LCSP is required for all covered systems and is the principal document establishing the system’s PS planning and sustainment, pursuant to 10 USC 4324. For covered systems, a detailed LCSP will include:

[6] A major defense acquisition program (MDAP) or a system designated by the Secretary of War, requiring specific LCSPs and PS management

- A comprehensive PSS.
- Performance goals (Sustainment Key Performance Parameters (KPPs),[7] Key System Attributes (KSAs), and other appropriate metrics.
- An approved life cycle cost estimate for the system.
- Results of the Product Support Business Case Analysis (PS BCA).
- Affordability constraints and key cost factors that could affect the system's operations and support (O&S) costs and proposed mitigation plans.
- Sustainment risks, Supply Chain Risk Management (SCRM), and Diminishing Manufacturing Sources and Material Shortage (DMSMS)[8] risk management and proposed mitigation plans.
- Engineering and design considerations, including DMSMS resilience, that support cost-effective sustainment for the system.
- A technical data and intellectual property (IP) management plan for Product Support.
- Major maintenance and overhaul requirements for the system's life cycle.
- A plan to leverage enterprise opportunities across programs and DoW Components.

1.7.3 Life Cycle Product Support

PS planning and PSS development begin prior to program initiation and the resultant method of executing Product Support (i.e., the Product Support solution) is re-evaluated and updated throughout the program's life cycle. The PM, with the support of the PSM, will begin life cycle PS planning by conducting early risk identification, mitigation, and PS analyses that inform best value solutions. The PSM must have input into systems engineering requirements, design, maintenance planning, and contract development. The PSM will collaborate with the lead systems engineer, who is responsible for executing a comprehensive R&M program, to ensure implementation of R&M through design, development, test, production, and sustainment. The PM and the PSM must consider total life cycle costs, schedule, performance, and risks when making programmatic decisions, including decisions impacting life cycle PS.

1.7.4 Information Technology and Product Support

PS includes the continuous support of IT systems and encompasses the facilities, hardware, software, firmware, documentation, labor, and personnel needed to operate and support mission

[7] The Sustainment KPP consists of Materiel Availability (Am) and Operational Availability (Ao) and three mandatory attributes (KSAs or APAs): reliability, maintainability, and O&S Costs.
[8] See DoDI 4245.15, Diminishing Manufacturing Sources and Material Shortages Management

critical information technology systems hardware/software systems. As the primary end item, SE, and training devices increase in complexity, more and more software is being used. The expense associated with the design and maintenance of software programs is so high that one cannot afford not to manage this process effectively and proactively. It should be standard practice for the PM and PSM to participate in the engineering and continuous development process from program inception. Such participation will ensure software engineers, systems engineers, users, and PSMs are collaborating continuously in order to accomplish the necessary planning and management of IT systems continuous support to include management of weapon system information assurance across the system life cycle.

1.7.5 Digital Product Support

DPS uses DE methods and digital data and system models to implement the PSS, enable data-driven decision-making, and deliver effective and efficient PS outcomes throughout the system lifecycle. In execution of a digital PS approach, DE and PS activities and teams are tightly integrated and mutually reinforcing in delivering affordable readiness to the warfighter. The 12 IPS Elements that comprise the PSS, may each benefit, in many cases substantially, from utilization of system models, particularly 3-dimensional computer-aided design (3D CAD) models. Ref: PSM Guidebook. DPS supports the following.

- Managing the technical baseline digitally among stakeholders (thus supporting the DE strategy of the program into sustainment)
- Optimizing and implementing data-driven decision-making through the system lifecycle achieving both PS and Human Systems Integration (HSI) performance outcomes.

The DPS approach applies both to systems that are “born digital” (e.g., designed using modern DE tools) and to digitally engineered modifications to legacy systems.

In support of the DoD Digital Engineering Strategy as stipulated in DoDI 5000.88 and DoDI 5000.91, PSMs should collaborate with Systems Engineering (SE) in developing and implementing the program's Digital Engineering Implementation Plan (Appendix E to the Systems Engineering Plan). This collaboration includes identifying Product Support activities enabled by DE (i.e., DPS) and documenting those activities in the LCSP. DoDI 5000.88 requires that supportability analyses be included in the evolution of the digital ASOT, which is managed and maintained throughout the life of the program.

Integrating DE with DPS assists in building a more lethal force, improving a Commander’s ability to rapidly aggregate and deploy forces worldwide, and support those forces over vast distances in contested environments. Integrated R&M and Product Support through a single authoritative source will help ensure that modernized weapon systems are maintainable when they fail, supportable with the established support infrastructure, and replenished based on

accurate demand rates and estimates. DoDI 5000.88, Engineering of Defense Systems, justifies the need to provide digital artifacts, for R&M activities and products such as the FMECA and a FRACAS maintained through design, development, test, production, and sustainment.

1.7.6 Using DE for Product Support Planning

DE capabilities typically are used to improve planning for PS in the following areas:

- Data – VAULTIS
- Complex data manipulation/calculations
- Change or configuration management of requirements and system hardware/software
- Trade studies
- Decision making based on data analysis
- Simulation of physical attributes and processes to a digital environment

The LCSP framework assists weapons programs in developing integrated planning factors to achieve the sustainment results quantified in user-specified requirements. To remain relevant and current, the LCSP is updated every five years or upon a major program change[9] However, changes to the system and its sustainment strategy occur on an on-going basis throughout the acquisition lifecycle. Most changes will not require a formal update to the LCSP but must be tracked with the relevant information captured and used to influence other areas of the program. DE can support the development and updating of the LCSP as shown in Table 1-2.

For more information on DE, see the Digital Engineering Body of Knowledge (de-bok.org), Defense Acquisition University (DAU) Digital Engineering, Modeling and Simulation Community of Practice, DAU course CLE 084, "Models, Simulations, and Digital Engineering," and the SE&A DEM&S web page (see References).

[9] Major upgrades or modifications, adjustments to program scope or structure, or a revised sustainment strategy.

Table 1-2. DE Supports the LCSP

LCSP Section	Application of DE
Performance Demonstrations and Tests that Impact Sustainment	• Data - VAULTIS • Simulation in a digital environment • Change or configuration management • Decision making based on data analysis
Obsolescence Risk Management	• Data VAULTIS • Change or configuration management • Simulation in a digital environment
Sustainment Considerations	• Data VAULTIS • Simulation in a digital environment
Digital Product Support	• Digital data flow defined • Digital infrastructure established • Use of digital engineering methodologies
Design Analysis	• Data - VAULTIS • Simulation in a digital environment • Change or configuration management • Decision making based on data analysis
FMECA	• Data VAULTIS • Complex data manipulation and calculations • Comparison of high-volume data
Reliability	• Data VAULTIS • Complex data manipulation and calculations • Comparison of high-volume data
Supportability Trades	• Data VAULTIS • Complex data manipulation and calculations • Comparison of high-volume data
Program and Design Reviews	• Data - VAULTIS • Decision making based on data analysis • Simulation in a digital environment
Development and Evolution of System O&S Cost Estimate	• Data VAULTIS • Complex data manipulation and calculations • Comparison of high-volume data • Change or configuration management

1.8 R&M Objectives Within the Acquisition Life Cycle

The following paragraphs highlight R&M objectives for each life cycle acquisition phase of programs following the MCA pathway. Use Figure 1-3 to align and apply the objectives to other AAF pathways or generic commercial life cycle phases.

1.8.1 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 the MSA 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.
- Analyze the draft CDD R&M and sustainment thresholds to ensure that they are valid and feasible.
- Translate the valid and feasible 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. The use of digital twins, AI, and ML may buy down these technical risks.
- Identify and refine the warfighter's critical PS performance and cost outcomes.
- Conducting a PS BCA to determine the best value solution for PS.
- Developing a Product Support Strategy (PSS) that identifies the execution plan to deliver IPS (integrated product support) elements to the warfighter.
- Provide inputs to the Life Cycle Sustainment Plan (LCSP).

Figure 1-5 illustrates the primary activities necessary to achieve MSA phase R&M objectives, in approximate chronological order.

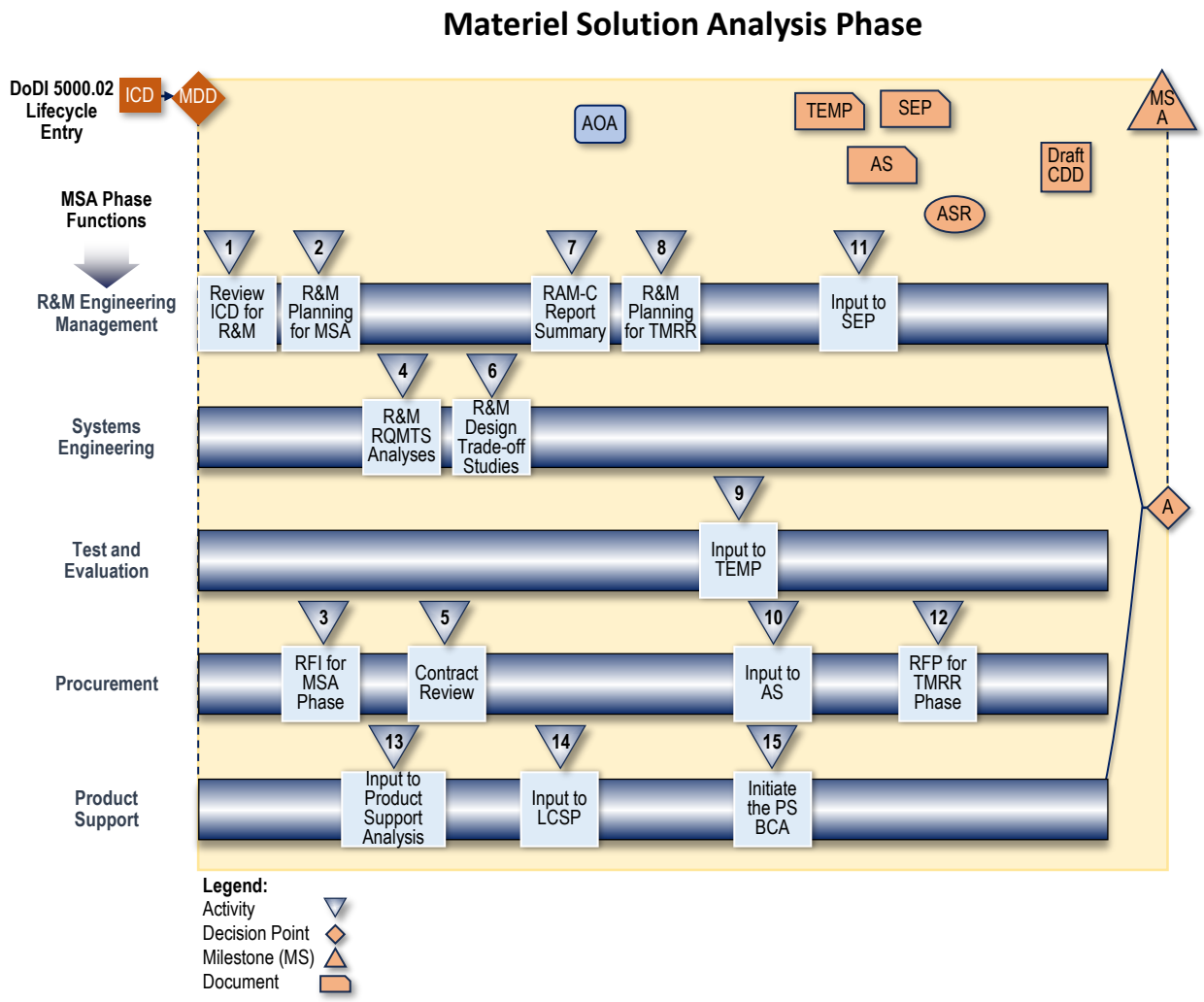


Figure 1-5. MSA Phase R&M Activities by Functional Area

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 the following:

- Estimate the feasibility of the R&M draft CDD thresholds using block diagrams, math models, model-based systems engineering, and preliminary estimate analysis.
- Perform trade-off studies among R&M, availability, and other system performance parameters to verify optimum balance using techniques in the DoD RAM-C Rationale Report Outline Guidance.

  - 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.

- 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:
  - 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 guide planning and conceptual design of the diagnostics concept, recovery designs, and maturation process.
- Define the appropriate contractor R&M engineering activities for analysis; design review; allocation; block diagram and modeling; estimates; FMECA with supporting Software Failure Mode and Effects Analysis (SFMEA); subsystem and system-level reliability growth planning activities; FRACAS, etc., in the Request for Proposal (RFP) and contract Statement of Work (SOW) for the TMRR phase.

  To aid in developing the SFMEA, the DoW Common Defect Enumeration (CDE) should be used. It is a categorized list of root causes for software failures in software-intensive systems, used to help identify and mitigate potential issues during development and testing.
- Ensure software reliability is addressed in all software deliveries. The sponsor and program office will develop and maintain a product roadmap to plan regular and iterative deliveries of software capabilities. The product owner and program office will also develop and maintain program backlogs that identify detailed user needs in prioritized lists. The backlogs allow for dynamic reallocation of current and planned software releases. Issues, errors, threats, and defects identified during development and operations, including software updates from third parties or suppliers, should be captured in the program's backlogs to address in future iterations and releases. Regular stakeholder feedback and inputs will shape the product roadmap and program backlogs.

  Program backlogs that identify detailed user needs in prioritized lists. The backlogs allow for dynamic reallocation of scope and priority of current and planned software releases. Issues,

errors, and defects identified during development and operations should be captured in the program's backlogs to address in future iterations and releases.

- 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.
- Prepare and document the PSS.
- Conducting a PS BCA to determine the best value solution for PS.
- Provide R&M inputs to the LCSP.

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.

Materiel 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.
- PSS developed.
- PS BCA conducted.
- R&M inputs to LCSP completed.

1.8.2 Technology Maturation and Risk Reduction (TMRR) 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. Consider the use of digital twins to support the feasibility assessment.
- The allocated baseline for contract definition has been established for the EMD phase.

Figure 1-6 lists the R&M activities for the TMRR phase in approximate chronological order.

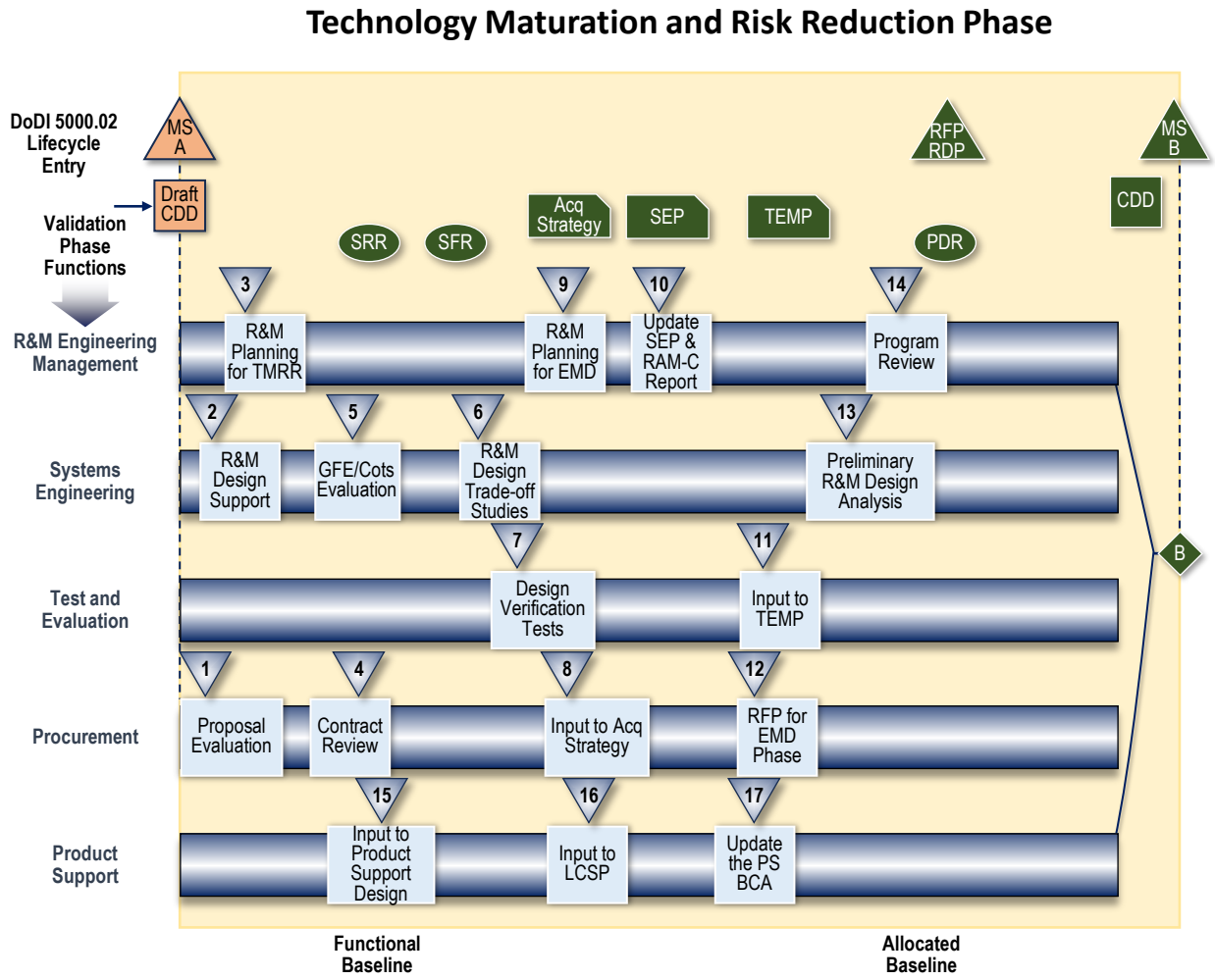


Figure 1-6. TMRR Phase R&M Activities by Functional Area

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, estimates, 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 estimates of the proposed design configuration to verify conformance to the specification requirements. As applicable, conduct the PDR in a model-based DE environment.

- Evaluate R&M modeling, allocation, and estimate 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; RCM and 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 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 estimate 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.

1.8.3 Engineering and Manufacturing Development (EMD) 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 comprehensive analysis documenting how the system's sustainment and R&M thresholds are valid and feasible. At Milestone B, the RAM-C Report is 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 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.

Figure 1-7 illustrates the R&M activities to be addressed in the EMD phase in approximate chronological order.

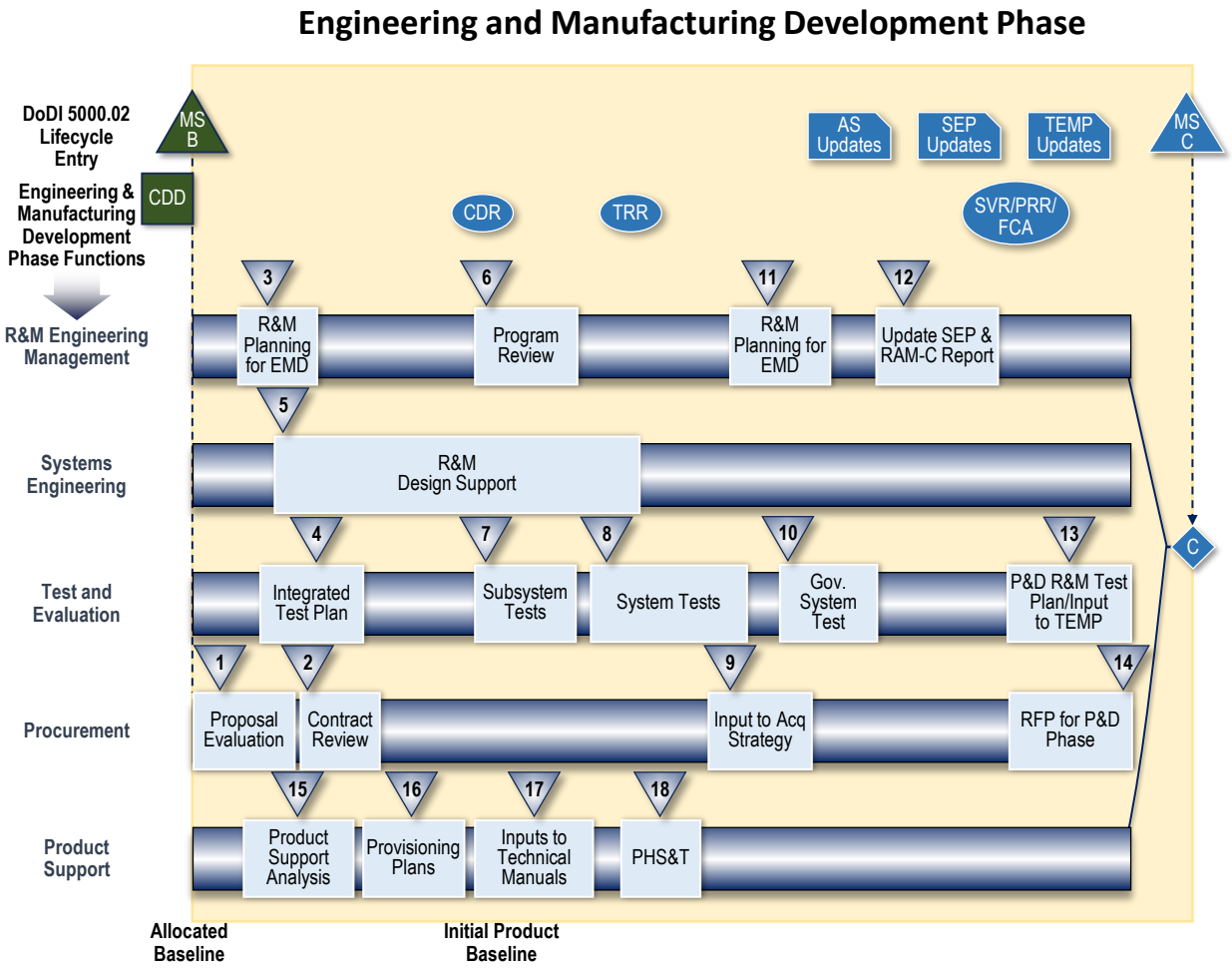


Figure 1-7. EMD Phase R&M Activities by Functional Area

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.
- 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 estimate to assess system potential to meet design requirements is complete. As applicable, conduct the CDR in a model-based DE environment.
- 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 of all failures: hardware, software, and interfaces.
- 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 estimate analyses using latest test data to identify potential R&M problem areas. Update digital twins as applicable.
- 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.

- In the Product Support row for EMD, the PS BCA will be an update from the TMRR phase. Also, in EMD, the LCSP will be updated for Milestone C.

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, SE, and manpower.

Factors such as part obsolescence and changes in technology can happen at any phase, including the EMD phase. These factors can prompt the need to make changes to the system design. It is important to monitor system design changes throughout the EMD phase to assess the impact of those changes on R&M performance and offer recommendations to improve R&M performance or plan for mitigations, as appropriate.

Engineering and Manufacturing Development (EMD) 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.

1.8.4 Production and Deployment (P&D) 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 (FRP) 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 CDD.
- Deliver the technical data, SE, 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 CDD thresholds.
- Update R&M estimates 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 tracking systems in the field through a Maintenance Data Collection System (MDCS) to correct problems in the operational environment.

Figure 1-8 illustrates the R&M activities to be considered during the production phase in approximate chronological order.

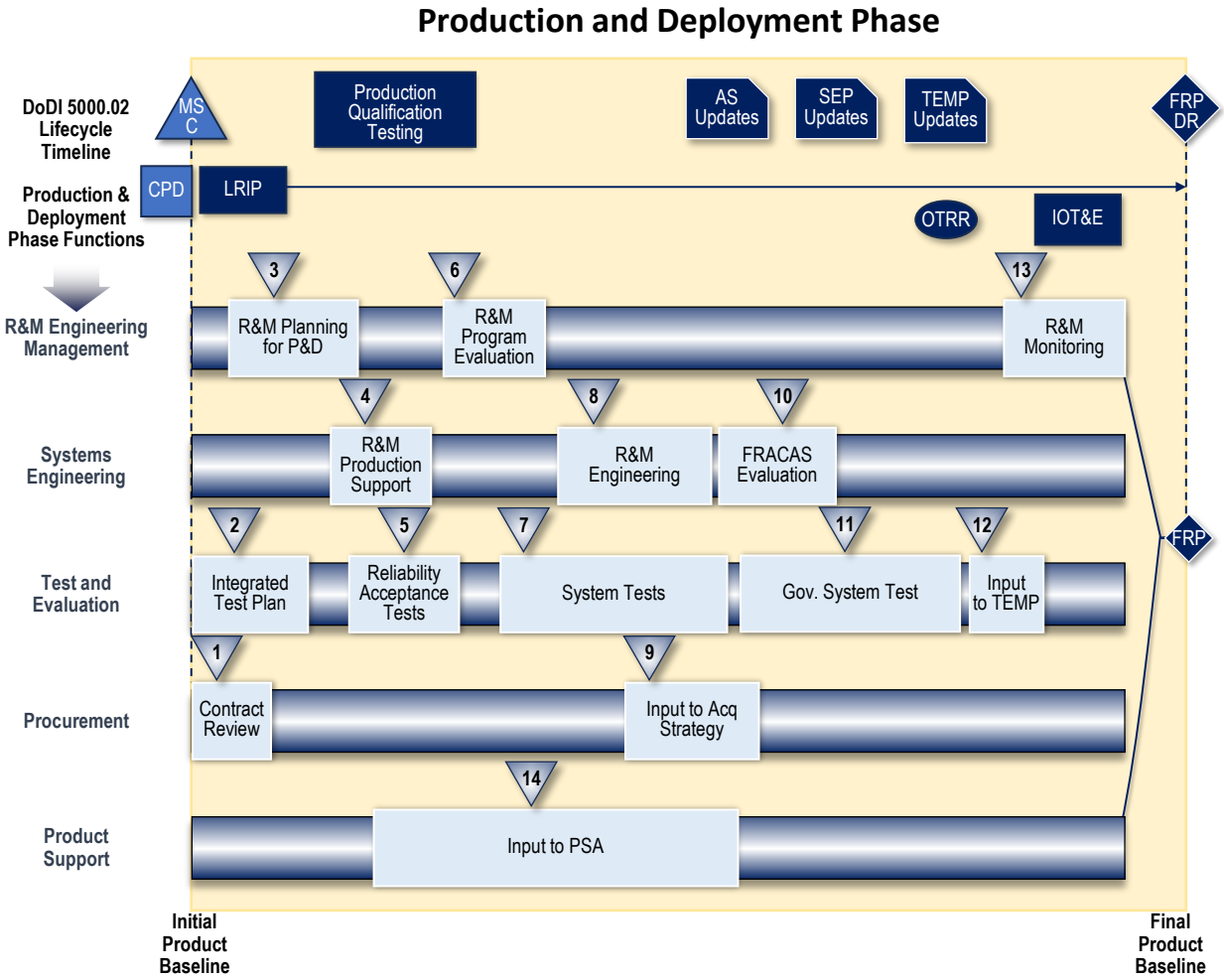


Figure 1-8. P&D Phase R&M Activities by Functional Area

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.

Factors such as part obsolescence and changes in technology can happen at any phase, including the P&D phase. These factors can prompt the need to make changes to the system design. It is important to monitor system design changes throughout the P&D phase to assess the impact of those changes on R&M performance and offer recommendations to improve R&M performance or plan for mitigations, as appropriate.

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).

1.8.5 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 the O&S 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 1-9 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.

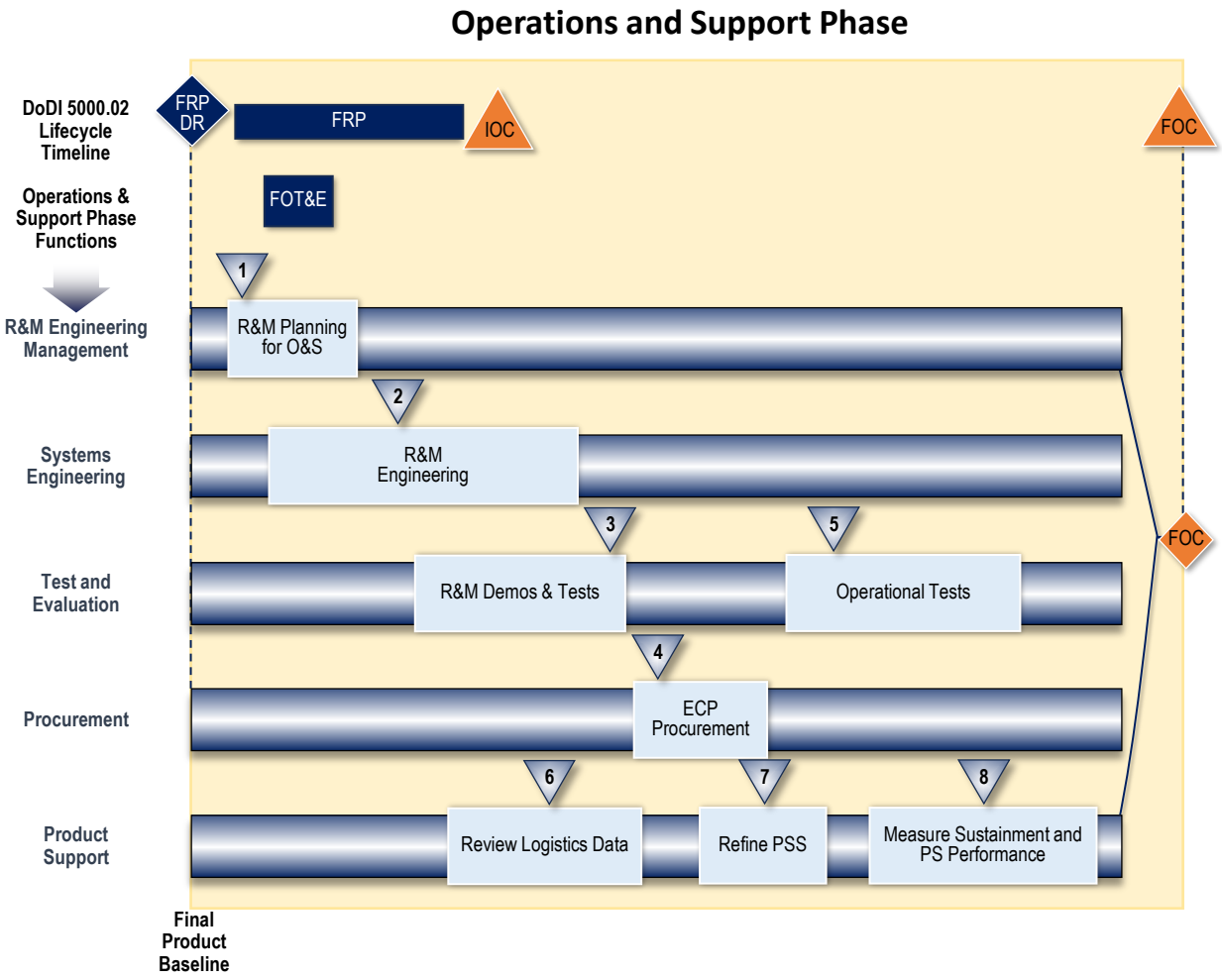


Figure 1-9. O&S Phase R&M Activities by Functional Area

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 initially performed during the P&D phase continue during O&S to ensure continued availability.

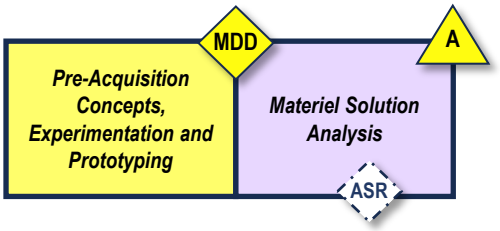
The software for most systems will continue to change and evolve as long as the system is used and the R&M activities will mirror those of the EMD phase with the extent of development being significantly reduced. Software will also be subject to continuous updates for security, corrections, and user 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.

2 R&M in the Materiel Solution Analysis Phase



Objectives of the Materiel Solution Analysis Phase

During the MSA phase, the program explores materiel concepts and alternatives, identifies potential solutions to stated Service needs, and evaluates technologies to include in the TMRR phase. The objective for R&M engineering in the MSA 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.

Any sustainment concepts that require new skills, special tools, training, or facilities should be identified now and carried into the preferred system concept for the next phase. Those technologies and R&M needs should not reflect a single solution but should support the preferred system concept.

The DoW acquisition component prepares the Analysis of Alternatives (AoA), from which the best concept to pursue are selected. The DoW 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 RAM-C Report that are critical to begin the TMRR phase.

R&M Activities in the Materiel Solution Analysis Phase

Figure 2-1 presents the R&M activities to be accomplished by the designated DoW acquisition component during the MSA phase (or early in the TMRR phase if the program initiates in that phase) in approximate chronological order. Table 2-1 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 5000.88 R&M engineering activities.

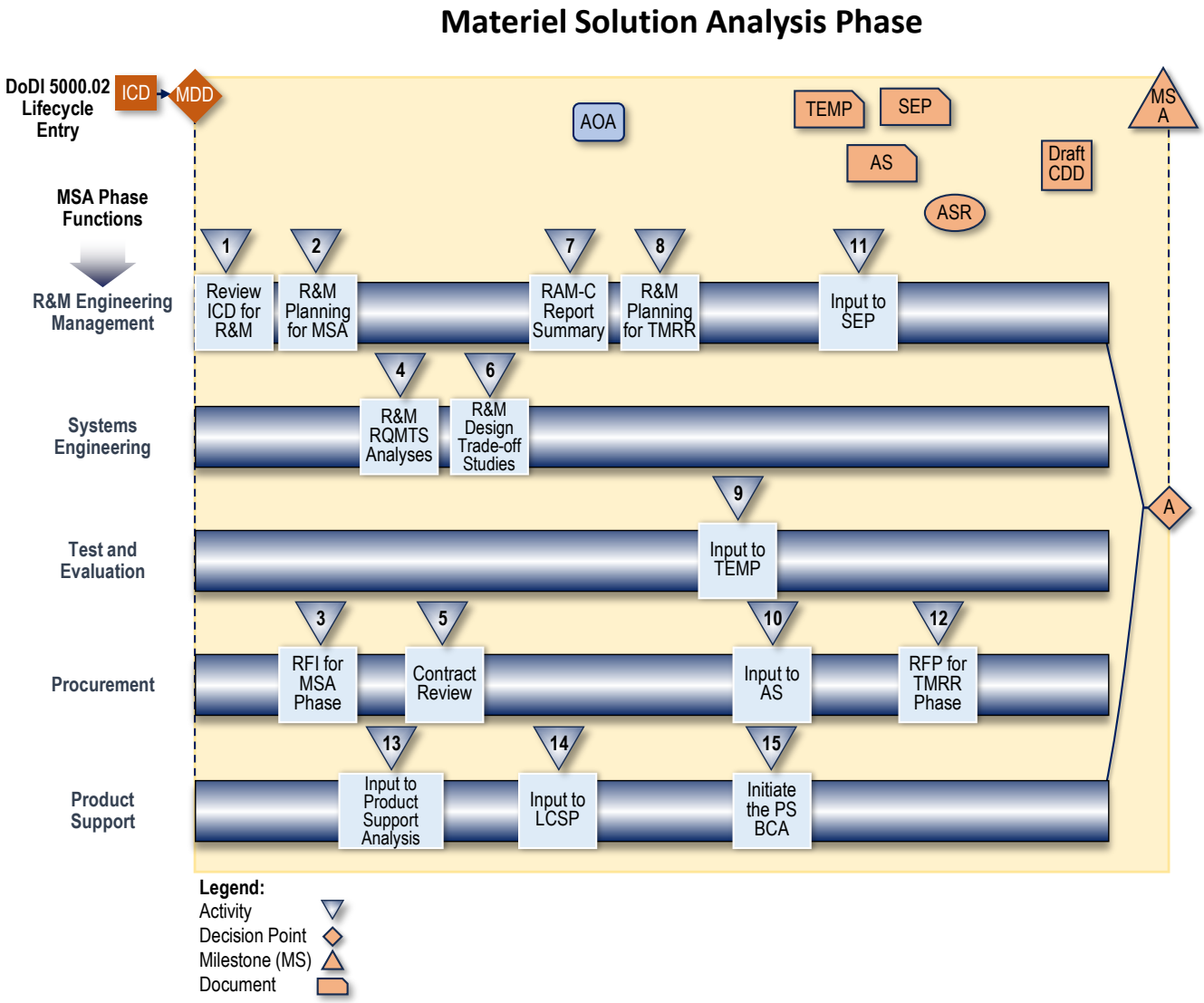


Figure 2-1. MSA Phase R&M Activities by Functional Area

Table 2-1. 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	2.1.1
2	Develop R&M planning for MSA phase	R&M Engineering Management	2.1.2
3	Prepare R&M input to MSA phase RFI or study contracts	Procurement	2.4.1
4	Perform R&M requirements analysis	Systems Engineering	2.2.1
5	Review MSA phase RFI or study contracts	Procurement	2.4.1
6	Perform design trade-off studies	Systems Engineering	2.2.2
7	Prepare RAM-C Report	R&M Engineering Management	2.1.3
8	Develop R&M planning for TMRR phase	R&M Engineering Management	2.1.4
9	Provide R&M input to TEMP	Test and Evaluation	2.3.1
10	Provide R&M input to the Acquisition Strategy (Acq Strat)	Procurement	2.4.2
11	Provide R&M input to SEP	R&M Engineering Management	2.1.5
12	Prepare R&M input to RFP for TMRR phase	Procurement	2.4.3
13	Provide input to Product Support Analysis	Product Support	2.5.1
14	Provide input to Life Cycle Sustainment Plan (LCSP)	Product Support	2.5.2
15	Conduct a PS BCA	Product Support	2.5.3

2.1 R&M Engineering Management

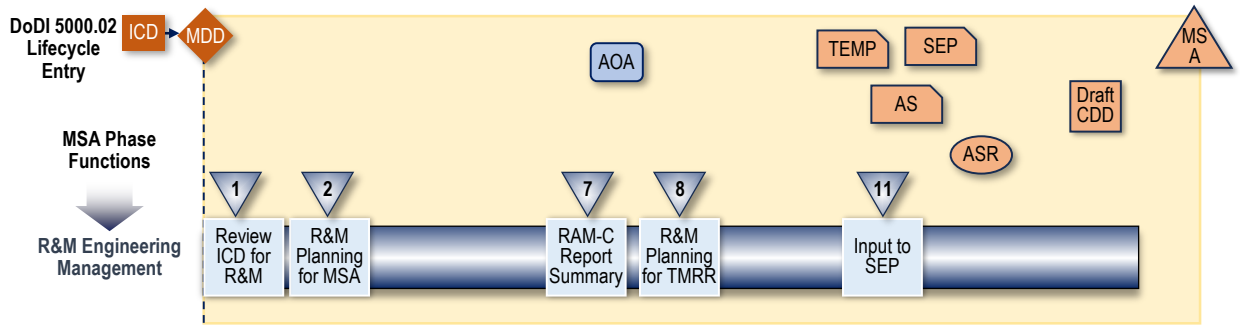


Table 2-2 lists the primary R&M activities associated with the R&M Engineering Management functional area in the MSA phase.

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

R&M Activity	Description
1 Review ICD for R&M objectives	• Review the ICD and extract the desired R&M capabilities.
2 Develop R&M planning for MSA phase	• 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	• 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	• Develop Government R&M planning for the TMMR and subsequent acquisition phases to identify specific R&M activities and provisions.
11 Provide R&M input to SEP	• Prepare the R&M inputs to the SEP for major programs prior to soliciting Service approval for Milestone A.

2.1.1 Review ICD for R&M Objectives 1

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.

2.1.2 Develop R&M Planning for MSA Phase 

The R&M engineering management planning performed by the DoW acquisition component early in the MSA phase should be updated continuously in subsequent phases of acquisition, to provide the PM 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, Acq Strat, and other management and reporting documents.
4. Provide the basis for specifying compatible R&M program requirements in contracts.

The DoW 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, estimation 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.

2.1.3 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 Report and its supporting analysis are required for all Major Defense Acquisition Programs (MDAPs) and designated special interest programs, and it is highly encouraged for all other defense systems. The RAM-C analysis or equivalent is essential to ensure that R&M thresholds are valid and feasible. Collaboration among key program personnel (PM, the lead command, R&M engineer, lead Systems Engineer, PSM, etc.) is vital for success in conducting the RAM-C Rationale analysis and preparing the RAM-C report.

RAM-C Report: Procedure

Refer to the RAM-C Rationale Report Outline 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 Outline Guidance.
- *Failure Definitions/Scoring Criteria (FDSC)* – Preliminary failure definitions, criteria for maintainability and 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 Key Performance Parameter (KPP)[10] and supporting Key Supporting Attribute (KSA) thresholds are valid and feasible.

2.1.4 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 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. At this stage, planning should define the contractor's approach and procedures for meeting 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 DoW acquisition component program plans and IMS.

[10] The Sustainment KPP is derived from system availability requirements to support the required capability, assumptions for its design and operational use as specified in the Concept of Operations (CONOPS) and/or Operational Mode Summary/Mission Profile (OMS/MP) trade-offs between reliability, maintenance concepts, life cycle cost (LCC), and the planned sustainment strategy. In order for the PM to develop a complete system to provide warfighting capability, sustainment attributes must be established and performance of the entire system measured against those metrics. The Sustainment KPP includes several mandatory components: Materiel Availability (Am) and Operational Availability (Ao), and three mandatory Key System Attributes (KSAs): Reliability (R), Maintainability (M), and Operating and Support (O&S) cost.

R&M Planning for TMRR: Procedure

R&M program planning should include the following information:

- A 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.
- A 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 level of detail (to support the allocated baseline and subcontractor/supplier contracts awarded to that point) completed by PDR.
    - R&M Estimates (Predictions)[11] – R&M estimates 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 estimation and trade-off studies. Preliminary estimates 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.

[11] Estimates are more inclusive than predictions. “Prediction” is most associated with using statistical methods to assess reliability. An estimate is broader and includes assessments based on field data, engineering judgment, and other analysis. Except when statistical methods are intended, the term “estimate” will be used. See 2.2.4 (6) in this document. For additional guidance in making R&M estimates, see Best Practices to Achieve Better R&M Estimates for DoD Systems (OUSD(R&E) February 2025).

        - Failure Modes and 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.
- A description of contractor R&M requirements and delivery schedule associated with the activities just described.

R&M Planning for TMRR: Data

Applicable planning data should be prepared in accordance with this guide and with DoW 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.

2.1.5 Provide R&M Input to System Engineering Plan (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., DoW provider services).
- Description of how the requirements development document 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.

2.2 SYSTEMS ENGINEERING

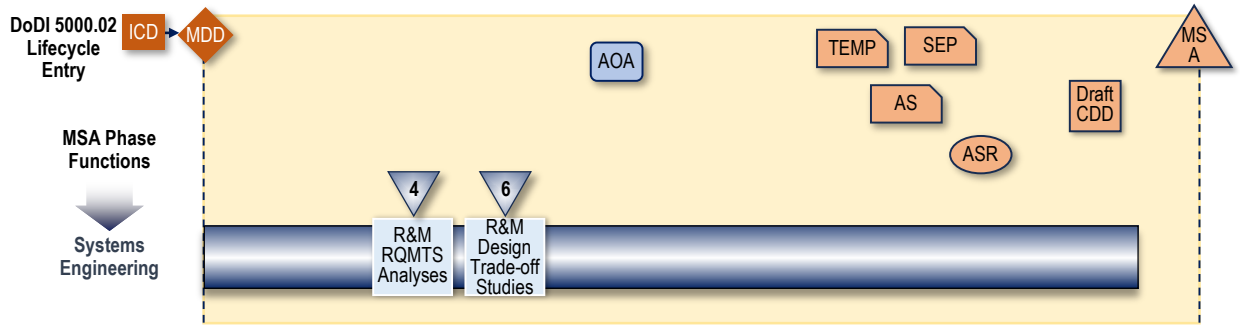


Table 2-3 lists the primary R&M activities associated with the activities for the Systems Engineering functional area in the MSA phase.

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

R&M Activity	Description
4 Perform R&M requirements analysis	• Perform system R&M requirements analysis supported by the mission profile, CONOPS and proposed sustainment concept.
6 Perform design trade-off studies	• 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.

2.2.1 Perform R&M Requirements Analysis 4

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 need to be realistic for the type of item that is under contract, specific and measurable in a way that can be achieved within the time available and without adversely impacting the overall affordability of the project. As the program progresses through the acquisition process, it is important to ensure that requirements are flowed down to lower levels of indenture of the item in a coherent and balanced way so that a full understanding of the R&M characteristics can be derived. Early attention to R&M plans and allocation of appropriate resources beginning in the MSA phase is needed to achieve the desired requirements.

When specifying requirements for R&M, it is necessary to:

- Ensure that R&M requirements are consistent with the technology that is anticipated to be used in the design. Cutting-edge technology often is less dependable than technology that has been in use for a period of time; however, the incorporation of older technology into designs may increase the likelihood of encountering obsolescence earlier in the system life cycle. Define the conditions of storage, transportation, installation and use that will be encountered by that item.
- Take account of the anticipated maintenance policy, the area in which that maintenance will be undertaken and the skill levels of the persons undertaking it. A maintenance action that is relatively simple in a purpose-built facility can become extremely difficult under operational conditions.

The R&M characteristics that are achieved by any item are very dependent on how it is used, as defined in the Mission or Life Profile. The profile is either an envisaged scenario based on current or previous experience, or a predicted pattern based on what the future use requirements are expected to be. However the profile is constructed, it is important to consider the following:

- *Period of Time Required* – How long the item is required to be in a fully operational state, how long it is required to be in some sort of low operational or stand by state, how long it is expected to be switched off during the chosen period of interest including any transportation that may be required.
- *Single or Multiple Use* – For example, a munition is used once. An aircraft flies multiple missions.
- *Alternate Modes of Operation* – Built in provisions to provide the user with a last resort should a catastrophic failure be encountered.
- *Maintenance* – It is important to consider where the maintenance is to be performed, the conditions in which maintenance may have to be performed, what information, tools and test equipment will need to be provided, what training will be required and the practicality of undertaking that maintenance particularly if it is required to be performed under operational conditions.
- *Anticipated Fleet Size* – Assuming that any item in the fleet will be 100% available will lead to wrong assumptions about the total number required to provide the capability and will lead to periods of time when the capability is not available.

When setting R&M requirements, it is important to remember that the item being considered may form part of a bigger system (i.e., a system or a system of systems) or rely on some form of external stimulus to perform according to its specification. The supply of these external stimuli may not form part of the contract for the item but they will be assumed to be present when

required. For this reason, it is important to ensure that the boundaries of the item being considered are clearly defined and all external stimuli that are required to be present are identified in the documentation, particularly if the item performance is part of a higher level performance contract. These external stimuli can take many forms and may include external power, data from other items, the availability of externally managed and provided items or even existing items within the inventory with which the item of interest will be required to work.

When specifying reliability, it is common and good practice to include requirements such as probability of mission success or probability of achieving a given period of time without encountering a mission failure. This pre-supposes an understanding of what constitutes success and thus when failure has occurred i.e. when an item is no longer performing in a manner that is considered acceptable to the user. Setting clear and agreed definitions of failure is an important step that is often overlooked during the specification of reliability requirements.

It is important to ensure that R&M requirements can be shown to have been achieved. In the same way as for other performance requirements, R&M can be proven by test (to include demonstrations), but unlike many performance requirements a single test is often not enough to show that R&M has been achieved. The statistical nature of R&M requires many tests to be carried out to deliver the required level of confidence. This is generated through the provision of objective evidence in support of verification or use validation.

The number of, or length of tests required depends on the level of statistical confidence that is considered acceptable. The higher the confidence required, the more tests or the longer the test time required. Thus, a robust test plan must be developed and included within the R&M program and the main development program for the item. It should be recognized that the R&M test plan is likely to require a lot of calendar time and can be a major driver in terms of overall development time. Thus, every opportunity to use other development tests to inform the R&M tasks should be taken.

R&M requirements can be stated as a quantitative nature, but maintainability and testability can also be defined in a qualitative way. Some examples of qualitative requirements are that the item shall be designed such that:

- It does not contain any fixing device that cannot be removed using a number 2 cross head screwdriver available from any commercial source.
- Any operator can conduct the regular checks required without special knowledge or training.
- All items the user is required to inspect or top up on a regular basis shall be immediately obvious.
- It has a go no/go capability that can be run by the operator at any time to give confidence that it is fully operable and committable.

- It contains a continuously running built in test routine that identifies and reports the loss of major functions to the operator.

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 conduct the following actions.

- *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 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 requirements development documentation (ICD, Draft CDD). During the MSA Phase, data gathering should begin as soon as preliminary inputs are available from the (user) e.g., from working versions or informal review of the requirements development documents. For each parameter, list the notes, rationale, and assumptions stated in the requirements development 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 requirements development 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 MDCS 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 are needed to validate A_O and A_M 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, considering 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 requirements development 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 estimated and required R&M (both of which should be based on the FDSC). Any disparity should be addressed to ensure the estimated and required values are based on the same criteria.
    - *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 estimates 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 Estimation* – 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 is not available, engineering estimates should be made based on best practices.
    - *R&M Requirements Trade Studies* – Perform sensitivity analysis (Figure 2-2) that shows the range of R&M parameters (e.g., Mean Time Between Failure (MTBF) and MDT) that will satisfy the A_O 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.

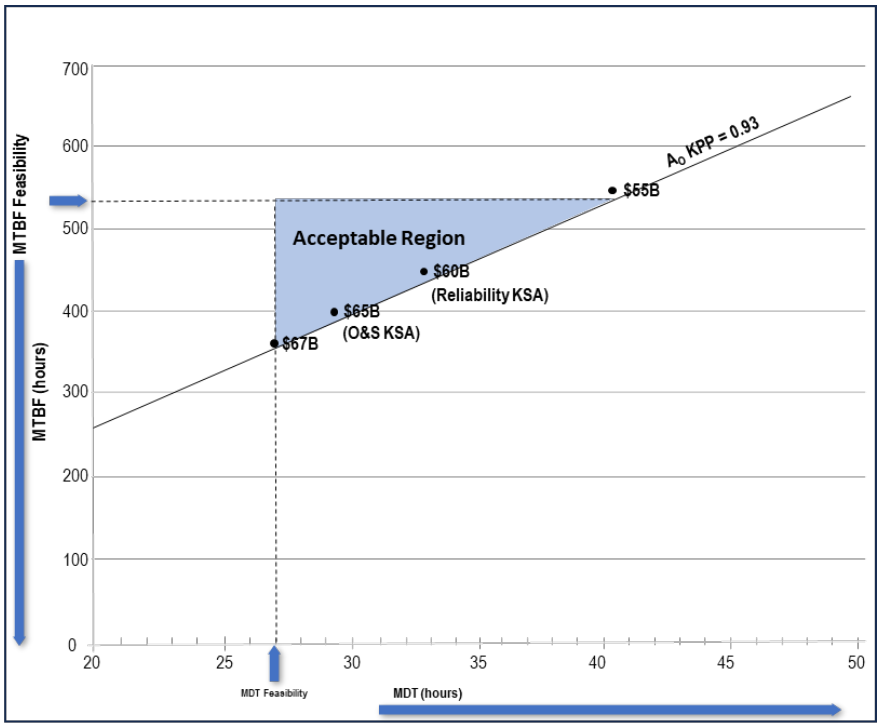


Figure 2-2. R&M Sensitivity Analysis

- *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, Milestone B, and Milestone 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 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.

2.2.2 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 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. Note that the ICD will likely not include quantitative thresholds, if available review the Draft CDD or equivalent operational requirements document.
- *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.

2.3 TEST AND EVALUATION

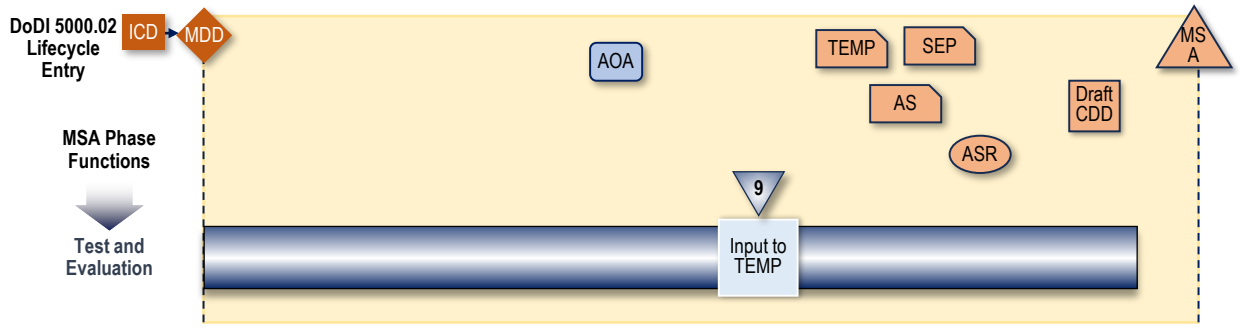


Table 2-4 lists the primary R&M activity for the Test and Evaluation functional area in the MSA phase.

Table 2-4. R&M T&E Activities – MSA Phase

Activity	Description
9 • Provide R&M input to the TEMP/TES	• Specify in the TEMP/TES how the reliability will be tested and evaluated in the associated acquisition phase.

2.3.1 Provide R&M Input to TEMP/TES 9

The program must identify R&M test requirements early in the TEMP/TES to ensure cost and schedule impacts are addressed in acquisition planning and contractor proposals. TES is the Test and Evaluation Strategy, an early, less detailed planning document that evolves into the TEMP over the program's life cycle. The program can reduce R&M testing costs by embedding measurement requirements and test conditions into existing equipment and system-level environmental and functional tests. These tests then also can inform reliability analysis and 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 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.

- *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 2-3). Depict the progression of required system level R&M performance tests, to the system R&M demonstration described above.

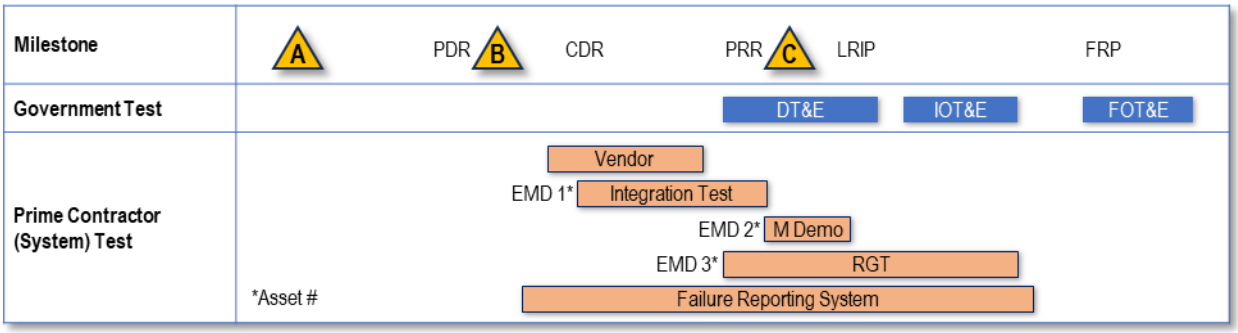


Figure 2-3. Sample Test Sequence

- *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 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.

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, planning, and cost estimating of the desired integrated test program.

2.4 PROCUREMENT

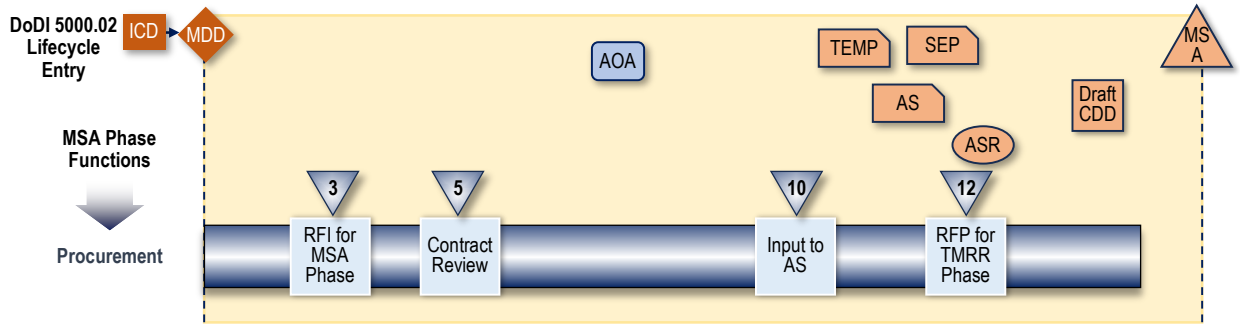


Table 2-5 lists the primary R&M activities associated with the activities for the Procurement functional area in the MSA phase.

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

Activity	Description
3 Prepare R&M input to MSA phase RFI or study contracts	• 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	• Review negotiated MSA phase RFI or study contracts to verify conformance to requirements.
10 Provide R&M input to Acq Strat	• Prepare input to the Acq Strat outlining the R&M requirements and activities for the TMRR phase.
12 Prepare R&M input to RFP for TMRR phase	• 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.

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

3 5

Once R&M activities and data needs are defined for the MSA phase, they should be incorporated into the 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 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.

2.4.2 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 Acquisition Strategy: Control Procedure

Describe the requirements and appropriately tailored R&M engineering activities for the Acq Strat being used. The Acq Strat Template contains the following requirements requiring an R&M input:

- Indicate the key operational and sustainment requirements for this system (i.e., the time-phased capability requirements as described in the Initial Capabilities Document, Capability

Development Document, and/or Capability Production Document). Highlight system characteristics driven by interoperability and/or joint integrated architectures, capability areas, and family- or system-of-systems.

- Identify the engineering activities to be stated in the RFP and required of the contractor to demonstrate the achievement of the reliability and maintainability design requirements.
- Describe how the support concept ensures integration with other logistics support and combat support functions to optimize total system availability while minimizing cost and the logistics footprint.
- Provide a table to specify how the Sustainment KPP thresholds have been translated into reliability and maintainability design and contract specifications. The actual format of this table may be varied to suit the nature of the procurement or to add additional requirements. The reliability threshold is often expressed as a probability of success for a given period of time and is translated to appropriate life units (e.g., miles, hours, cycles) to facilitate assessment during testing or to estimate the required quantity of spares. Input to Acq Strat: 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 Acquisition Strategy: 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.

2.4.3 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. Planned R&M tests or demonstrations 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.
- 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, estimate, 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 (estimates and predictions) to be performed at major systems engineering reviews, 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.

2.5 PRODUCT SUPPORT

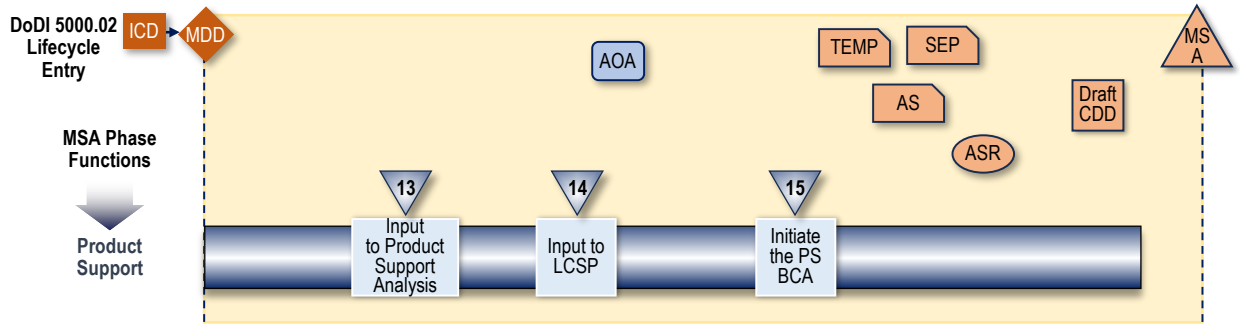


Table 2-6 lists the primary R&M activities associated with the Product Support functional area in the MSA phase.

Table 2-6. R&M Product Support Activities – MSA Phase

Activity		Description
13	Provide R&M Input to Product Support Analysis	Provide R&M inputs to Product Support based on R&M analyses and RAM-C report.
14	Provide R&M Input to LCSP	Provide R&M inputs to the Life Cycle Sustainment Plan (LCSP).
15	Conduct a BCA	Provide a structured framework for evaluating different product support options and making informed decisions. Includes a thorough assessment of potential risks associated with each alternative.

In addition to these tasks, tasks in the R&M Engineering Management and Systems Engineering functional areas contribute and support PS.

- The draft CDD is reviewed for R&M objectives. For each sustainment requirement in the Draft CDD and other requirements documents, the LCSP will document:
  - Which are the KPP/KSA/APAs.
  - Their authoritative requirements document.
  - Threshold and objective values.
- The CONOPS established by the applicable joint capabilities document is reviewed to refine (if necessary) the operational sequence, sustainment functions, and R&M capabilities
- The R&M engineering management planning performed early in the MSA phase should be updated continuously in subsequent phases of acquisition, to provide PSM with a dynamic

source of data pertaining to specific R&M requirements, current status, problems, and progress relative to established R&M activities.

- The R&M activities identified during planning for the MSA phase are used to provide inputs to the LCSP.

2.5.1 Provide R&M Input to PS Analysis 

Product Support Analysis (PSA) is a wide range of analyses conducted within the systems engineering process. The goals of PSA are to ensure that supportability is included as a system performance requirement and to ensure the system is concurrently developed or acquired with the optimal support system and infrastructure.

PSA includes the integration of various analytical techniques with the objective of designing and developing an effective and efficient Product Support Package. The primary techniques used in PSA are:

- *Failure Mode, Effects, and Criticality Analysis (FMECA)* – The FMECA is performed by a team consisting of the R&M engineer, design engineers, safety, and other program specialists to identify independent single item failures and the resulting potential impact on mission success, performance, safety, and maintainability.
  - The FMECA is an engineering activity that informs the design and the subsequent product support analyses.
  - This analysis promotes corrective actions by identifying potential failure risk and maintainability issues in order that appropriate corrective actions may be taken early to eliminate or control high risk items to improve operational readiness and reduce life cycle cost.
  - The FMECA also establishes the baseline engineering information to identify and eliminate or control all failure modes throughout the system's life cycle.
  - Inputs to Product Support Analysis include the basis for fault detection, fault isolation, operator and maintainer failure recognition, depot test parameters and repair parts.
- *Fault Tree Analysis (FTA)* – FTA is a type of failure analysis in which an undesired state of a system is examined. This analysis method is mainly used in safety engineering and reliability engineering to understand how systems can fail, to identify the best ways to reduce risk and to determine event rates of a safety accident or a particular system level failure.
  - FTA determines the areas in the product which could cause a potential failure and to determine the risk and severity of any such potential failure. The timing of this analysis is important and should start during the design phase to identify top-level hazards.

  - Initial fault tree diagrams might represent functional blocks (e.g., units, equipment, etc.), becoming more definitive at lower levels as the design materializes in the form of specific parts and materials.
  - The output of an FTA is a graphical or tabular representation of the chain of faults that will provide the Government with the reporting of a system failure on a platform.
  - The FTA results complement and should align to FMECA results.

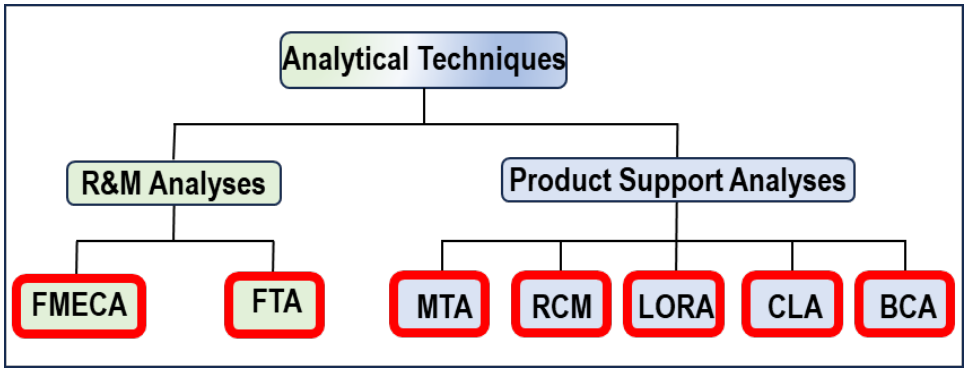
- *RCM Analysis* – RCM Analysis is a systems engineering tool that uses an analytical approach to determine the failure management strategies that should be applied to ensure a system achieves the desired levels of safety, reliability, environmental soundness, and operational readiness in the most cost-effective manner. It is developed in coordination among Systems Engineering, R&M engineering, and Product Support to ensure that RCM analysis is performed and used over the course of the weapon system life cycle.
  - The RCM process is used to determine preventive maintenance requirements. It applies to all levels of system or equipment grouping, and to all scheduled maintenance, whether equipment is in use, ready for use, or in standby or lay-up condition.
  - RCM addresses the total scheduled maintenance program for an enterprise; that is, organizational, intermediate, and depot level maintenance, regardless of the maintenance echelon possessing the capability to perform the maintenance.
  - RCM methodology provides the foundation for a CBM+ program. RCM is the process that is used to develop the maintenance tasks needed to implement CBM+. CBM+ needs to be a design criterion implemented during the MSA phase.
  - The DoW-approved RCM process includes the identification of the following items in sequence: functions, functional failures, failure modes, failure effects, failure consequences, maintenance tasks and intervals, and other logical actions. Note that a FMECA may often be part of an RCM process, but the RCM analysis should not be considered a replacement for the FMECA.
  - RCM seeks to manage the consequences of failure, not prevent all failures.
  - RCM analysis is not a replacement for the FMECA.

- *Level of Repair Analysis (LORA)* – The LORA process involves a group of three systematic and comprehensive evaluations: Economic, Noneconomic, and Sensitivity. These are conducted on an iterative basis throughout all phases of the system/equipment life cycle, and they arrive at a level of repair/discard alternatives that satisfy sustainment objectives.
  - The analysis uses updated data from R&M analysis, Product Support Analysis, Test, and Prototype evaluation.

  - Through these iterative evaluation processes, a maintenance and support concept for the system/equipment that is effective, yet economical, and can be established by influencing the system's design for supportability.
  - The LORA process should integrate design, operations, performance, cost, readiness, and product support characteristics to assist in identifying and refining the maintenance and support concept for the system/equipment.

- *Depot Level of Repair Analysis (DLORA)* – A depot-level analysis, part of LORA that helps determine the most efficient and cost-effective maintenance strategy for a system, considering where repairs should be performed (on-site, in a back shop, or at a depot). Key considerations are:
  - Cost: Analyze the costs of different repair options, including labor, parts, transportation, and downtime.
  - Operational Readiness: Assess the impact of repairs on system availability and operational readiness.
  - Resources: Consider the skills, tools, and facilities required for different repair levels.
  - Feasibility: Determine what repairs are technically feasible at each level (organizational, intermediate, and depot).
- *Maintenance Task Analysis (MTA)* – MTA is the identification of the steps, spares and materials, tools, SE, personnel skill levels, elapsed times required for the performance of each task, and any facility issues that must be considered for a given repair task. MTAs cover both corrective and preventive maintenance tasks and, when complete, identify all physical resources required to support a system. MTA applies to new hardware and software, as well as Government Off-the-Shelf (GOTS) and Commercial Off-the-Shelf (COTS) equipment. R&M inputs to an MTA include outputs from:
  - Failure Analysis (FMECA and FTA)
  - RCM analysis
  - A detailed review of the system/equipment functional requirements
  - Core Logistics Analysis (CLA)
  - Source of Repair Analysis (SORA)
  - Depot Source of Repair Analysis (DSORA).

Figure 2-4 illustrates the major R&M and PS analytical techniques. The RAM-C Rationale Analysis, jointly developed by R&M engineering, PS analysts, and cost analysts, establishes the validity and feasibility of the Sustainment parameters setting the baseline for all R&M and PS analyses.



BCA: Business Case Analysis; CLA: Core Logistics Analysis; FMECA: Failure Modes, Effects, and Criticality Analysis; FTA: Fault Tree Analysis; LORA: Level of Repair Analysis; MTA: Maintenance Task Analysis; RCM: Reliability-Centered Maintenance.

Figure 2-4. Major R&M and PS Analytical Techniques

R&M engineering should work closely with the PSM to ensure that appropriate analyses are performed and that predictive and analytical tools are used over the course of the weapon system life cycle. The R&M engineering activities supporting Product Support Analysis during the MSA acquisition phase are discussed in this section.

Input to PSA: Procedure

During the MSA acquisition phase, R&M analyses are conducted to develop realistic and achievable goals. Specific R&M engineering activities to support these goals include:

- *Making Feasibility Estimates.* Estimating the feasibility of the R&M Draft Capabilities Design Document (CDD) thresholds using block diagrams and math models and preliminary prediction analysis.
- *Conducting Trade-off Studies*. Performing trade-off studies among R&M, availability, and other system performance parameters to verify optimum balance using techniques in the DoD RAM-C Rationale Report Outline Guidance.
- *Developing Use Cases*. Supporting development of system use cases defining desired system behavior for failures including software maintenance (e.g., installing new release or patch).
- *Preparing Initial Specification*. Preparing 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.
- *Providing Data for Logistics Design Support*. Using data from the RAM-C Rationale Report and other R&M trade studies to provide the following for logistics design support
    - The initial failure mode assessment (outputs from a functional FMECA and FTA), to include effects of failure on system performance and the probable way each failure mode would be detected to provide guidance to planning and conceptual design of the

diagnostics and compensating provisions (either design provisions or operator actions to circumvent or mitigate a failure).

- Initial failure rate and removal rate estimates (from historical data), for both corrective and preventive maintenance, to provide a basis for equipment and replaceable unit spares provisioning planning.

- *Identifying R&M Drivers and Associated Risks*. Identifying R&M drivers and associated risks, establishing reliability growth strategies, ascertaining that proposed alternatives prove the feasibility of accomplishing R&M requirements, and modifying requirements as required to demonstrate feasibility and practicality.

- *Performing R&M Requirements Analysis***.** The R&M engineer should review the desired capabilities established in the Initial Capabilities Document (ICD) or updated by subsequent documentation to refine (if necessary) the Operational Mode Summary/Mission Profile (OMS/MP) operational sequence, and maintenance concept. The goal of this activity 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. Working closely with the Life Cycle Logistician (LCL) and Cost Analyst, the R&M engineer performs the preliminary R&M analyses, feasibility, and trade-off studies of the design concepts required for the RAM-C Rationale analysis activities that include:
  - Identifying major subsystems that are subject to R&M requirements.
  - Identifying the sustainment capabilities and parameters being proposed in the requirements development 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 requirements development documents).
  - Summarizing the Operational Mode Summary/Mission Profile (OMS/MP) and environment expected for the materiel solution, highlighting 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.
  - Listing 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 A_O and A_M and should provide a realistic, definitive, and uniform basis to determine downtime.
  - Assessing the sustainment parameters to ensure they are valid. The parameters should support each other, as shown by calculation and/or modeling and simulation and be traceable to the appropriate requirements development document.

- Developing a composite model of the system that is based on the best available R&M data that would apply to those subsystems. Sources include legacy, similar systems, market surveys and actual data from the system under development.

- *Performing 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 characteristics, availability, and life cycle cost factors that govern the operational suitability for the alternatives being considered in the Analysis of Alternatives (AoA).

  R&M engineers perform the following analyses in support of the series of trade-off studies[12]:

  - 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. 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.

- *Preparing the RAM-C Report*. The RAM-C Rationale Report is prepared using current guidance and the information provided by the Requirements Analysis. The RAM-C Rationale Report is attached to the Systems Engineering Plan (SEP). The report describes the sustainment parameters, maintenance concept, feasibility, and trade-off analyses for each alternative investigated. The initial RAM-C Rationale Report supports the Milestone (MS) A

[12] Results of trade-off studies and availability modeling should be prepared and documented in the RAM-C Rationale Report.

decision point. Updates to the RAM-C Rationale Report are prepared to support all subsequent program decision points.

- *Providing Input to Product Support Analysis*. Product support planning personnel[13] develop maintenance plans, provisioning plans, and plans for application of automatic test equipment (ATE) based on realistic estimates of equipment failure/removal rates, failure modes, and diagnostics concept developed as part of the AoA and the RAM-C process.
    - Trade studies among reliability, maintainability, alternative maintenance concepts, and product support requirements should be performed by R&M engineers working in cooperation with product support planning personnel.
    - Results of the R&M assessments should be provided to product support and documented in the Life Cycle Sustainment Plan (LCSP), maintenance concept/plans, and other product support planning documents.
    - Though the conceptual design during the MSA phase is preliminary, failure and removal rate estimates should be provided to the lowest level of configuration for which conceptual design data is available.

Input to PSA: Data

The R&M engineer should provide the results of R&M assessments to Product Support and to document them in MSA plans, such as the LCSP and other Product Support plans. These plans should evolve as a cumulative process, based on R&M statuses derived from in-process reviews performed for each of the R&M tasks in concept formulation.

Input to PSA: Review Criteria

An accept decision on preliminary maintenance and logistics support plans can be made, from an R&M point of view, when the following criteria are satisfied:

- *Data Validity* – Equipment failure rates and removal rates should be identical to those used in the R&M analyses of Section 1.2, *Systems Engineering*, and reflected in the RAM-C report, and failure mode estimates should be based on verified experience data from predecessor systems of similar design.
- *Data Utilization* – Maintenance concept and provisioning plans should be based on the RAM-C analysis for the current design configuration.

[13] R&M engineers collaborate with Life Cycle Logisticians (LCLs) to incorporate the results of R&M engineering analyses into PSA.

Failure to satisfy these criteria should result in a decision to require restudy of maintenance and logistics planning factors, using the required validated data.

2.5.2 Provide Input to LCSP 

The LCSP documents the plan for formulating, implementing and executing the sustainment strategy so that the system's design as well as the development of the PS package are integrated and contribute to the mission requirements by achieving and maintaining the Sustainment KPP and KSAs. The LCSP starts in the MSA phase as the sustainment concept. At this stage, the LCSP will capture initial support and maintenance concepts based on AoA results and requirements identified in the ICD.

The LCSP is written using the outline per the LCSP Outline V3.0 dated October 13, 2022. The sections most germane for R&M are:

- PSS
- PS performance
  - Supply Support
  - Packaging, Handling, Storage, and Transportation (PHS&T) Planning
  - Maintenance Planning and Management
    - Maintenance Concept
    - Depot Activation Planning
  - Design Interface and Sustaining Engineering
    - Supportability Analysis
    - Design Analysis
    - Failure Modes, Effects, and Criticality Analysis (FMECA)
    - Reliability
  - Technical Data
  - Information Technology (IT) Systems Continuous Support
    - Cybersecurity
    - Software Sustainment and Software/System Operability
    - Digital Product Support
  - Manpower and Personnel
  - Training and Training Support

- SE
- Facilities and Infrastructure (Including Leveraging Enterprise Opportunities Across Programs and DoW Components)
- Product Support Arrangements
- Product Support Risk, Issue or Opportunity Management
- Obsolescence Risk Management
- Supply Chain Risk Management
- Manufacturing Risk
- Sustainment Considerations
- Influencing Design and Sustainment
- Program and Design Reviews
- Program Funding and Life-Cycle Cost Estimate

LCSP: Procedure

The R&M program planning and the LCSP must identify and define the interfaces between R&M as an engineering function and the planning functions of the product support activities. The R&M program should participate with product support in the development of maintenance concepts and detailed maintenance plans based on specified operational and support requirements for the system. Maintenance concepts and plans are to be evolved concurrently (and iteratively) with each R&M design analysis to establish an optimum maintenance concept as the basis for equipment design and logistics support planning.

PS planning tasks identify requirements for R&M engineering coordination or direct participation for effective task execution. The mutually dependent task interfaces relevant to the MSA Phase are discussed below as part of the LCSP:

- PSS[14]. As stated earlier, the PSS is the overarching approach to meet sustainment requirements. The goal of the PSS is to balance and integrate the support activities necessary to design weapon systems to affordably deliver the required warfighting capability and to ensure the product support solution is efficient and effective and reduces the demand for product support while meeting warfighter requirements. The PSS should be considered early and continually addressed throughout development and production. DoDI 5000.91 requires that an LCSP be developed and approved no later than Milestone A.

[14] For details on developing the PSS, refer to the Product Support Manager Handbook, The Office of the Deputy Assistant Secretary of Defense for Product Support, May 2022.

- Supply Support. Early in development, the PSM should describe the approach to identify, plan for, resource, and implement management actions to provisioning spares and repair parts necessary to maintain the system following delivery to the field. R&M data essential to these plans includes failure rate and failure mode and effects analysis of replaceable items for each level of maintenance.
- PHS&T. PHS&T requirements are needed to maximize availability and usability of the materiel, including support items whenever they are needed for training or mission success. Management controls are established to ensure consideration of system requirements and constraints related to (or dependent on) PHS&T of the system and its lower-level elements. R&M data required for the execution of this task includes failure mode and effects analyses.
- Maintenance Planning and Management. This section elaborates on the overall maintenance concept and overhaul requirements. The plan describes maintenance concepts and repair policies for the system, logistics resources required for all levels of maintenance, and basic maintenance procedures. This information includes, for example, a description of the maintenance approach (e.g., preventive, predictive, prognostic; use of RCM or equivalent processes); levels of maintenance for the platform and major sub-systems; CBM+ concept and architecture; scheduled maintenance (including calendar or operating hours/cycles-based); and other factors relevant to maintenance, repair, and overhaul. Maintenance planning is developed in the MSA phase and is defined and updated as design progresses. The program should ensure close coordination (and joint participation) among R&M analyses and maintenance engineering activities.
- Design Interface and Sustaining Engineering. This section aligns with the activities and events required to incrementally develop and inform logistics products (e.g., maintenance and repair manuals and maintainability demonstrations and test events) to identify design flaws to make necessary improvements that meet operational (user) objectives, through the lens of actual users. Likewise, design interface and sustaining engineering identified in the System Engineering Plan (SEP) should also align with the product support strategy, so the product support community can reference important engagement points as the weapon system design matures. The PSM team is encouraged to interface with the engineering team, especially the R&M engineer, reviewing draft FMECA, RAM, reliability growth planning, and other DI documentation such as FRACAS, FTA, MTA and LORA. This process ensures a common understanding of failure modes, and the impacts to the technical manuals, training, manpower and skillsets.
- Reliability. As part of PS planning and execution, it is critical to identify the top system and subsystem reliability drivers and issues that affect O&S cost, including allocations and current estimates. This activity includes identifying the impacts to maintenance procedures, repair capabilities, spares, manpower, and training, and mitigation actions, including potential actions if the reliability allocation is not achieved. The R&M engineer provides estimates of reliability, achieved to date and projected, identifies critical failures, helps in

developing actions to mitigate failures, and provides inputs to that include the basis for fault detection, fault isolation, operator and maintainer failure recognition, depot test parameters and repair parts.

LCSP: Data

Results of the maintenance analyses and RAM-C should be reflected in the maintenance concept and product support planning described in the LCSP. Integration with R&M and systems engineering should also be described as just stated and should complement the SEP and other program planning documents.

LCSP: Review Criteria

An approval decision from an R&M perspective can be made when review of the LCSP indicates that R&M data, requirements, schedule, and engineering tasks are properly integrated into the PS program. Failure to achieve this integration should result in withholding approval of the LCSP documentation pending correction of deficiencies.

2.5.3 Conduct a PS BCA 

A PS BCA[15] uses a structured methodology that aids decision making by identifying and comparing possible PSS alternatives. The PS BCA process includes a careful analysis of the mission and business impacts (both financial and non-financial), including risk and sensitivity impacts, to inform a program's LCSP. A PS BCA may be somewhat different from other decision support analyses because it emphasizes the enterprise wide perspective of stakeholders and decision makers, and it assesses the holistic effects impacted by the decision. Other names for a PS BCA are Economic Analysis, Cost-Benefit Analysis, and Benefit/Cost Analysis. The PS BCA process culminates in a PS BCA Report, which - once approved - is included as an annex in the program's LCSP. PS BCAs are completed and revalidated throughout the life cycle. The data, factors, alternatives, and focus of the PS BCA will evolve consistent with the point at which the analysis is performed within the life cycle.

The primary goal of the PS BCA is to analyze and determine the best value PSS of the system at the notional, projected, or known, work breakdown structure (WBS) level. Once the system is analyzed at the WBS level, the PM can then consider broader Department-wide impacts and context throughout the analysis. The PSM prepares a PS BCA, often based on analogous system data, to inform designing for supportability after understanding past performance (e.g., system's actual performance of the IPS elements, root causes to cost drivers, technical data, software, and license rights impacts, lessons learned) during program development. This analysis helps the

[15] The discussion of the PS BCA in this document is necessarily limited. For complete details on conducting a PS BCA, consult the PS BCA Guidebook, Deputy Assistant Secretary of Defense for Product Support, July 2024.

PSM integrated product team (IPT) drive a best value maintenance concept, supply support concept, modular open systems approach (MOSA) and supplemental supply support and maintenance concepts in a contested logistics environment.

A successful PS BCA has three major elements: (1) a clearly identified purpose, (2) detailed process elements, which are further elaborated in the PS BCA process steps and (3) a quality foundation comprising governance, data (to include measurement against the prior PS BCA baseline), and planning (see Figure 2-5). The PS BCA begins with identification of the problem statement, objectives, and metrics; these should clearly annotate what issue the PS BCA is attempting to solve and how success will be measured. The PS BCA process elements are those subsections of the PS BCA that directly execute and report on analytical actions. The PS BCA supporting foundation should reflect the quality and completeness of the analysis which includes background research, proper planning, governance, and data management. Such control provides a foundation for critical thinking and analysis throughout the process. It is important to establish a strong foundation – with effective governance and oversight – to ensure the PS BCA maintains an enterprise-wide context that will guide the analysis. These three elements work together to ensure the PS BCA targets the relevant subject matter, credibly analyzes and reports the results, and integrates into the organization's mission and vision.

Although the logistician is responsible for ensuring the sustainment strategy, requirements, and performance measures are addressed in the PS BCA, engineering support is required. Systems engineers, typically supported by R&M engineers, system safety and environmental safety and occupational health engineers, and human systems integrators validate that the alternatives are considering operationally suitable requirements which are technically feasible to achieve optimal total system performance at minimal life cycle cost.

It is essential to identify the warfighters' desired outcomes in addition to documented requirements. Identifying both the desired outcomes and requirements ensures that the results of the analysis are not buried in the details of the requirements. The PS BCA team and its stakeholders should come to consensus on the desired outcomes and periodically refer to them to stay on track. The governance board should concur with planned deliverables and outcomes. After identifying the desired outcomes, state the program requirements. DoDI 3110.05, "Sustainment Health Metrics in Support of Materiel Availability," establishes other criteria, including availability and cost changes. For MCA programs, sources of the requirements include KPPs, KSAs, Performance Metrics identified in the Reliability, Availability, Maintainability-Cost (RAM-C) Rationale Report, CDD, Legacy System Capabilities Production Document (CPD), or updates to these documents. The Sustainment KPP and the R&M KSAs are particularly of importance. For programs in acquisition pathways other than the MCA, requirements are determined within the appropriate governing DoDIs.

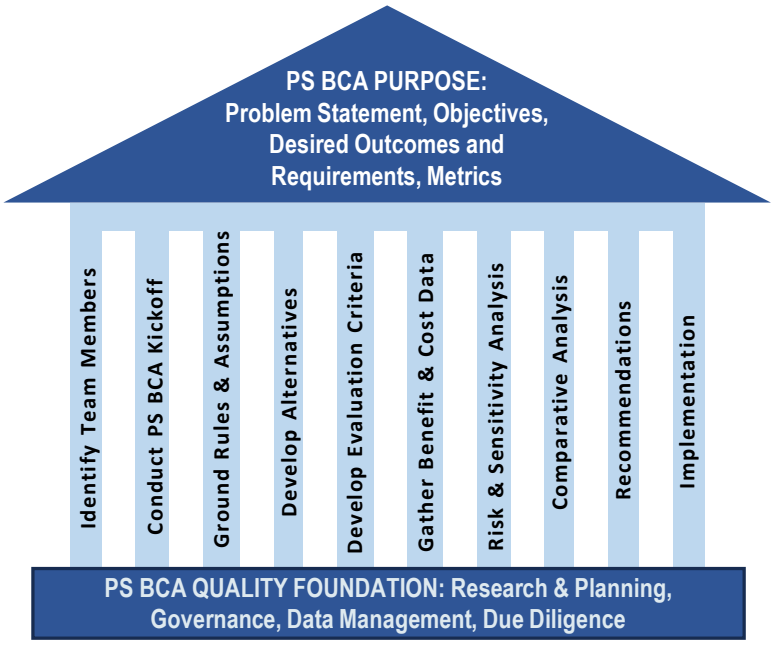


Figure 2-5. Elements of a Successful PS BCA.

BCA: Procedure

The PSM will conduct a PS BCA to assess courses of action being considered and then document (within the LCSP) the recommended course of action that achieves readiness goals, manages risks, and is cost-effective (see DoDI 5000.91 para 4.3d.). The PS BCA report and any revalidation documentation should be included as an Annex in the LCSP. The PS BCA frames the program's alternatives or courses of action for implementing the PSS, which is expanded upon and further defined and documented in the LCSP. At milestone decisions, or at least once every five years, an assessment should be made that validates the program has not changed enough to warrant a PSS change.

By Milestone A, the PSM should have:

- Developed a proposed methodology for conducting the PS BCA.
- Conducted the initial PS BCA and scoped the PS Strategy.
- Developed a strategy to acquire necessary rights and the delivery of technical data, computer software, and software documentation.
- Ensured the information and data needed is being requested and will be available.
- Developed the Implementation Plan and Communication Plan for the selected alternative.

BCA: Data

The BCA requires real-world performance, supportability (reliability, availability, and maintainability), and cost data In the MSA life cycle phase, prior to Milestone A, the PS BCA is often constrained by the lack of this real-world data, making it highly reliant on analogous data, if available.

Data can be collected from several sources including KPPs, KSAs, Performance Metrics identified in the RAM-C Rationale Report, CDD, Legacy System Capabilities Production Document (CPD) or updates to these documents.

BCA: Review Criteria

The PSM actions required by Milestone A are completed.

If the recommendations from the PS BCA are not implemented, the PSM should provide amplifying information in the program LCSP to explain the rationale behind the decision not to implement or delineate the factors inhibiting implementation.

Table 2-7 is a checklist of the required R&M inputs to PS during the MSA phase.

Table 2-7. Checklist for R&M Inputs to Product Support During MSA

R&M INPUT TO PS CHECKLIST		ADEQUATE		REMARKS
		YES	NO	
(1)	Maintenance planning and management consistent with R&M requirements.			
(2)	Preliminary maintenance concept based on and compatible with RAM-C.			
(3)	Preliminary O&S cost, provisioning and support plans based on and consistent with removal rates estimated in R&M report(s).			
(4)	Plans and schedules for contractor design of test and SE defined as integral part of system design function.			
(5)	Plans and schedules for formal review of product support/R&M coordination and planning established.			
(6)	LCSP reflects and is consistent with required and predicted R&M.			
(7)	Sustainment parameters have been assessed as feasible, consistent with state of the art and technical maturity. Any disparity between predicted and required R&M (both of which should be based on the FDSC) has been addressed to ensure the estimates are based on the same criteria.			
(8)	Initial failure modes have been assessed to determine the probable way each failure mode would be detected to provide guidance to planning and conceptual design of the diagnostics concept, recovery designs and maturation process			
(9)	Failure removal rates have been estimated for both corrective and preventive maintenance, to provide a realistic basis for equipment and replaceable unit spares provisioning planning			
(10)	Maintenance and support requirements and planning criteria are consistent with R&M requirements.			
(11)	Initial maintenance and sustainment concepts established based on & compatible with RAM-C.			
(12)	Preliminary O&S cost, provisioning and support plans are based on and consistent with removal rates estimated in R&M report(s).			
(13)	Plans and schedules for contractor design of test and SE are defined as integral part of system design function.			
(14)	Plans and schedules for formal review of PS/R&M coordination and planning established.			
(15)	Maintenance concept planning factors and the values used to determine Mean Down Time (MDT) and other maintainability KSAs or APAs needed to validate A_O and A_M are identified and provide a realistic, definitive, and uniform basis to determine downtime			
(16)	The TMRR RFP adequately addresses R&M as a discipline and its role in PS.			

2.6 MILESTONE A REVIEW

Achievement of Milestone (MS) A signifies satisfactory completion of the activities listed in Table 2-1, thus concluding the MSA phase. As part of the MS review, R&M assessments (estimates and predictions) 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. Assessment includes reviewing the R&M activities proposed by the Government in the RFP (SOW and data requirements), specification(s), tests, and demonstrations to ensure adequate control of R&M during the TMRR phase.

2.6.1 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, SOW, 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
- LCSP
- PSA
- An initial PS BCA

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:

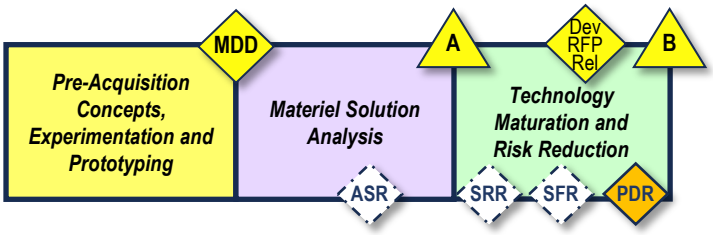
- *Verify Analytical Procedures* – Verify accuracy and appropriateness of mathematical models and methods, their consistency with functional block diagrams, and their representativeness of "current" conceptual design configuration.
- *Validate Data* – Validate the input data (e.g., failure rates and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

2.6.2 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.

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



Objectives of the Technology Maturation and Risk Reduction Phase

During the 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 PDR in the TMRR phase) and contract for the 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 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 3-1 shows the primary activities to be performed during the TMRR phase. Table 3-1 lists the activities in approximate chronological order. The activities are usually performed jointly by DoW acquisition component program personnel and the contractor. Government R&M personnel are responsible for in-process monitoring and control of the activities.

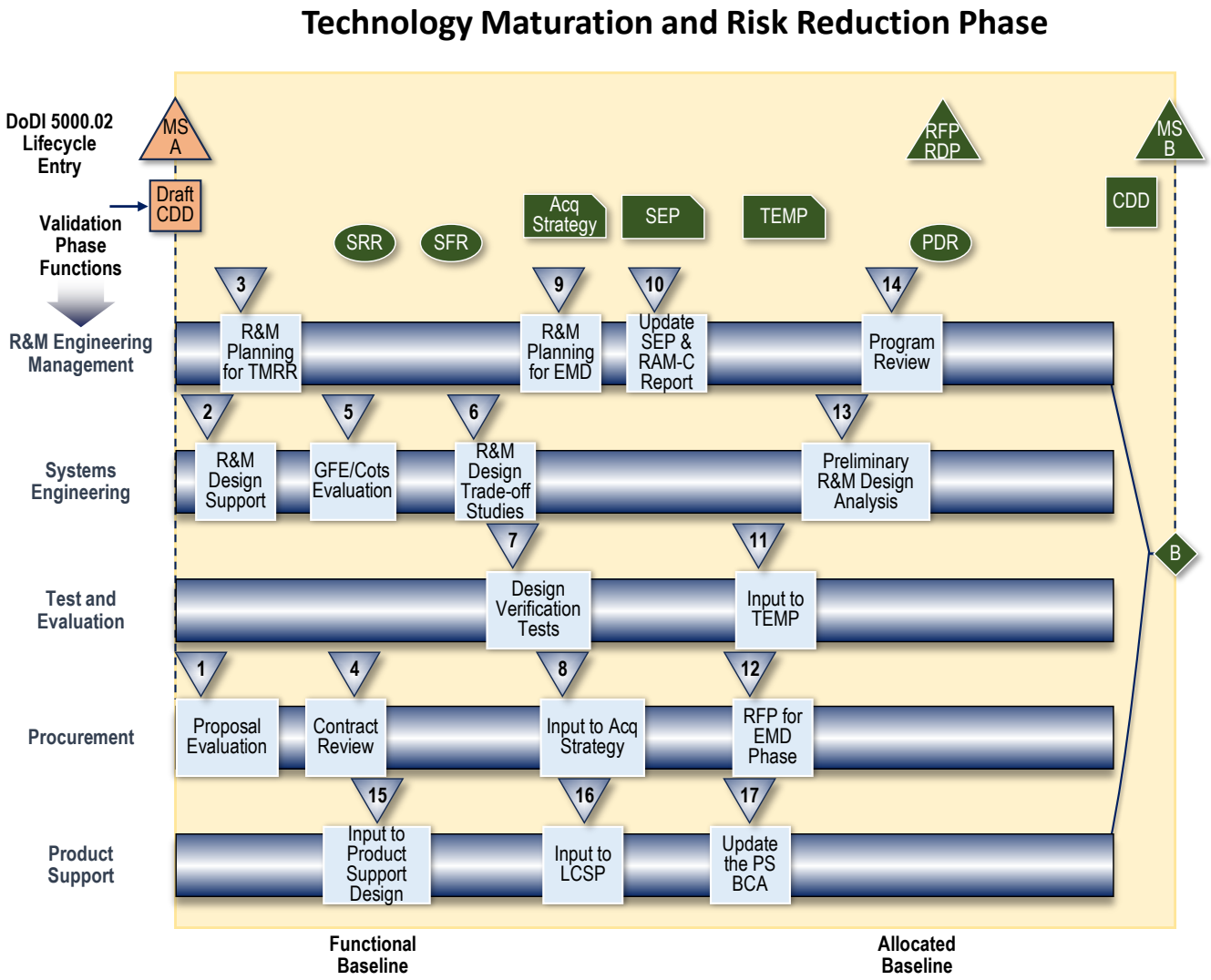


Figure 3-1. TMRR Phase R&M Activities by Functional Area

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

TMRR R&M Activity		Functional Area	Paragraph
1	Evaluate proposals	Procurement	3.4.1
2	Provide R&M design support	Systems Engineering	3.2.1
3	Develop/review R&M planning for TMRR phase	R&M Engineering Management	3.1.1
4	Review TMRR phase contract	Procurement	3.4.2
5	Evaluate GFE/COTS	Systems Engineering	3.2.2
6	Perform design trade-off studies	Systems Engineering	3.2.3
7	Conduct design verification tests	Test and Evaluation	3.3.1
8	Provide R&M input to Acquisition Strategy	Procurement	3.4.3
9	Develop R&M planning for EMD phase	R&M Engineering Management	3.1.2
10	Update SEP and RAM-C Report	R&M Engineering Management	3.1.3
11	Provide R&M input to TEMP for EMD	Test and Evaluation	3.3.2
12	Prepare R&M input to RFP for EMD phase	Procurement	3.4.4
13	Conduct preliminary R&M design analyses	Systems Engineering	3.2.4
14	Conduct program review	R&M Engineering Management	3.1.4
15	Provide input to Product Support Design	Product Support	3.5.1
16	Provide input to LCSP	Product Support	3.5.2
17	Update the PS BCS	Product Support	3.5.3

3.1 R&M Engineering Management

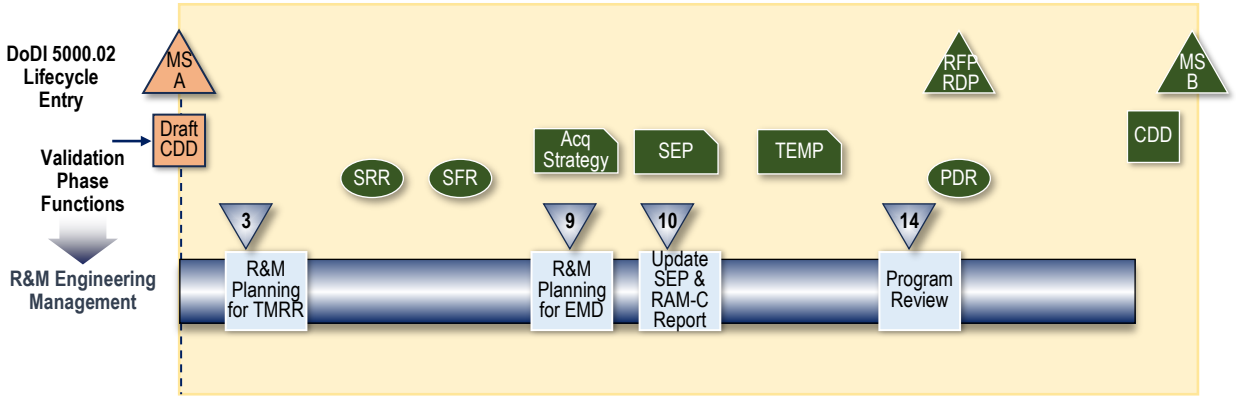


Table 3-2 lists the primary R&M activities associated with the R&M Engineering Management functional area in the TMRR phase.

Table 3-2. 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.

3.1.1 Develop/Review R&M Planning for TMRR Phase 3

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 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 3-1 and Table 3-1, 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 (Acq Strat), the RAM-C Report, the 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. *E*nsure that the R&M system and 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 WBS, 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 estimation, 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 preceding control procedure and data requirements.

3.1.2 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 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.

3.1.3 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: 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

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.

3.1.4 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 (estimates and predictions) 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 estimate analysis of design R&M; 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.

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 (estimate and prediction) 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 estimates verify feasibility of achievement of design requirements as defined in the functional baseline specification.

3.2 SYSTEMS ENGINEERING

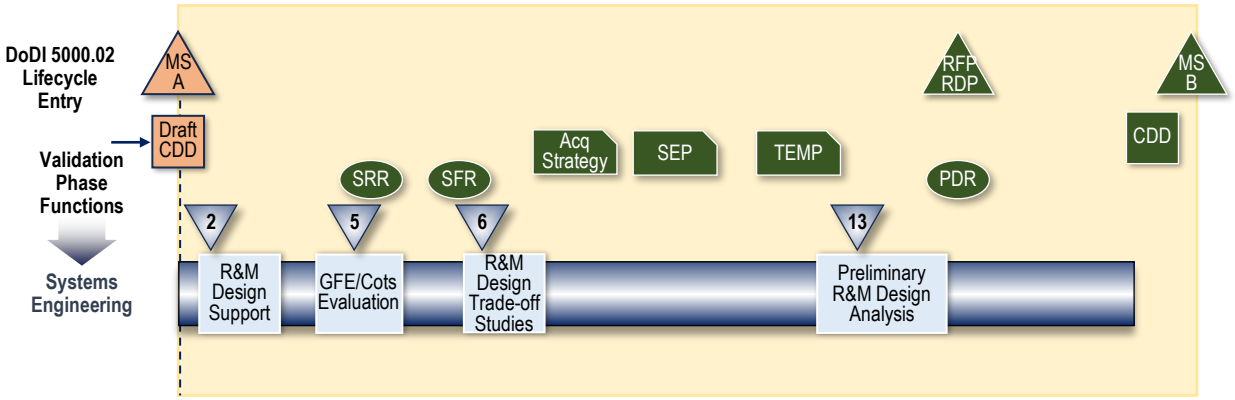


Table 3-3 lists the primary R&M activities associated with the Systems Engineering functional area in the TMRR phase.

Table 3-3. 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.
5 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.

3.2.1 Provide R&M Design Support 2

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: 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 (MAR) 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, weight, 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.

3.2.2 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 been 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 estimated) failure rates, repair rates, and 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.

3.2.3 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 estimates, 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:

- *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, estimated, 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 – D*esign 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.

3.2.4 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.

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 processes described in the following paragraphs constitute the R&M design analyses to be performed prior to appropriate design reviews. Not all these processes may be required for every program. The specific processes 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 design 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 design analyses in roughly the following order:

(1) Parts Derating Guideline and Stress Analysis

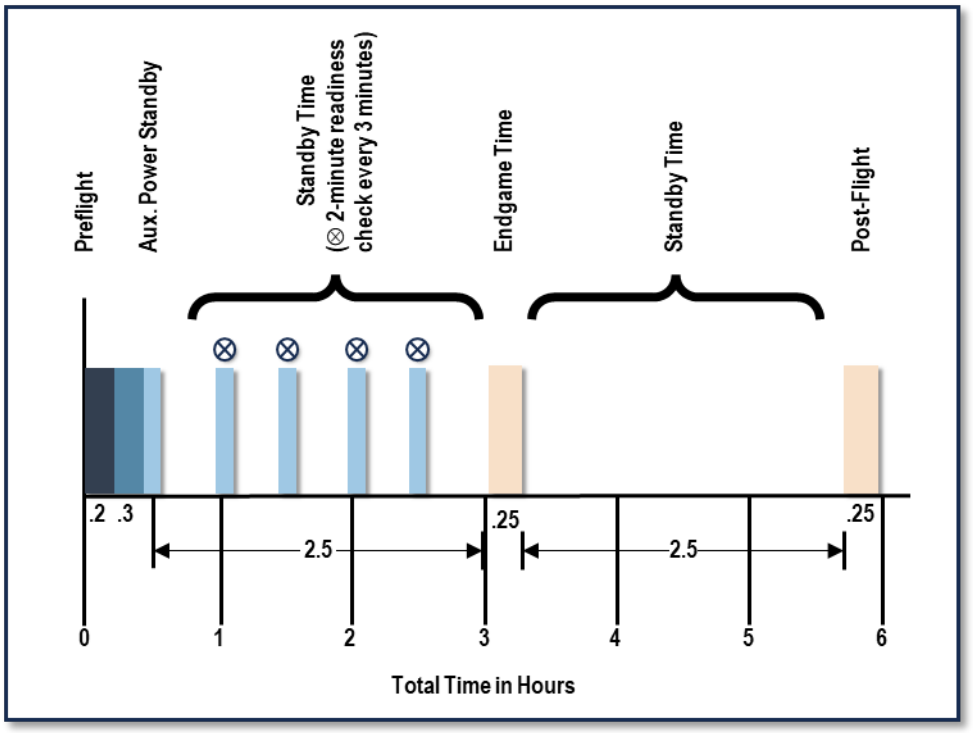
Establish, use, and maintain design derating for all types of electrical and mechanical parts and materials to provide for reliable operation at the maximum operating stress levels. These design deratings should be based on the maximum rating for the parts and materials that, as limiting values, define 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 3-2 illustrates a sample mission profile for an aircraft.

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.



Source: Original BoK
Figure 2-2. Sample Aircraft Mission Profile

Figure 3-2. Sample Aircraft Mission Profile

Contractors need to know what parameter exceedance will be scored as mission critical in the FDSC process.

(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.

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.

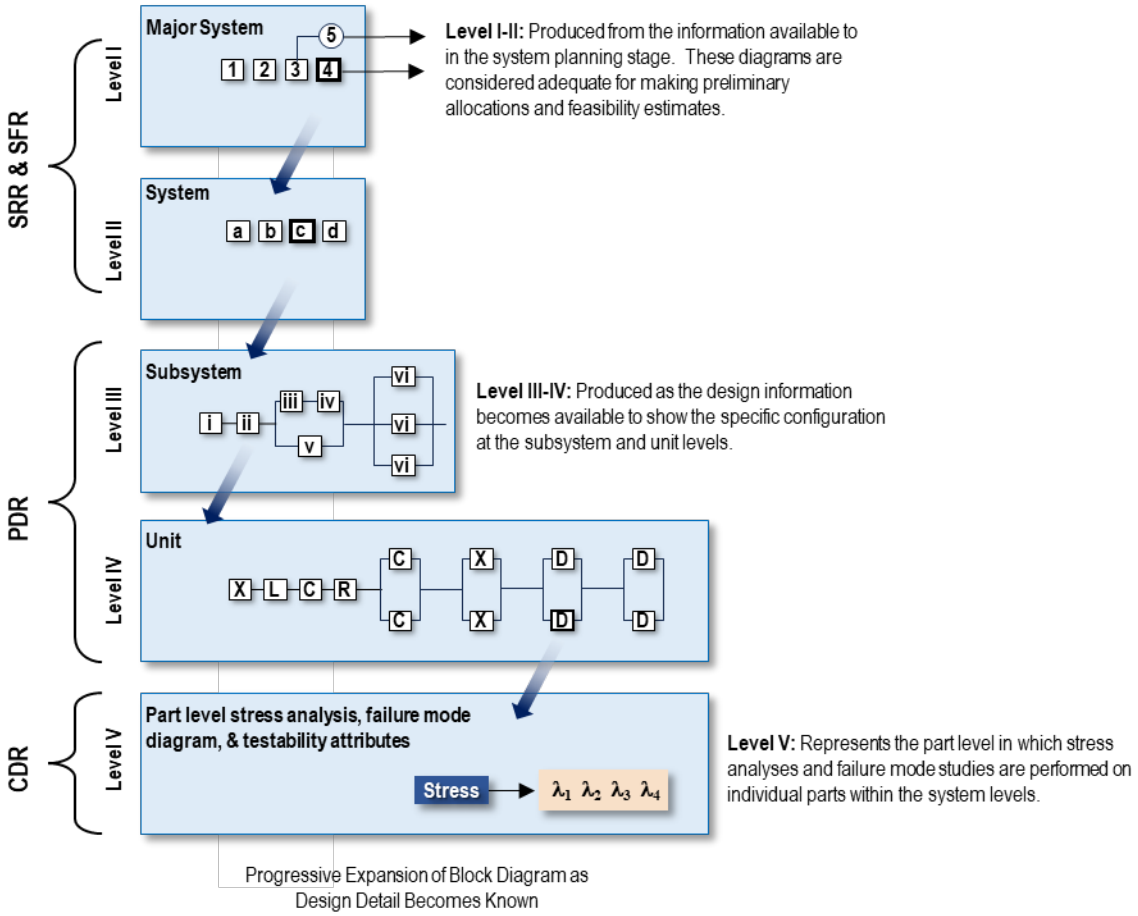
The more completely the life cycle profile is defined and understood, the better the system can be designed for reliability. In the total mission, the events and situations representing a significant portion of an item's life are systematically analyzed to determine their effect on reliability. The total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

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) Interface: Frequencies G-Levels Duration Thermal and Humidity: Heat Sink Characteristics (water coolants, et Cooling Capacity	
Interactions with Support Systems	**Description**
Maintenance Policy: Off-board/On-board Maintenance Tools Preventive and Marginal Testing Procedures Level of Technician Qualification Operating Policy: Procedures Qualification of Personnel Failure Dependencies: Isolation Requirements Protective Features, Inherent Fail-Safe Protection Required	
Interference from (and to) Adjacent Systems	**Description**
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 3-3. 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 estimates. One approach to R&M block diagrams contains several levels of indenture. Figure 3-4 illustrates a sample block diagram.



Source: Derived from DI-SESS-81496B

Figure 3-4. 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, consider 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 Estimates

The role of R&M estimates during design is to provide an evaluation of the proposed design or a comparison of alternative designs. Historically, the term “prediction” is used. Estimates are more inclusive than predictions. Prediction is most associated with using statistical methods to assess reliability. An estimate is broader and includes assessments based on statistical methods, field data, engineering judgment, and other analysis. R&M estimation is the process of quantitatively assessing the system’s R&M performance during its development. There is inherent uncertainty involved in R&M estimates. Care should be taken to understand the level of uncertainty present in the estimate, 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. Estimates should be used as the basis for refining design alternatives and for evaluating the feasibility (estimate versus specification requirement) and risk factors associated with R&M requirements.

Reliability estimation methods include using historical data, parts count, stress analyses, and physics of failure methods during design and field data during operation. These methods require different types of data sets to operate, and they vary in degree of information needed to apply them. Consequently, each estimation effort is evaluated in view of the development phase it represents. For more information on best practices for making R&M estimates, see Best

Practices to Achieve Better Reliability and Maintainability Estimates for DoD Systems (OUSD(R&E) February 2025).

Maintainability estimates 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 estimation 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 estimates 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 estimate 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.

3.2.5 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 estimates 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).
    - 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.
  - Draft FDSC
- By PDR:
  - Design derating guide and criteria.
  - Final environmental studies.

  - R&M block diagrams, allocations, and estimates 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 the following.
  - Definition of equipment failure in terms of required performance parameters.
  - Description of source of data and analytical models and methods used in the estimate analysis and basis for the assumption of validity.
  - Preliminary identification and description of R&M problems, solution alternatives, and growth potential.

3.2.6 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 estimates 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.

3.3 TEST AND EVALUATION

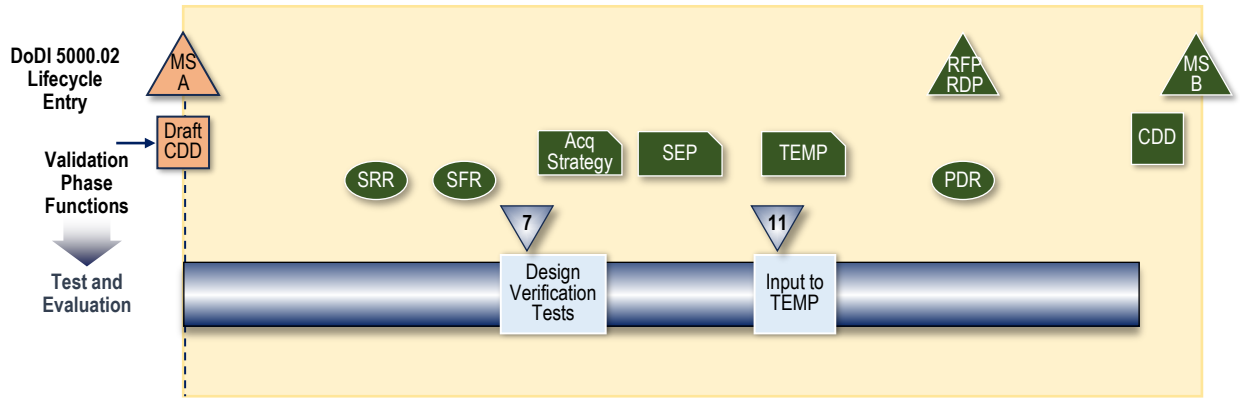


Table 3-4 lists the R&M engineering activities applicable to the TMRR phase Test and Evaluation functional area.

Table 3-4. Test and Evaluation R&M Activities – TMRR Phase

R&M Activity		Description
7	Conduct design verification tests	Review R&M verification tests to verify adequacy of the test program and evaluate significance of test results.
11	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.

3.3.1 Conduct Design Verification Tests 7

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., estimates, 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.
- *Tolerance and Interaction Problems* – Evaluate design interface tolerances, interaction and interference problems, and other problems 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.

3.3.2 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 TMRR.

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 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, describing the conditions and measurement requirements to be integrated into scheduled applicable equipment, subsystem, and system development tests. 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 3-5 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 TRR, 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.

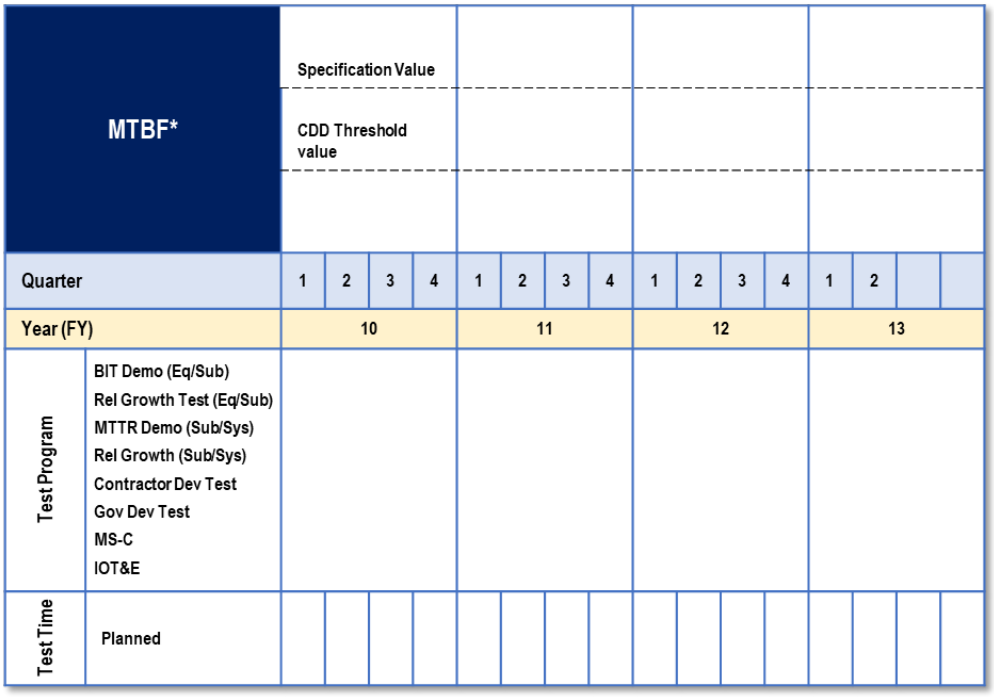


Figure 3-5. Sample EMD Test Sequence and SEP/TEMP Sample Growth Curve

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

3.4 PROCUREMENT

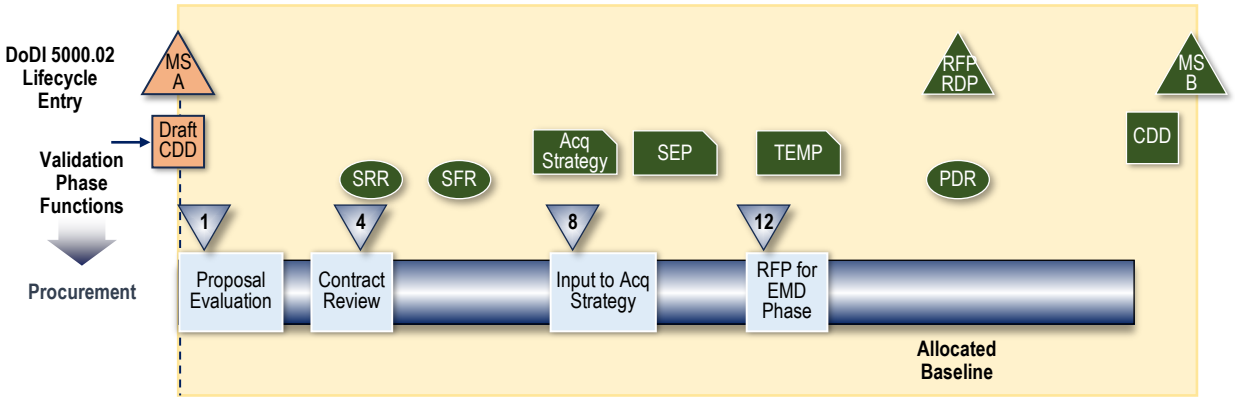


Table 3-5 lists the primary R&M activities associated with the Procurement functional area in the TMRR phase.

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

R&M Activity	Description
1 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.
4 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.
8 Provide R&M input to Acquisition Strategy	Provide R&M-specific language for incorporation into the Acquisition Strategy.
12 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.

3.4.1 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 a program receives Milestone B approval to proceed from the TMRR phase to the EMD phase under the provisions of DoDI 5000.85, “Major Capability Acquisition,” 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 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* – *C*omplete 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.

3.4.2 Review TMRR Phase Contract 

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 DoW 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.

3.4.3 Provide R&M Input to Acquisition Strategy 

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

Input to Acquisition Strategy: Procedure

- Prepare R&M Input to RFP for EMD, describes the activities to be performed that will result in the inputs to the Acq Strat. The Acq Strat Template 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 reliability and maintainability design requirements.
  - Provide a table to specify how the Sustainment KPP thresholds have been translated into R&M design and contract specifications.

Input to Acquisition Strategy: Data

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

Input to Acquisition Strategy: Review Criteria

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

3.4.4 Prepare R&M Input to RFP for EMD Phase 

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.
- *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:
  - Data requirements (CDRLs and Data Item Descriptions (DIDs)).
  - Integrated test requirements, including demonstration and test design requirements and criteria.
  - 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: 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.

3.5 PRODUCT SUPPORT

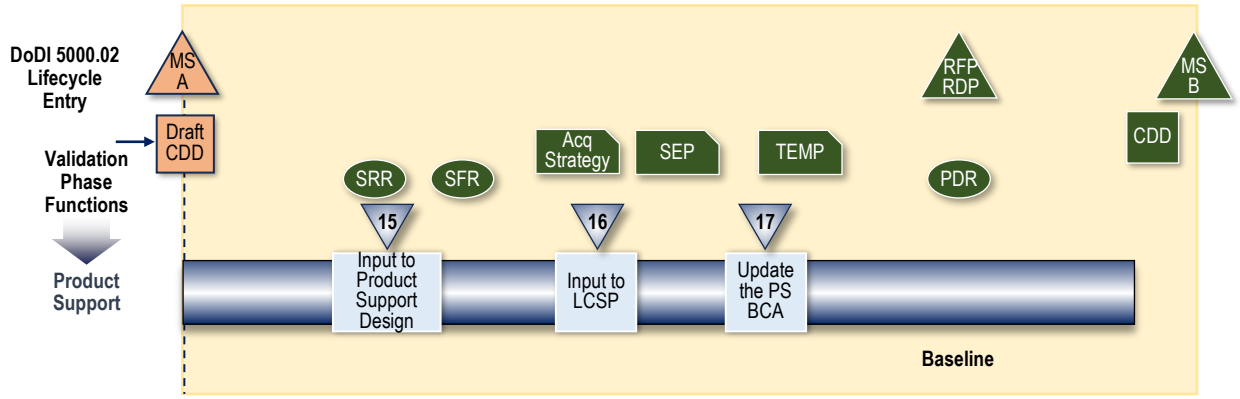


Table 3-6 lists the primary R&M activities associated with the Product Support functional area in the TMRR phase.

Table 3-6. Product Support R&M Activities – TMRR Phase

TMRR R&M Activity	Description
15 Provide Input to Product Support Design	Integrate R&M activities with Product Support Design
16 Provide Input to LCSP	Update R&M inputs to the LCSP
17 Update the PS BCA	Provide R&M inputs to the PSM for PS BCA updates

In addition to these tasks, tasks in the R&M Engineering Management and Systems Engineering functional areas contribute to and support PS.

- The support implications of using GFE or COTS are evaluated. The potential use of existing repair facilities and procedures can save costs in developing the support package for a new system. However, at the same time, it may be more difficult or expensive to develop organic support for COTS. To fully investigate GFE and 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 and COTS items identified in the contract.
- Design trade-off studies are conducted. Program engineers, PS staff, and managers use trade studies to evaluate techniques, methods, systems, concepts, and policies in terms of cost and effectiveness to optimize the design and development of a system and its PS during the acquisition process.

- During TMRR, collaboration should continue between the R&M engineer, logistics analysis, and cost analyst to monitor the maturity of the design and potential changes to the PSS, both of which may impact the feasibility of achieving the Sustainment KPP. During the TMRR phase, the SEP and RAM-C should be updated.
- Preliminary R&M design analyses are conducted.

R&M block diagrams and math models are developed and used to predict and allocate R&M, key supporting elements of the Sustainment KPP

3.5.1 Provide Input to Product Support Design 

The Product Support specialist and maintenance planners should closely coordinate the Product Support function with the design process to reflect accurately the needs of the design in its current configuration and conversely, to influence design formulation consistent with the maintenance concept determined to be optimum from an operational effectiveness and life cycle cost viewpoint.

Integrating R&M with Product Support Design Interface activities during the TMRR phase is necessary in the areas of requirements and functional analysis, test planning, RCM, and refinement of the LCSP.

Accurate R&M data is a vital input to trade studies that balance the pros and cons of alternative methods for optimization of operational effectiveness, e.g., improved design reliability/availability vs. incorporation of daily system operability checkout, and improved reliability vs. rapid maintenance through use of BIT. In performing analyses in support of the design, the R&M engineer:

- Considers alternative methods (e.g., new technologies, use of redundancy, hardware vs. software functionality, etc.) for optimizing operational effectiveness
- Provides the basic failure rate and failure mode data to Product Support analyses
- Ensures common R&M data is used by system engineering, design, and Product Support activities.

Input to Product Support Design: Procedure

The R&M engineer reviews the following analyses and data for the current design configuration to verify consistency with program requirements:

- *R&M Data* — Verify that results of the FMECA used in maintenance planning are consistent with the R&M and failure rate analyses performed, as engineering functions, on the current design configuration.

- *R&M Analyses* — Verify that the analyses performed on the current design configuration have in fact considered the design features contemplated by the maintenance concept, e.g., BIT capability, maintenance support requirements, “throwaway" modules, redundancy with on-line repair, etc.

The R&M engineer considers the R&M requirements and results of R&M analyses and uses them in developing the Product Support performance requirements and the design attributes needed to implement them, described as follows.

- Requirement and functional analysis:
    - Ensure Product Support contract specification requirements, traceable to the CDD, have been developed in accordance with the RAM-C results and are compatible with R&M contract specification requirements. Analysis should be performed to identify the impacts the sustainment metrics will have on mission success and materiel availability[16].
    - Ensure contracted Product Support tasks align with R&M engineering tasks, and the FMECA and R&M allocations and predictions are factored into the Product Support allocated requirements, preliminary design, and risk assessments.
    - Specify qualitatively and define quantitatively, as a result of the R&M task of specifying requirements, system-level design requirements for the diagnostic features in the specifications in terms of failure detectability, false alarm rates, degree of fault isolation to be provided, fail-safe provisions, and R&M of sensors and interface hardware. R&M and Product Support should be involved in tradeoff analyses and use cases as part of the functional analysis process to evaluate the advantages of performance monitoring and fault isolation in terms of their effect on operational effectiveness, logistics and maintenance efficiency, and life cycle costs of the system.

      When properly implemented and used, BIT should reduce corrective maintenance time and increase system availability. In some cases, the diagnostic features can be adapted to detect (or predict) impending failure, thus permitting the correction of system degradation problems as a preventive maintenance routine and thereby increasing reliability. Fault isolation techniques may be advantageous at all levels of maintenance, where their use may reduce both the number of maintenance personnel and the maintenance skill levels required to maintain the system. Selection of the BIT features to incorporate into a

[16] DoDI 3110.05, “Sustainment Health Metrics in Support of Materiel Availability,” provided standard equations to calculate Am and Ao. These equations may not align with legacy Am and Ao calculation methods within each Service’s authoritative data system. When conducting the RAM-C analysis of the CDD sustainment metrics, ensure that the users (including maintenance data collection systems), program office, and test agencies agree to the formulas used.

system design involves consideration of the following basic requirements and constraints, and form the basis of determining diagnostic requirements and functionality:

- BIT Function — maintainability enhancement, performance optimization, operational readiness monitoring, reliability improvement, safety alarm.
- BIT Modes — on-line with system operating, on-line with system under test, off-line.
- Level of Detection — subsystems, equipment, replaceable units.
- Degree of Fault Isolation — equipment, groups of replaceable units, individual replaceable units, individual circuits.

- *Test planning* – Establish detailed plans for monitoring and validating requirements to provide data to evaluate technical performance. Test criteria should be developed for each requirement to provide information about risk and risk mitigation as the development and testing continue. The test strategy/requirements to provide data and analysis support to the decision process should align with the R&M test requirements and strategies and should be documented in the TEMP.
- *RCM* - Once the FMECA and R&M predictions are completed and system design has been established, use RCM analysis to develop a focused, cost-effective system preventive maintenance program. RCM uses a system-based approach to determine causes of failure, failure consequences, and a logic tree analysis to identify the most applicable and effective maintenance task(s) to prevent failure, if possible. RCM also provides rules for determining evidence of need for condition based maintenance.
- *Maintenance planning* – Follow up after the adoption of a particular maintenance concept to satisfy system operational requirements with an adequate plan to support the concept. The LORA and MTA are part of the planning process.
  - *LORA* - A LORA allocates maintenance functions for maximum affordability and materiel availability. The FMECA helps identify the ways in which systems can fail, performance consequences, and serves as basis in the identification of Critical Safety Items as well as potential areas for preventive maintenance for the system. In the LORA, decisions should be made concerning the repair of replaceable units and assemblies removed from the equipment under the repair-by-replacement concept. A determination should be made as to which (if any) of these failures should be repaired at the intermediate maintenance shops, and which should be transferred to depot shops or contractor facilities for repair. Ultimately, a decision should be made relative to the classification of items below a certain cost as expendable "throwaway" items. These determinations will be essential to the formulation of an overall maintenance plan for the system.

The LORA should consider the following maintenance scenarios:

- Field Level Corrective Maintenance – As a general rule, maintenance tasks at the field level should be limited to system testing, fault isolation, and only the simpler repair tasks. The basic corrective maintenance procedure for field maintenance should employ BIT as the normal method for determining the repair task. When the fault can be isolated to a replaceable unit, maintenance technicians thereupon remove the defective item and replace it. The defective element is then returned to a lower level repair shop for disposition.
- Field Level Preventive Maintenance – The preventive maintenance plan for a system should strive to minimize the complexity and frequency of required servicing, while providing maximum system performance and prolonged operational life. Maintenance concepts employing diagnostics and prognostics for early detection of impending failures optimizes preventive maintenance.
- Intermediate Level Maintenance – Tasks performed should be limited to those involving calibration, module repair, replacement of electronic assemblies and parts, and similar maintenance not requiring unrealistic quantities and types of skill levels, test equipment, documentation and spare part inventories in consideration of footprint and environmental limitations.
- Depot Level Maintenance – Major overhaul, repair, rework and alterations, and equipment installation compatibility tests should be accomplished at the depot level of maintenance. Designated support facilities should have the capability to make component replacements, alterations and repairs, inspection tests, and checkout of the complete system.
- Contractor Maintenance – Factory repair and major alterations should be accomplished by contractor maintenance when such maintenance tasks require special facilities, tools, fixtures and skills not available at Service maintenance facilities.
- BIT – The task of outlining platform and system maintenance and support concepts might include existing equipment for which R&M design attributes are already established and the program engineer has no input into the design requirements, maintenance and support concept, or other elements that make up the fundamental R&M attributes that are to be procured. The engineer does have control over the integration concept for diagnostics, the compatibility of the maintenance concept to the host platforms' general concept, the diagnostics maturation program, and general compatibility with the field support of that platform. The advantages of maintenance concepts which rely on repair-by-unit-replacement policies cannot be fully exploited without means for quick failure detection and fault isolation. This implies a design

requirement for performance monitoring at the system and equipment levels for failure-detection and fault-sensing devices within equipment to isolate the failures.

- *Maintenance task analysis* – An MTA identifies detailed logistics and support requirements to sustain system readiness. The maintainability prediction assesses the maintenance aspects of the system's architecture, including maintenance times and resources. This analysis identifies strategic opportunities for focused diagnostics, prognostics, and performance monitoring/fault localization, leading to reduced system maintenance times and cost drivers. Ultimately, these practices can increase materiel availability and readiness at a reduced cost throughout the life cycle.

Input to Product Support Design: Data

Data needed includes the following.

- *Design Information* – design configuration description, functional and physical, for the current design configuration.
- *R&M Analysis* – R&M predictions and FMECA for the current design configuration.
- *Product Support Analyses and Maintenance Concept*— showing detailed failure-rate/failure-mode basis which influenced selection of the particular maintenance concept and describing outstanding maintenance features and requirements proposed for the design.

Input to Product Support Design: Criteria

Approval of product support analyses from an R&M standpoint is contingent on satisfying the following criteria:

- *Consistency of Data* – Failure rates and failure modes derived in the FMECA of the current design configuration should also have been used in maintenance planning, maintenance concept formulation, test equipment requirements definition and SE studies, and other maintenance-enhancing design features.
- *Validity of Analysis* – Results should be valid and compatible with R&M analyses.

If these criteria fail to be satisfied, the R&M engineer should reject the logistics analyses and maintenance concept pending re-evaluation with valid failure mode and failure rate data.

3.5.2 Provide Input to LCSP 

In the TMRR phase, the LCSP documents and refines the maintenance and support concepts based on the results of any technology demonstrations and analyses performed to date. Review the updated LCSP for the system to verify compatibility with the proposed allocated baseline design and R&M requirements. Evaluate R&M data and results of trade studies underlying the

plan, validate failure-rate and removal-rate estimates used in the provisioning plan, and verify adequacy of PHS&T plans.

Input to LCSP: Procedure

As in the MSA phase, the LCSP should describe the requirements for R&M engineering coordination or participation. Each of these mutually dependent task interfaces is discussed below and should be discussed as part of the LCSP:

- *Maintenance Plan* – The maintenance plan for the system is defined and updated as design progresses. There should be close coordination (and joint participation) by R&M engineering and Product Support teams.
- *Personnel and Training* – A personnel and training program is planned, to satisfy the personnel and skill requirements for system maintenance at all levels. Current data from R&M prediction analysis, design analysis, BIT analysis, and failure mode analysis is a necessary input to the planning task.
- *Support Equipment* – Technical data for the design and acquisition of test equipment necessary for system maintenance is developed on a schedule compatible with the system development schedule. R&M data needed for the definition of parameter measurements, tolerances, and calibration requirements includes equipment and BIT design analysis and FMECA.
- *Spares and Repair Parts* – Plans are prepared early in development for the provision of spares and repair parts necessary to maintain the system following delivery to the field. These plans should be consistent with accurate estimates of removal rates of the individual items covered by the provisioning plan. Inherent predicted failure rates are not the same as actual removal rates by a considerable margin due to those replacements attributable to maintenance error, failure diagnoses, tolerance deterioration problems at other interfacing points, and other areas in which no part failure actually occurred. Experience data from service maintenance data collection systems is useful to derive a ratio between inherent predicted failure rate and observed replacement rate for parts and components of the type proposed for the current design. Specification requirements for replacement parts and components on the provisioning list should have the same reliability, failure rate and maintainability control provisions as those ultimately proposed for production procurement.
- *PHS&T* – Management controls are established to ensure consideration of system requirements and constraints related to (or dependent on) packaging, handling, storage, and transportation of the system and its lower-level elements. R&M data needed for the execution of this task includes FMECA evaluation.

Provide Input to LCSP: Data Requirements

Results of the requirements derivation, maintenance analyses, and provisioning plan should be reflected in the maintenance concept and Product Support planning described in the LCSP. Integration with R&M and systems engineering should also be described, and should complement the SEP, AS, and other program planning documents.

Provide Input to LCSP: Review Criteria

An approval decision from an R&M perspective can be made when review of the LCSP indicates that R&M data, requirements, schedule, and engineering tasks are properly integrated into the Product Support program. Failure rates used in provisioning plans should have been modified by an appropriate removal-rate factor derived from service maintenance data or equivalent valid data source. Specifications for replacement spares and repair parts should be described by the same procurement specifications used for procurement of initial production articles. Failure to achieve should result in withholding approval of the LCSP documentation pending correction of deficiencies.

3.5.3 Update the PS BCA 

A Milestone B PS BCA will have the same format and section content as subsequent PS BCAs but will likely contain much less detail and include data from like or similar systems that will be replaced with actual system, subsystem, or component supportability data, as appropriate, as it becomes available. Each iterative PS BCA update or revalidation will improve the ability of the PSM to identify and compare viable product support strategies.

During TMRR, the current R&M data, other factors, and alternatives are used to update the BCA. The approved PS BCA Report, included as an annex in the program's LCSP, is updated.

BCA: Control Procedure

The PSM will update the PS BCA and the PS BCA report and any revalidation documentation as an Annex to the LCSP. At Milestone B, the PSM will make an assessment to validate that the program has not changed enough to warrant a PSS change.

By Milestone B, the PSM should have:

- Updated the initial PS BCA and PS BCA report
- Ensured the necessary rights to data and the delivery of technical data, computer software, and software documentation.
- Ensured the information and data needed is being requested and will be available.
- Developed the Implementation Plan and Communication Plan for the selected alternative.

BCA: Data Requirements

The BCA requires real-world performance, supportability (reliability, availability, and maintainability), and cost data In the TMRR life cycle phase, prior to Milestone B, the PS BCA will be based on available data to supplement or replace the analogous data initially used for the BCA during MSA.

BCA: Review Criteria

The PSM actions required by Milestone B are completed.

If the recommendations from the PS BCA are not implemented, the PSM should provide amplifying information in the program LCSP to explain the rationale behind the decision not to implement or delineate the factors inhibiting implementation.

MSA Checklist for Product Support

Table 3-7 is a checklist for ensuring the needed R&M inputs to PS are made prior to the end of the TMRR phase.

Table 3-7. Checklist for R&M Inputs to PS during TMRR

R&M INPUT TO PS CHECKLIST	ADEQUATE		REMARKS
	YES	NO	
(1) Basis and requirements for Support planning defined for EMD.			
(2) Maintenance plans and concepts for end items are compatible with allocated baseline and FMECA.			
(3) Test support equipment requirements are integrated into system design and consistent with R&M analysis.			
(4) Provisioning plans for spare items and repair parts are based on validated removal rates derived in the R&M analysis.			
(5) Preliminary requirements are defined for packaging, storage, handling, and transportation of end items.			
(6) Performance metrics defined for PS contracts and organic support requirements consistent with R&M predictions			
(7) Sustainment KPP and supporting KSAs (especially R&M) are refined in the CDD.			

R&M INPUT TO PS CHECKLIST	ADEQUATE		REMARKS
	YES	NO	
(8) Sustainment requirements are based on and consistent with R&M analyses and decomposed into more detailed requirements to support the Preliminary Design Review (PDR)			
(9) PS risks have been identified and mitigation plans are in place			
(10) Affordability constraints and key cost factors that could affect system's O&S costs identified and mitigation plans proposed			

3.6 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 PDR should include a review of R&M considerations and updates to the Digital Engineering plan.

The contractor's estimate 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). An assessment of necessary and appropriate R&M program planning for EMD and beyond has been prepared.

3.6.1 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 Digital Artifacts:* Artifacts produced within, or generated from, the digital engineering ecosystem in accordance with contract requirements.
- *R&M Analysis Reports* – Final TMRR phase R&M analyses and allocation reports.
- *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 Acq Strat.
- *Product Support Planning and Documentation* -The LCSP, PS BCA, and related documentation.

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:

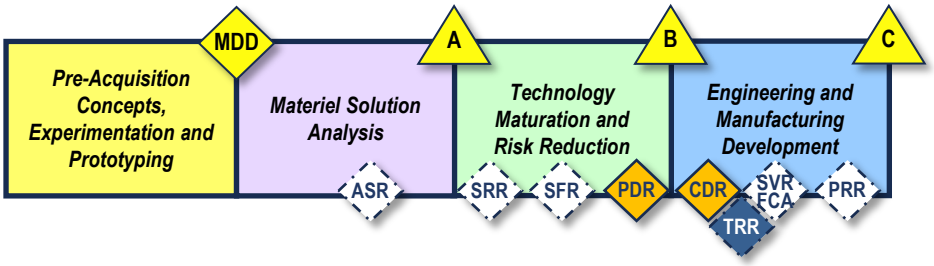
- Verify adequacy of R&M achievements and current status as reflected in the key documents needed at Milestone B for decision to initiate the EMD phase. Identify any inconsistencies or deficiencies noted in the review. Key references for evaluating adequacy of compliance with checklists are identified 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.

3.6.2 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.

4 R&M in the Engineering and Manufacturing Development Phase



Objectives of the Engineering and Manufacturing Development Phase

The EMD phase continues the design that evolved in the preceding 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 (estimates and predictions) 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 4-1 shows the primary activities to be performed during the EMD phase for a typical program. Table 4-1 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.

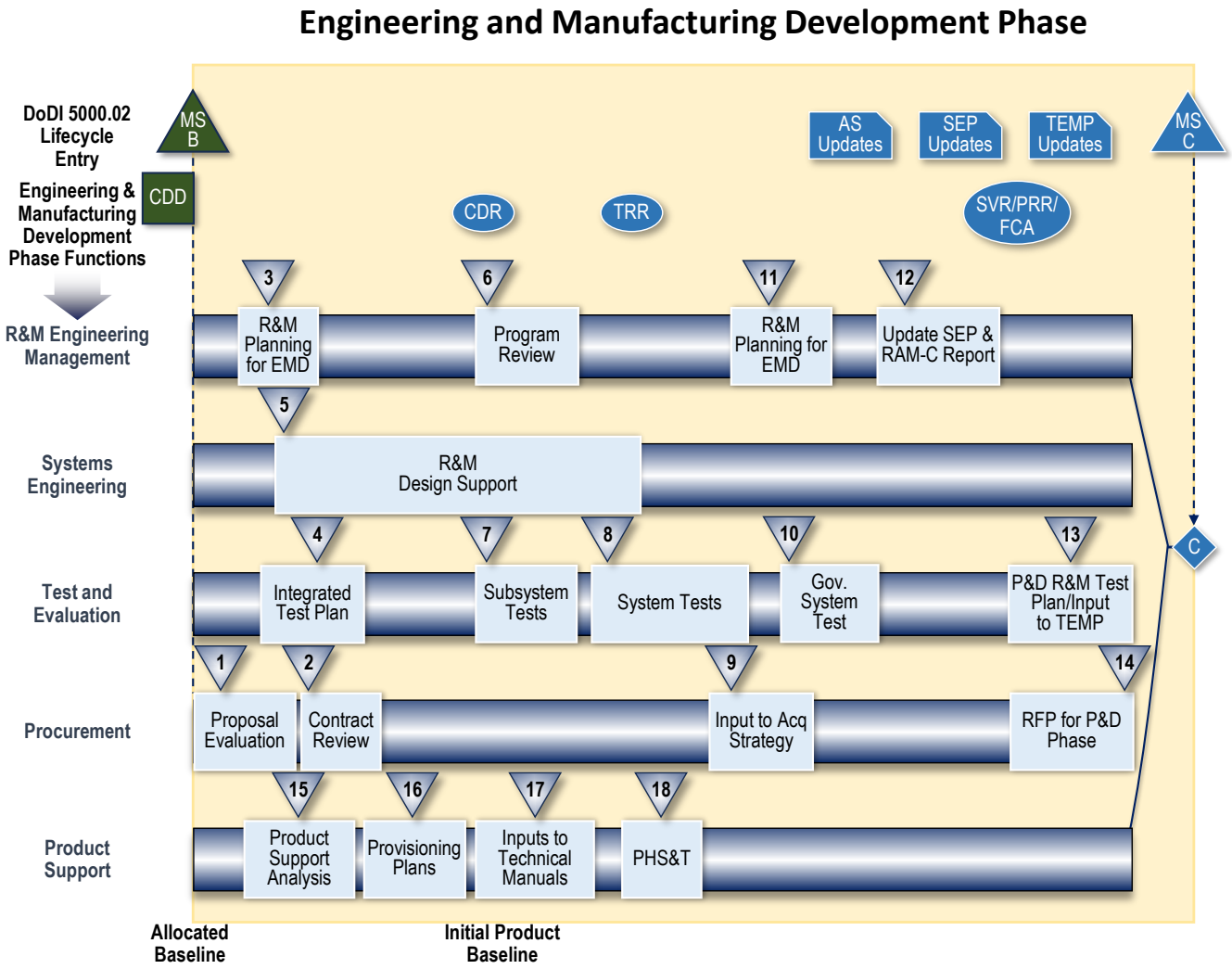


Figure 4-1. EMD Phase R&M Activities by Functional Area

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

R&M Task		Functional Area	Paragraph
1	Evaluate proposals	Procurement	4.4.1
2	Review EMD phase contract	Procurement	4.4.1
3	Develop/review R&M planning for EMD	R&M Engineering Management	4.1.1
4	Review integrated test plan	Test and Evaluation	4.3.1
5	Provide R&M design support	Systems Engineering	4.2.1
6	Conduct program review	R&M Engineering Management	4.1.2
7	Perform subsystem tests	Test and Evaluation	4.3.2
8	Perform system test	Test and Evaluation	4.3.3
9	Provide R&M input to Acquisition Strategy	Procurement	4.4.2
10	Perform Government system test	Test and Evaluation	4.3.4
11	Develop R&M planning for EMD phase	R&M Engineering Management	4.1.3
12	Update SEP and RAM-C Report	R&M Engineering Management	4.1.4
13	Review P&D R&M test plan/input to TEMP	Test and Evaluation	4.3.5
14	Prepare R&M input to RFP for P&D	Procurement	4.4.3
15	Product Support Analysis	Product Support	4.5.1
16	Provisioning plans	Product Support	4.5.2
17	Input to technical manuals	Product Support	4.5.3
18	PHS&T	Product Support	4.5.4

4.1 R&M Engineering Management

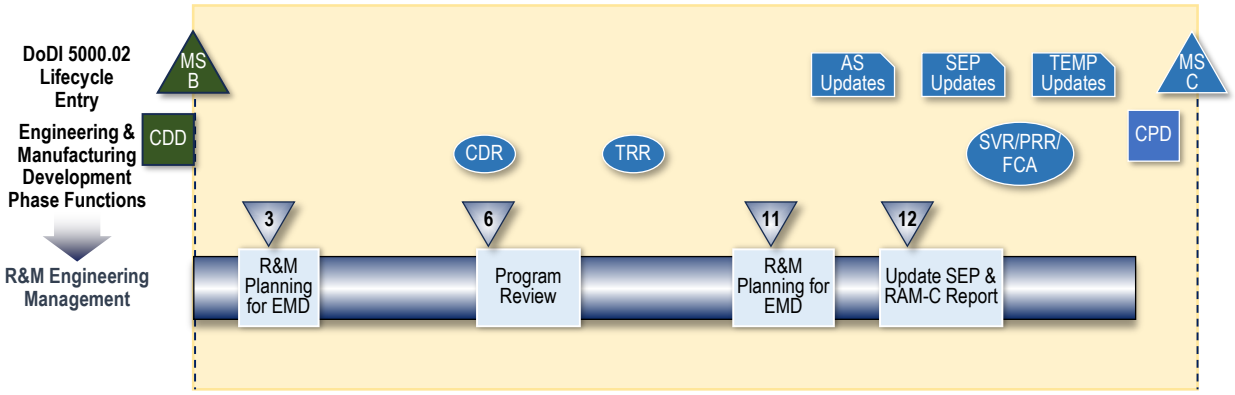


Table 4-2 lists the primary R&M activities associated with the activities for the R&M Engineering Management functional area in the EMD phase.

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

R&M Task		Description
3	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.
6	Conduct program review	Perform 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.
11	Develop R&M planning for EMD phase	Prepare (or review contractor preparation of) R&M requirements, program plans, and specific R&M activities for the EMD phase.
12	Update SEP and RAM-C Report	Update the SEP and RAM-C report to account for any changes that have occurred since Milestone B.

4.1.1 Develop/Review R&M Planning for EMD Phase 3

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.

The Government R&M engineer verifies that Parts Management Program requirements for limiting reliability risk are used during the selection of parts and materials for the initial design and any design changes that take place during the EMD phase due to obsolescence and DMSMS issues or any other required change.

R&M Planning for EMD: Procedure

The Government planning should be reviewed to ensure it complies 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 is 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 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.
  - 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 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 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.

4.1.2 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 (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 (estimates, 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 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.
- *Parts and Materials Selection and Control* – Evaluate procedures for the selection and control of parts and materials for use in the initial design and any design changes during the EMD phase, as well as 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.

Using the R&M estimate 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 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 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 activates 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.

4.1.3 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.
- *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.
- 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.

4.1.4 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.

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.

4.2 SYSTEMS ENGINEERING

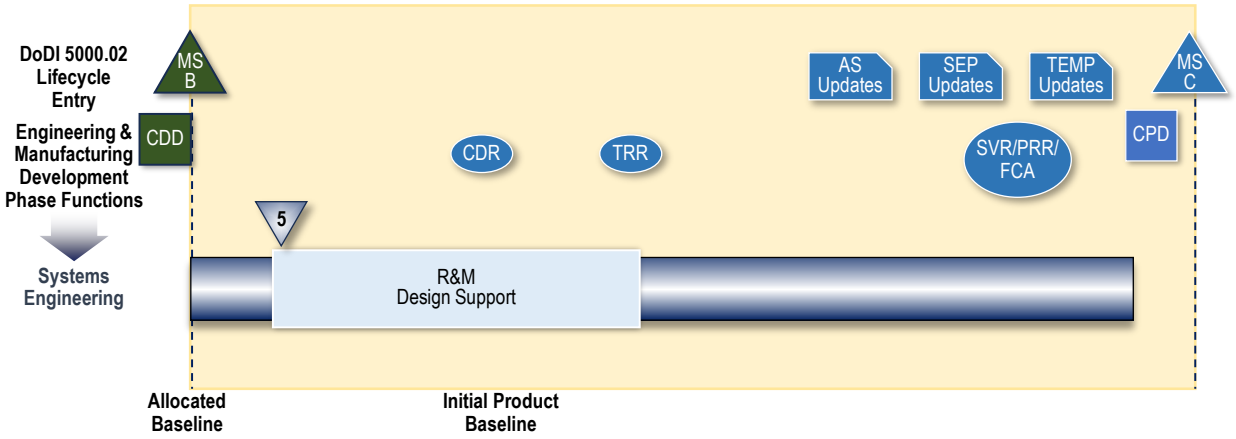


Table 4-3 lists the R&M activities applicable to the EMD phase Systems Engineering functional area.

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

R&M Task	Description
5 Provide R&M design support	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 the production-representative article.

4.2.1 Provide R&M Design Support 5

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 estimate 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 estimates
- 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 I the following paragraphs.

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 estimate 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).
  - 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.
- *GFE/COTS Investigation* – Evaluate the adequacy of R&M assessments of GFE/COTS and to ensure that equipment with a proven history of R&M has been 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, SE 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 Multivariate Adaptive Regression Splines (MARS)[17] 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 estimate 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.
- *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.

[17] MARS is an algorithm for complex non-linear regression problems. The algorithm involves finding a set of simple linear functions that in aggregate result in the best predictive performance.

- *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.

4.3 Test and Evaluation

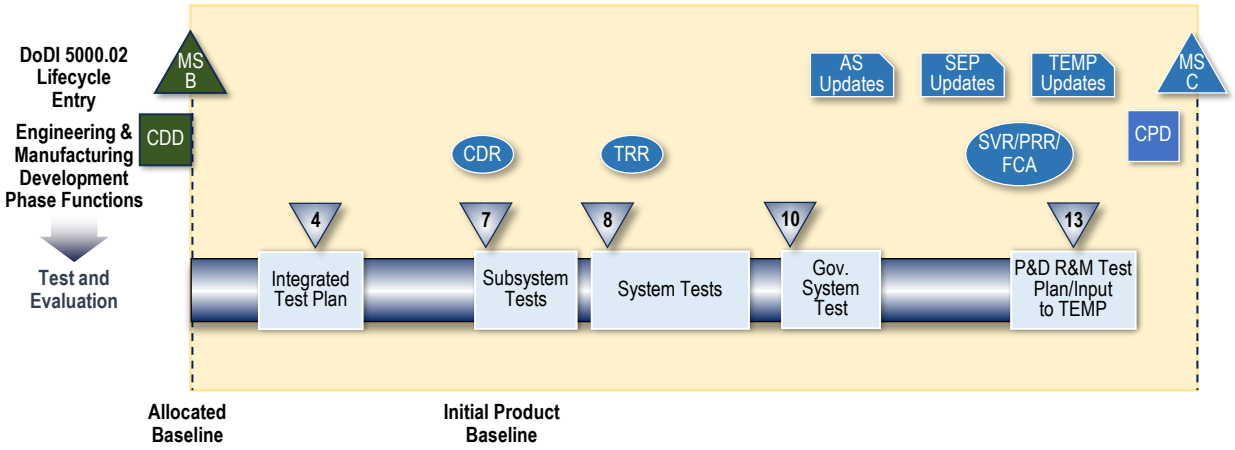


Table 4-4 lists the R&M activities applicable to the EMD phase Test and Evaluation functional area.

Table 4-4. 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.

4.3.1 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:
  - 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.

- 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.
  - 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.

4.3.2 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 following requirements.

- *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 as follows.

- *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 SE.

- *Mockup Demonstration* – Virtual Mockup technology allows product design engineers to replace or augment physical prototypes with virtual ones, using 3-D computer-aided design (CAD) and simulations. Digital Mock Ups (DMU) allow 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. A Human Engineering Design Approach Document-Maintainer (HEDAD-M) CDRL, derived from the digital system model, provides the analysis to support the mockup review/demonstration.

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 estimates.
  - 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, drawings, and models 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.

4.3.3 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/MDCS 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, the system R&M assessment FRACAS, and the R&M Review Board.

- *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 discrete values, an adequate number of those values 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.
  - 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.

4.3.4 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.

4.3.5 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 that follow 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 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 following contractor data.

- *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.

4.4 PROCUREMENT

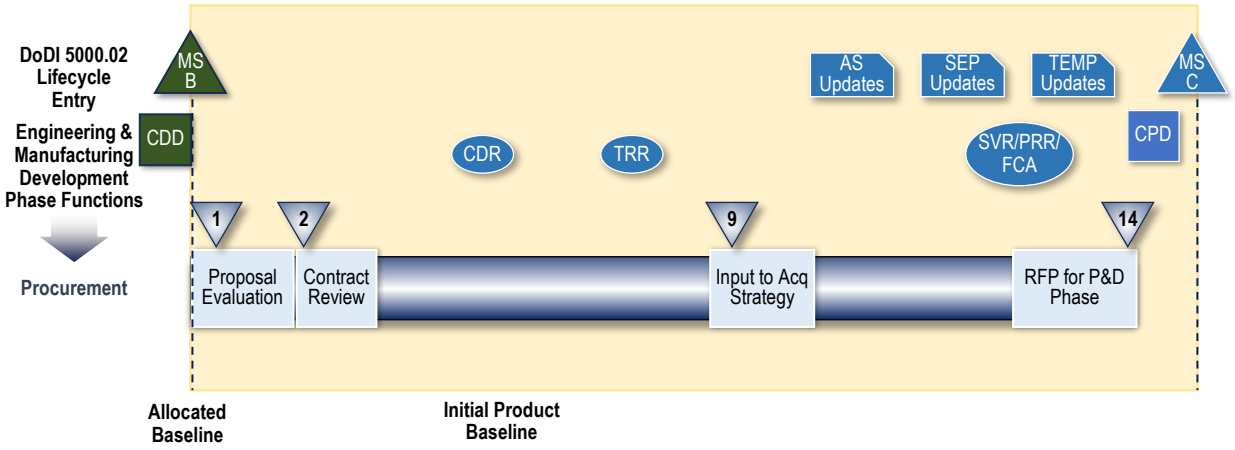


Table 4-5 lists the R&M activities applicable to the EMD phase Procurement functional area.

Table 4-5. 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 Acq Strat.
14	Prepare R&M input to RFP for P&D phase	Verify adequacy of R&M requirements and provisions in RFP for production.

4.4.1 Evaluate Proposals and Review EMD Phase Contract 1 2

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 following R&M criteria.

- *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 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 estimates.
  - 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 evaluating the proposal.

- *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.

4.4.2 Provide R&M Input to Acq Start 

The program Acq Strat should include a description of the R&M engineering activities essential for achieving and verifying the requirements. The Acq Strat also should specify how the Sustainment KPP thresholds have been translated into R&M design and contract specifications. The Acq Strat Template addresses the required R&M inputs for MDAPs and MTAs.

Input to Acquisition Strategy: Procedure

The R&M Input to Acq Strat 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 Acquisition Strategy: Data

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

Input to Acquisition Strategy: 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 CDD and RAM-C Report.

4.4.3 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 perspectives.

- *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).

4.5 PRODUCT SUPPORT

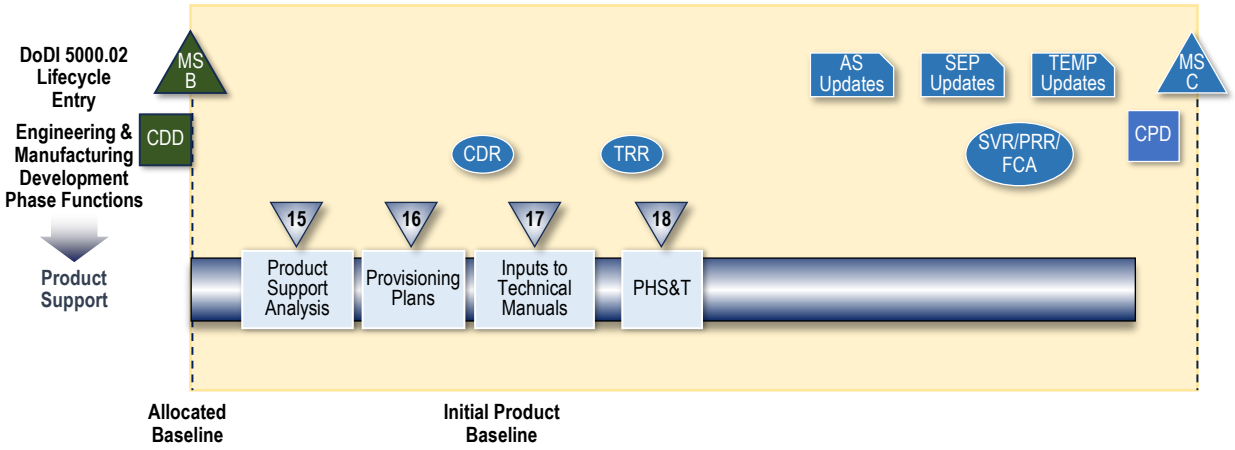


Table 4-6 lists the R&M activities applicable to the EMD phase Product Support functional area.

Table 4-6. R&M Product Support Activities – EMD Phase

R&M Task		Description
15	Product Support Analysis	Provide PS Analysis to support MIL-HDBK-502 PSA activities
16	Provisioning Plans	Provide R&M inputs to provisioning plans using appropriate R&M metrics
17	Input to Technical Manuals	Provide inputs to technical manuals including human factor considerations
18	PHS&T	Provide R&M inputs to PHS&T

In addition to these tasks, tasks in other functional areas contribute to and support PS.

- The R&M engineer updates analyses required at previous design reviews to support CDR-level analyses that provide inputs to PS. These include the FMECA, FTA, failure analysis, and R&M predictions. These and other tasks under Systems Engineering provide inputs to:
  - RCM
  - The CBM+ Plan
  - The Scheduled Maintenance Plan
  - The LORA
  - The Support Equipment Requirements Document (SERD)
  - Technical manuals
  - PHST
- Tasks under the Test and Evaluation functional area confirm and update the results of R&M analyses to reduce the uncertainty with earlier R&M estimates used for PS decisions.

4.5.1 Product Support Analysis

MIL-HDBK-502A, Product Support Analysis, describes the PSA process as a wide range of analyses. Inputs to the system level PSA include system analysis and engineering at the hardware, operating, and support trade levels. The PSA provides outputs to the interfacing activities in the form of boundary conditions or goals for both engineering performance and IPS Element concepts and plans. These outputs affect design and operational concepts; identify gross product support resource requirements of alternative concepts; and relate design, operational, and supportability characteristics to system readiness objectives and goals.

Table 4-7 defines the process steps and the details the activities required for accomplishing each step. Coordinating these interfaces and activities is a significant management task for all the disciplines involved.

Table 4-7. MIL-HDBK-502A PSA Activities

ACTIVITY / MIL-HDBK-502A TITLE /PARA.	PURPOSE
1. Product Support Analysis Strategy (5.2.3)	Develop proposed PSA strategy early in the acquisition program, identify the PSA activities providing best return on investment, and document risks of accomplishing these objectives.
2. Product Support Analysis Planning (5.2.3)	Develop a PSAP to effectively implement the PSA program. Document the PSA management structure and authority; the PSA activities to be accomplished; when each activity will be accomplished; what organizational units will be responsible for accomplishing each activity; how all activities are integrated; and how results of each activity will be used.
3. Program and Design Reviews (5.2.4)	Provide for timely PSA program participation in the official review and control of design information; the scheduling of detailed PSA program reviews; and logistics risk assessments at program reviews. It also ensures that all pertinent aspects of the PSA program are addressed as an integral part of all formal program and design reviews.
4. Application Assessment (5.3.2)	Identify support factors related to the system's intended use. Also, to document quantitative data results which should be considered when developing support alternatives.
5. Support System Standardization (5.3.3)	Define support and support related design constraints based upon support standardization considerations. It also provides support related input to standardization efforts.
6. Comparative Analysis (5.3.4)	Define a sound analytical foundation for making projections for new system/equipment parameters and identifying targets of improvement; identify the supportability, cost, and readiness drivers for the new system/equipment; identify risks involved in using comparative system data in subsequent analyses.
7. Technological Opportunities (5.3.5)	Identify technological advancements and state-of-the-art design approaches offering opportunities to achieve new system support improvements. Use of available technology is emphasized to improve projected safety, cost, support, and readiness values, which reduce a new system's environmental impact, and resolve qualitative support problems or constraints identified.

Table 4-7. MIL-HDBK-502A PSA Activities (continued)

ACTIVITY / MIL-HDBK-502A TITLE /PARA.	PURPOSE
8. Supportability and Supportability Related Design Factors (5.3.6)	Establish quantitative O&S characteristics of alternative design and operational concepts; and support related design objectives, goals and thresholds, and constraints for inclusion in requirement, decision, and program documents and specifications.
9. Functional Requirements (5.4.2)	Identify missions, maintenance, and support (transport, maintain, dispose) functions that should be performed for each system/equipment alternative in the intended environment. It also identifies requirements for operations, maintenance and support, and documenting task performance requirements in a task inventory.
10. Support System Alternative (5.4.3)	Establish support system alternatives for evaluation, tradeoff analysis, develop a detailed support plan, and determination of the best system to be developed.
11. Evaluation of Alternatives and Tradeoff Analysis (5.4.4)	Determine the preferred support system alternative(s) and their associated risks for each proposed system; and determine, through tradeoff analysis, the best approach to satisfying the need (the one that provides the best balance between risk, cost, environmental impact, schedule, performance, readiness, and support). Includes refinement and extension as development progresses.
12. Task Analysis (5.5.2)	Analyze required operations, maintenance, and support tasks to: identify resources required for each task; highlight new or critical resource requirements and any risks associated with those resource requirements, including hazardous materials/waste and their environmental impact; define transportability requirements; identify support requirements exceeding established goals/thresholds/ constraints; provide data supporting recommended design alternatives to improve data supporting recommended design alternatives to improve supportability/enhance readiness; and provide source data to develop required documents, e.g., Maintenance Plans, Technical Manuals, and Provisioning Documentation.
13. Early Distribution Analysis (5.5.3)	Assess new system impact on existing systems to include quantifying risk levels which surround system performance/ supportability; to identify sources of manpower/ personnel skills to meet new system requirements; to determine impact of failure to obtain necessary product support resource requirements.
14. DMSMS/Obsolescence Analysis (5.6.2)	Analyze the loss or impending loss of manufacturers or suppliers of parts and material required to operate and sustain the system/ equipment and support development of a program to establish alternate sources of supply.
15. Field Feedback (5.6.3)	Correct potential postproduction support problems prior to closing production lines and to develop a plan to ensure effective support of the system during its life cycle. Postproduction support plan should identify single/dual source items and those for which the Government has no data rights. Plans should include available organic support assets, production line buy-out, or contractor logistics support agreements.
16. Disposal Activity (5.6.4)	Identify the disposal/demilitarization procedures associated with a system/end item including facility equipment that focuses on those components, assemblies, sub-assemblies, parts and materials that contain hazardous materials, wastes and pollutant; identify those items that can be recycled, reused or salvaged.
17. Operational Suitability (5.7.2)	Assess achievement of support parameters specified; identify reasons for deviations from projections; recommend changes to correct deficiencies and improve system readiness.

The primary techniques used in PSA are FMECA, FTA, RCM Analysis, LORA, MTA, and core logistics analysis, SORA, and DSORA. See Section 1.5.1 for a description of these techniques.

To reflect accurately the needs of the design in its current configuration, and to influence design consistent with the updated maintenance concept and support plans, the development of PS and support of PSA should continue to be closely coordinated with design iterations in the EMD phase. Accurate R&M data are vital inputs to the engineering considerations that underlie the selection of specific levels of repair and design of SE and test equipment. R&M analyses performed in support of PS consider several alternatives (e.g., 2-level vs. 3-level repair, BIT vs. SE, etc.) in each of these areas, and in addition provide the required basic failure rate and failure mode data, to ensure commonality in R&M data used by system engineering, design, and Product Support planning.

Results of the contractor's R&M analyses, failure diagnosis, problem investigation, functional and environmental tests, and R&M demonstration tests can be combined to provide a full description of system parameters essential for realistic maintenance engineering analysis and PS planning. The functional FMECA performed in the TMRR phase is refined to reflect the physical design configuration and updated with test data as the EMD phase progresses, to provide a realistic basis for maintenance planning, test equipment design, and maintenance procedures development.

The MTA is supported by the FMECA, which provides outputs valuable in developing troubleshooting logic, which in turn supports the identification of the maintenance steps and needed test equipment.

Provide Input to Product Support Analysis: Procedure

The R&M engineers review the contractor’s PSA activities, to validate R&M data and verify adequacy of maintenance plans, test and SE requirements for the current system configuration, to accomplish the following.

- *R&M Data* — Verify that results of the FMECA used in MEA and SE planning are consistent with the R&M and failure rate data derived from R&M assessment, as test data is accrued on the current design configuration.
- *Maintenance SE* — Evaluate the R&M data on which maintenance and SE requirements have been based. This evaluation should include review of failure modes and symptoms used as the basis for selection of test points, definition of sensor requirements for performance monitoring and fault indication, and design of BIT and maintenance SE. Evaluate consideration of test equipment interaction on system R&M and other performance parameters.
- *R&M Analyses* — Verify that the R&M assessments and design guidelines provided for the current design configuration have been considered and design features contemplated by the

maintenance concept, e.g., “throwaway" modules, redundancy with on-line repair. Evaluate prediction analyses and verification test results related to SE including failure detectability and false alarm rate associated with fault indication and performance monitoring.

Provide Input to Product Support Analysis: Data Requirements

The R&M engineer needs data to validate R&M data and verify the adequacy of maintenance plans, and test and SE requirements for the current system configuration, including data from the following.

- *MTA*— complete analysis with description of failure rate/failure mode basis that influenced selection of maintenance procedures, test equipment, and maintenance SE required to support the maintenance plan.
- *R&M Analysis*— R&M assessment, FMECA, and failure diagnosis reports for the current design configuration of the system, including SE.
- *Design Data* — design configuration description, functional and physical, for the current design configuration.

Provide Input to Product Support Analysis: Review Criteria

Approval of the PS analysis is contingent on satisfying the following criteria:

- *Consistency of Planning Data* — Failure rates and failure modes observed (or predicted) in the current design configuration have been used in maintenance analysis and definition of requirements for test equipment and other SE.
- *Validity of Analysis* — Results of maintenance analysis have been verified by test data accrued in EMD.

Failure to satisfy these criteria should result in disapproval of PSA results pending correction of discrepancies.

4.5.2 Provide Input to Provisioning Plan 

Plans pertaining to provisioning of spares and repair parts should be consistent with accurate estimates of removal rates of the individual items covered by the provisioning plan. Removal rates usually exceed actual failure rates by a considerable margin due to those removals (and replacements) attributable to maintenance error, inaccurate failure diagnosis, tolerance deterioration problems at other interfacing points, removal to facilitate other maintenance, and any other instances in which no part failures occur. Test data supplemented by experience data from service field data on other similar equipment designs is useful for this computation.

See DoDM 4140.01, Volume 2 for detailed information on provisioning.

Provide Input to Provisioning Plan: Procedure

The R&M engineer reviews provisioning plans proposed for the LRIP design to evaluate the following:

- *Data*— Verify that EMD test data and service field data have been used to derive a ratio between true failure rate and observed replacement rate for parts and components of the type proposed for the current design. Verify that these ratios have been applied in the estimation of spare parts and components required to support the system under the planned and verified maintenance concept.
- *Specification* — Verify that specification requirements for replacement parts and components on the provisioning list have the same R&M control provisions as those proposed for production procurement.

Provide Input to Provisioning Plan: Data Requirements

The R&M engineer requires data at this review point including data from the following:

- *Provisioning Plan* — analysis of EMD test data and applicable service field data underlying the spares and repair parts provisioning plan.
- *Specifications* — specifications and drawings describing the items in the provisioning list.
- *Design R&M Assessment*— results of failure rate, failure mode, and removal rate analyses performed on the current design configuration.

Provide Input to Provisioning Plan: Review Criteria

Approval of the provisioning plan from R&M points of view is justified when the following criteria are satisfied:

- *Validity of Data*— Removal rates used in spares estimation are based on test data and service field data.
- *Specification Consistency* — Specifications for replacement spares and repair parts are described by the same procurement specifications and drawings used for procurement of production items.

It is important from an operational standpoint that support plans be based on realistic estimates of removal rates. When the R&M review reveals that these criteria have not been satisfied, the provisioning plan should be rejected for correction and re-evaluation.

4.5.3 Provide Inputs to Technical Manuals 

The R&M engineer performs analysis via the FMECA, FTA, RCM, FDSC, and FRACAS processes to develop information needed to develop the MTA which establishes the baseline set of procedures for technical manuals (TMs).

Operational field use conditions highly depend on the clarity and simplicity of instruction manuals and procedures for operation and maintenance of the system. The development, evaluation, and on-time publication of TMs (the term "technical manuals" includes operating, maintenance, and training manuals, whether in hard copy, electronic format, or Interactive Electronic Technical Manuals [IETMs][18]) should be contractually defined as a vital task in the contractor's Product Support function.

New, improved ways for rapidly communicating technical information to maintenance personnel should be considered, especially for maintaining complex systems. Collaborative planning among design engineers, R&M engineers, configuration control, and technical manual preparation teams is essential to ensure publication of manuals that are current with the equipment configuration, technically adequate for failure diagnosis and repair of the equipment, and practical from the user standpoint. Elements of the system known to be critically sensitive to variations from prescribed procedures for operation, checkout, maintenance, and handling should be clearly identified. Procedures and instructions described in these manuals should be tested on the production-representative system, using actual maintenance personnel, to identify and eliminate ambiguous or erroneous instructions that could degrade performance, reliability or maintainability.

The FMECA outputs related to troubleshooting and criticality directly support the development of the instructions and precautions for conducting required maintenance on the system, specifically data that includes failure modes, failure mode criticality, insight into troubleshooting, and verification of proper function after repair.

Provide Inputs to Technical Manuals: Procedure

The R&M engineer, using the results of the FMECA and the FTA (part of R&M Design Support), provides inputs to the development and validation of TMs that meet these objectives.

- Support the development of prototypes and the DE practices used to do "pre-verification" prior to building the system.
- Identify needed instrumentation for operators to monitor for normal operation.

[18] IETMs are digital in form and designed for interactive display to the maintenance technicians or system operator end users by means of a computer controlled Electronic Display System (EDS).

- Identify compensating actions, primarily for operating personnel:
  - Procedures in coping with emergency procedures.
  - Backup equipment or alternative actions
- Provide failure modes to the MTA, which forms the basis for the maintenance manual.
- Identify all failure modes to ensure failures are addressed by procedures during operation, preventive, and corrective maintenance.
  - Identifying emergencies and unusual operation to be addressed by operating procedures.
  - Recommending operating procedures that minimize the possibility of operator error.
  - Developing troubleshooting procedures.
- Identify BIT, manual and ATE, and needed instrumentation for maintenance personnel for checkout and diagnostics.

Operating Manuals. The inputs that R&M engineering provides to operating manuals identify:

- Normal operation of the system.
- Procedures for conducting pre- and post-operation tests.
- Cautions for ensuring operations do not exceed design limitations.
- Operations under extremes of environmental conditions.
- Conducting operator-level maintenance and troubleshooting.
- Emergency operation.
- Packaging for transport to or from an operating site.
- Preparing for storage.
- Listings of references, end item components, additional authorized support items, and information for requisitioning replacements.

Maintenance Manuals. The R&M engineer, in cooperation with a team of maintenance personnel experienced on similar types of equipment provides inputs to maintenance manuals that identify:

- Organizational-level (O-level) maintenance (i.e., on-equipment maintenance). This level of maintenance normally consists of inspecting, servicing, lubricating, adjusting, and removing and replacing parts, minor assemblies, and subassemblies. O-level maintenance is the responsibility of and performed by a using organization on its assigned equipment.
- Intermediate-level (I-level) maintenance. This level of maintenance normally consists of

  - Calibration, repair, or replacement of damaged or unserviceable parts, components, or assemblies. The emergency manufacture of non-available parts.
  - Providing technical assistance to using organizations.
  - Screening removed WRAs or LRUs that must be shipped to depot for repair to prevent retest OKs (RETOKs) at the depot level.
- Depot level (D-level) maintenance. This level of maintenance involves the material maintenance or repair requiring overhaul, upgrading, or rebuilding of parts, assemblies, or subassemblies, and the testing, and reclamation of equipment, as necessary. Depot level maintenance may be performed by either Government or Commercial repair facilities.

  Note: Most maintenance strategies for programs currently in the EMD phase include only the O-level and D-level and omit the I-level of maintenance.

Training Manuals. While a user manual provides instructions on how to use a product or system, a training manual provides instructions on how to train someone to use or maintain a product or system. Understanding these differences is important because it can help product designers, trainers, and users ensure that the product or system is used effectively and efficiently.

- The structure of a training manual may include training techniques, learning objectives, and exercises or activities to help users apply what they have learned.
- A training manual's content focuses on providing guidance on how to train someone to use the product or system.

Training personnel develop the training curriculum, training aids, and training manuals based on the operating and maintenance manuals. The R&M inputs to training manuals are like those for operating and maintenance manual and include the following.

- Identification of critical tasks and operations (from FMECA and FTA)
- Identification of the standards, conditions, performance measures and other criteria needed to perform each critical task and operation (from environmental information and input to MTA)
- Information on diagnostics and troubleshooting (from FMECA and FTA)
- System description, OMS/MP, maintenance concept, and KPPs (from RAM-C Report)

TMs and Human Factors. Another important input made by the R&M engineer, in collaboration with human-factors engineers, involves human factors engineering. Human factors engineering is the application of knowledge about human capabilities and limitations to system or equipment design and development to achieve efficient, effective, and safe system performance at minimum cost and manpower, skill, and training demands. (Note: The terms Human Engineering and Human Factors Engineering are considered synonymous.)

Human factors engineering requires that the system or equipment design, required human tasks, and work environment are compatible with the sensory, perceptual, mental, and physical attributes of the personnel who will operate, maintain, control, and support it.

- The R&M engineer must collaborate with the human factors engineer, and consider human engineering factors during design efforts, to ensure the required range of expected human maintainers can indeed accomplish the tasks. This includes the development of operator and maintenance manuals.
- Human factors are important considerations used in technical manual task statement development to ensure operators:
    - Understand normal operating procedures; procedures must be logical, easy to understand, and complete.
    - Can identify an emergency or improper system operation; procedures must address indicators of abnormal operation.
    - Can take immediate and effective actions in the event of an emergency or improper operation; procedures must be logical and easy to understand.
    - Understand the limits of operation (e.g., maximum take-off weight under different temperature conditions); manuals must include performance limitations.
- For maintenance manuals, human factors are important considerations to ensure planned maintenance procedures can be performed:
    - Safely – identify hazards associated with a procedure, any needed protective gear, written precautions, etc.
    - By personnel having the strength, mobility, reach, and other physical attributes of a given percentile of humans (i.e., anthropometry).
    - In the prescribed time without causing undue physical or cognitive fatigue, either of which can result in errors or accidents.
    - Based on an understanding of how humans interpret and process information.
    - With tools that are ergonomically designed (i.e., tools designed to let the user engage in repetitive motions comfortably and without undue risk of injury).
- For training manuals, human factors are an important consideration to ensure training is conducted safely and within the limits of and consistent with human physical and cognitive capabilities.

Provide Inputs to Technical Manuals: Data Requirements

The FMECA and the FTA provides data that include:

- Needed instrumentation for operators to monitor for normal operation
- Compensating actions, primarily for operating personnel
- Failure modes
- Emergencies and unusual operation to be addressed by operating procedures.
- Information for troubleshooting procedures.
- Identification of BIT and manual and ATE

FRACAS provides data supporting the development and verification of maintenance manuals that include:

- The failure reports, subsequent analysis, and associated corrective actions create a baseline of specific failure information that is captured by the MTA. The MTA incorporates this information into the technical manual operating and maintenance procedures for both preventive and corrective maintenance.
- Also, root causes identified by analysis may identify incorrect or inadequate organizational level technical manuals that may result in false removals or cannot duplicates.

RCM analysis provides data for maintenance manuals that include:

- Failures having some indication of impending occurrence. These are candidates for on-condition tasks, such as, visual inspection, testing oil or other fluid for contamination, monitoring vibration for abnormal levels, etc.
- Failure modes that are more likely to occur with age. For these, scheduled restorations and discards can be performed as the probability of occurrence of a failure mode reaches some predefined limit (for example, when a tire wears down to a tread wear indicator).
- Failures of protective devices, e.g., low pressure cutoff systems, circuit breakers, and relief valves, requiring some form of preventive maintenance.

The Maintainability Demonstrations (M-Demo) provide data to:

- Verify maintenance procedures, human factor considerations, and repair times.
- Identify potential problems in implementing specific maintenance procedures and finding fixes prior to fielding the system.
- Assess the adequacy of written maintenance procedures (i.e., the maintenance manuals).
- Evaluate built-in test effectiveness (detection, isolation).

Provide Inputs to Technical Manuals: Review Criteria

Operating, maintenance, and training manuals can be approved from an R&M and Product Support perspective when the following criteria are satisfied:

- *Non-degrading* — Procedures should not contribute significantly to R&M or performance degradation where the performance threshold is used as an indicator of "reliability" failure.
- *Effectiveness* — Procedures should detect and correct failures within specified requirements for detectability and false alarm rate. Training is effective for operators and maintainers.
- *Field Suitability* — Procedures and training should be readily usable by field personnel with specified background defined by Product Support.

Failure to conform to these criteria requires a reject decision on the procedures, and a hold on further R&M demonstration and Government tests, pending correction of deficiencies and successful reevaluation.

4.5.4 Provide Input to PHS&T Design

PHS&T is an IPS Element that includes the principles and methods for packaging, handling, storing, and transporting equipment and materials. PSMs, and Lead LCLs should develop plans for PHS&T concurrently and in coordination with the system design evolution, to ensure availability of adequate PHS&T equipment and instructions compatible with the needs and configuration features of the system. The R&M engineer works with the PSMs and LCLs as part of a PHS&T Integrated Product Team (IPT) to ensure PHS&T requirements are addressed during EMD program reviews and PHS&T requirements and implementation plans are verified and validated during system testing and demonstrations.

Provide Input to PHS&T: Procedure

During EMD, the R&M engineer evaluates PHS&T design requirements in tradeoffs with system R&M sensitivity to the environments and conditions driving the PHS&T design. These tradeoffs should consider the costs for making the design rugged vs. the cost of PHS&T to reduce the need for doing so. The objective is to design the system and its PHS&T equipment to achieve complementary design features that in combination protect the system from R&M degradation under the specified PHS&T conditions and ensure that systems and equipment reach the warfighter in a mission-ready state.

- *Requirements Analysis* — Verify that R&M sensitivity of the system design to environmental extremes for which it is being designed[19] are accurately and quantitatively known, to provide the basis and criteria for PHS&T design, to include R&M degradation as a function of:
  - Shock and vibration exposure during transportation and handling.
  - Thermal ambients in transportation and storage.
  - Relative humidity in the storage environment.
- *Design Criteria* — Verify that derived design criteria for PHS&T are consistent with PHS&T requirements defined in functional and allocated baseline specifications.
- *Tradeoff Studies*— Validate the tradeoff studies and cost analysis for alternative equipment/PHS&T design combinations to achieve the same level of protection.
- *Tests* – Verify through test that the PHS&T design is adequate.
- *Configuration Control* — Verify PHS&T requirements specified in allocated baseline specifications are consistent with the preceding validated test and analysis results.

Table 4-8. summarizes other R&M analyses and the specific tests providing inputs to PHS&T.

Table 4-8. R&M Inputs to PHS&T

R&M Analysis & Test	PHS&T Consideration	
FMECA, FTA, HALT, RGT, System Test	Short- & long-term preservation	Handling requirements
	Packaging requirements	Transportation requirements
	Containerization requirements	
Environmental testing[20]	Environmental control requirements	Static shock control requirements
	Physical shock control requirements	

Provide Input to PHS&T: Data

Data needed for the R&M engineer's review of PHS&T includes the following:

- *Documentation* — the design data and EMD phase analyses, trade studies, and test results accrued on the PHS&T design.

[19] HALT/ALT and PoF analyses can accurately and quantitatively assess R&M sensitivity to environmental extremes.
[20] Dedicated environmental testing per MIL-STD-810H, Environmental Engineering Considerations and Laboratory Tests. In addition, R&M tests provide information on acceptable environmental limits and control measures.

- *Specifications* — specifications of parts and materials to be subjected to the handling, storage, and transportation environment for which the PHS&T design is specified.
- *R&M Analysis*— final EMD phase design R&M analysis, specifically the following data:
  - Failure rate/failure mode/removal rate analysis and test results for the unprotected system throughout the complex environmental spectrum in which it is expected to survive (e.g., operational, storage, handling).
  - Failure rate/failure mode/removal rate analysis, as above, with the system mounted in its PHS&T equipment.

Table 4-9 summarizes the data requirements for reviewing PHS&T.

Table 4-9. R&M Data Needed for PHS&T

Failure rates/modes including electrostatic discharge, chemical decomposition, corrosion
Failure modes and limits and sensitivity to environmental conditions
Failures due to physical shock, maximum physical shock limit
Failures due to static shock, maximum static shock limit

Provide Input to PHS&T: Review Criteria

Approval of proposed PHS&T configuration is contingent on satisfying the following criteria. Failure to satisfy these criteria should result in rejecting the PHS&T design until deficiencies are corrected.

- *Adequacy of Protection* — The PHS&T design should provide the degree of protection against R&M degradation required by the specification.
- *Validity of Underlying Analyses* — The PHS&T design should be verified to be optimum from the life cycle cost standpoint.

EMD Checklist for Product Support

Table 4-10 is a checklist for ensuring the needed R&M inputs to Product Support are provided prior to the end (Milestone C) of the EMD phase.

Table 4-10. Checklist for R&M Inputs to Product Support Prior to Milestone C.

R&M INPUT TO PRODUCT SUPPORT & SUSTAINMENT CHECKLIST		ADEQUATE		REMARKS
		YES	NO	
(1)	Is the reliability growth on target?			
(2)	Is the LCSP documented in conformance to requirements?			
(3)	Is MEA verified by test; are maintenance concept, repair policies, maintenance procedures, and test equipment requirements consistent with results thereof?			
(4)	BIT procedures documented and verified by demonstration/test?			
(5)	PS plans based on and applicable to the specific LRIP design configuration described in design documentation?			
(6)	Spares and repair parts provisioning plan based on predicted "removal" rates as verified by test?			
(7)	Are technical manuals prepared, updated with current LRIP design configuration, verified by test, and available for distribution?			
(8)	Are sustainment metrics achievable by Full Operational Capability (FOC)?			
(9)	Have disposal costs been updated to the final production design?			
(10)	Has the packaging design verified to be compatible with the item protection requirements and proven acceptable by demonstration test under specified conditions of handling, storage, and transportation?			
(11)	Has contract operation & maintenance training program established & verified effective during Government system test & any operational tests?			
(12)	Are contractor PS tasks & compliance requirements defined in P&D RFP?			
(13)	Does P&D planning addresses production processes, acceptance testing, inspection criteria, R&M requirements, R&M activities schedule, production surveillance, use of FRACAS, & evaluation of proposed system changes.			

Source: Table developed from several sources including the PSM Guidebook, the existing BoK, and the DAU site https://aaf.dau.edu/aaf/mca/milestone-c/.

4.6 MILESTONE C REVIEW

4.6.1 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.

4.6.2 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 SE.
- *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 Acq Strat.

4.6.3 R&M Recommendation

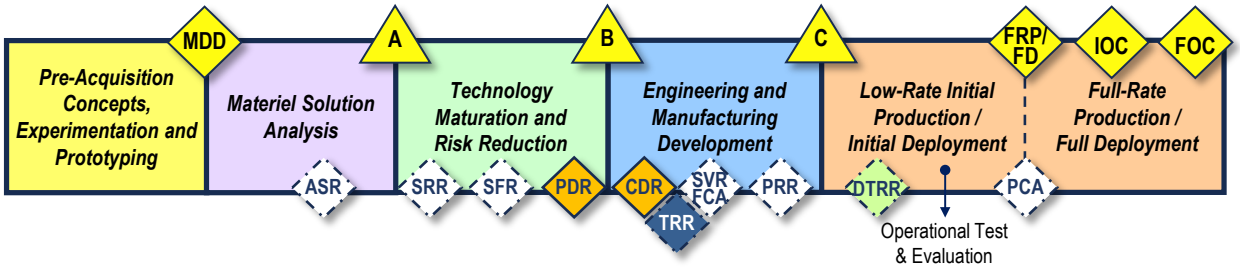
On the basis of the review, make recommendations (with justification) for disposition of the program by one of the following alternatives:

- *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.

5 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 FRP, the 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, such as 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 as a result of 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.

- Maintain surveillance of deployed and operational systems through the Service MDCS and other continued closed-loop 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 5-1. Table 5-1 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 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 BIT improvement opportunities via FRACAS and field data assessment.
- Review ECPs, operational mission/deployment changes, and variations for impact on R&M.
- Update R&M estimates, 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, resolution of obsolescence and DMSMS issues, 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.

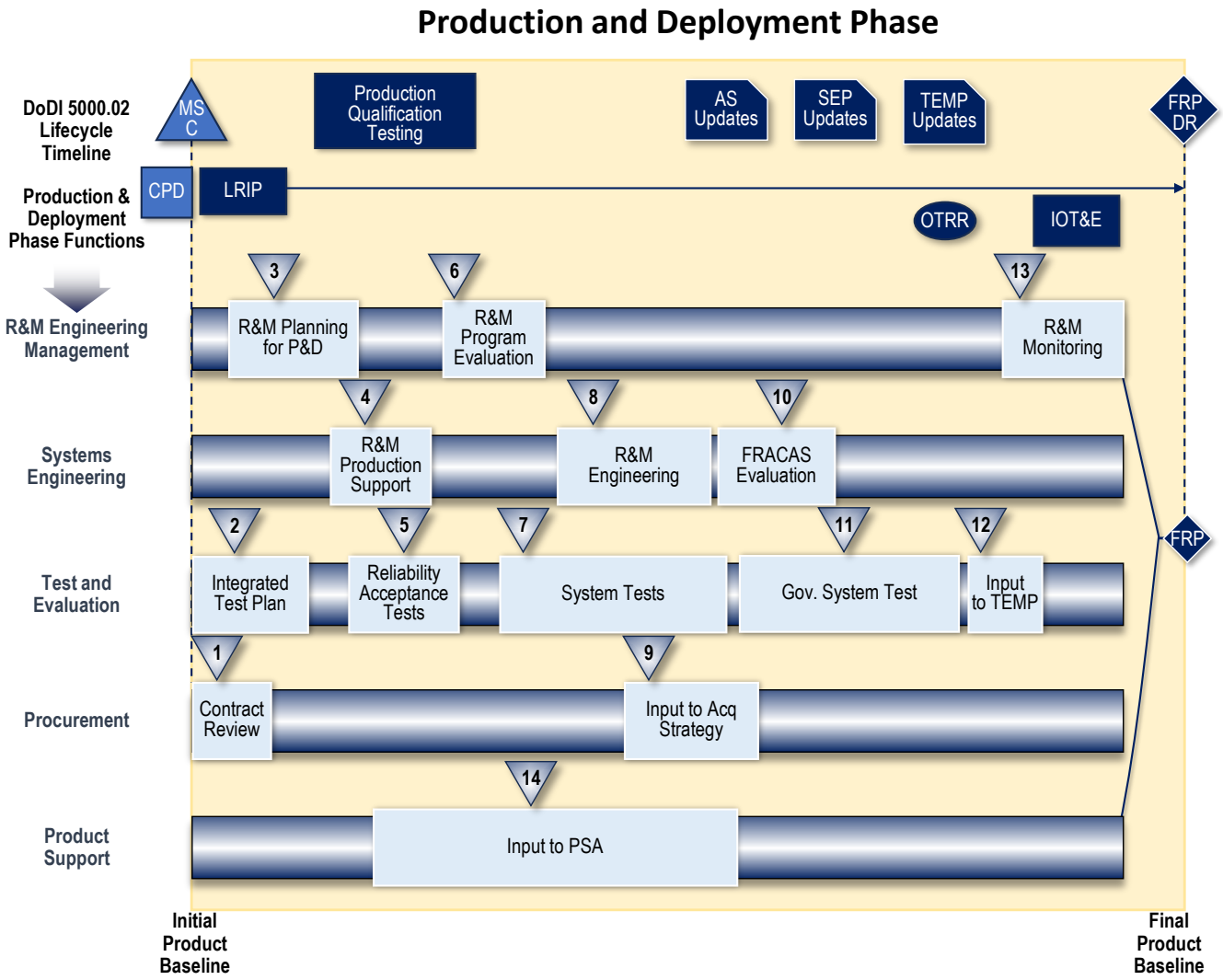


Figure 5-1. P&D Phase R&M Activities by Functional Area

Table 5-1. R&M Activities in the P&D Phase

R&M Activities		Functional Area	Paragraph
1	Review P&D phase contract	Procurement	5.4.1
2	Review Integrated Test Plan	Test and Evaluation	5.3.1
3	Review R&M Planning for P&D phase	R&M Engineering Management	5.1.1
4	Provide R&M production support	Systems Engineering	5.2.1
5	Perform Production Reliability Acceptance Test	Test and Evaluation	5.3.2
6	Evaluate R&M Program	R&M Engineering Management	5.1.2
7	Perform System Test	Test and Evaluation	5.3.3
8	Perform R&M engineering	Systems Engineering	5.2.2
9	Provide R&M Input to Acquisition Strategy	Procurement	5.4.2
10	Evaluate FRACAS	Systems Engineering	5.2.3
11	Perform Government System Test	Test and Evaluation	5.3.3
12	Provide R&M input to TEMP	Test and Evaluation	5.3.4
13	Monitor R&M in production	R&M Engineering Management	5.1.3
14	Input to PSA	Product Support	5.5.1

5.1 R&M Engineering Management

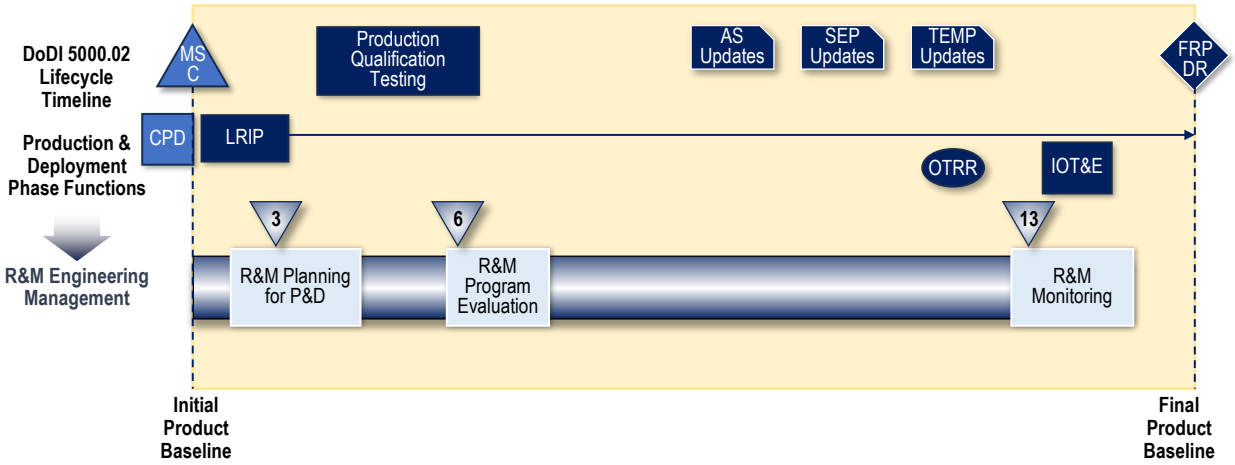


Table 5-2 lists the R&M activities applicable to the P&D phase R&M Engineering Management functional area:

Table 5-2. R&M Engineering Management Activities – P&D Phase

R&M Activity	Description
3 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.
6 Evaluate R&M Program	Evaluate effectiveness of the implemented program in P&D to refine R&M procedures.
13 Monitor R&M in production	Manage and control R&M status, trends, and problems in production items.

5.1.1 Review R&M Planning for P&D Phase 3

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 each Service MDCS. Production inspection, engineering, and quality control activities have an impact on R&M and should be considered 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 for use in any design changes implemented during the P&D phase and 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 among 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 affect 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 MDCS. 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 planning provisions.
- *R&M Procedures* – Contractor's R&M procedures related specifically to production control of R&M covered in the planning provisions.

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), WBS, 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 defects are not introduced into the products being manufactured.

5.1.2 Evaluate R&M Program 

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., estimates, FMECA, SFMEA).

Evaluation may include 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 identifying and solving problems. Ensure that previous R&M analyses are updated to reflect changes to the system design resulting from analyzing 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 LRIP 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 MARs 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.
- *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 for this function generally can be defined on the basis of contractor-assigned R&M activities, 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, MARs, 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 specified acceptance test.
- *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.

5.1.3 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 correcting problems (including updates to previous R&M analyses), controlling 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 measurements 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, including 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 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.

5.2 Systems Engineering

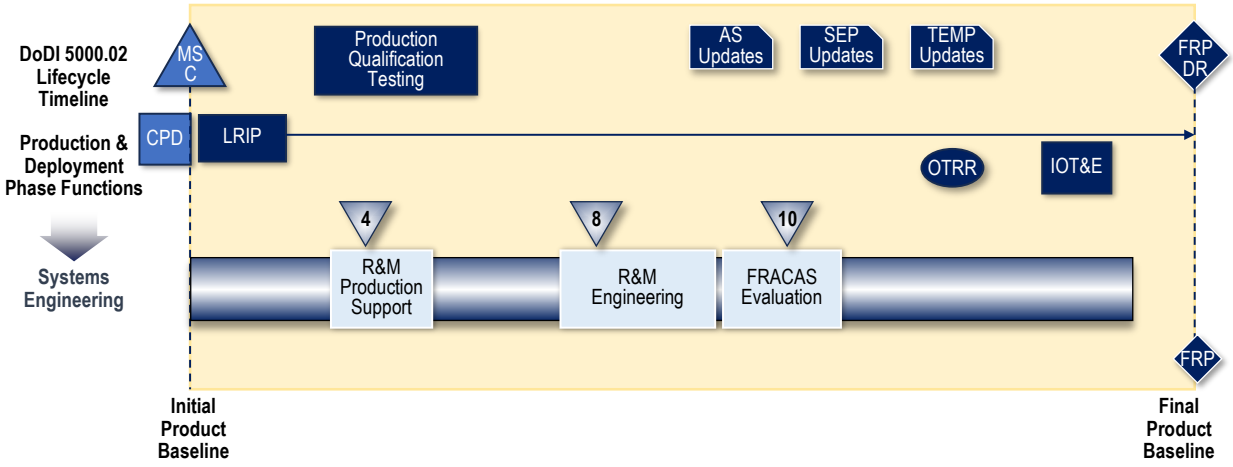


Table 5-3 lists the primary R&M activities for the Systems Engineering functional area in the P&D phase.

Table 5-3. R&M Systems Engineering Activities – P&D Phase

R&M Activity		Description
4	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.
8	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.
10	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.

5.2.1 Provide R&M Production Support 4

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.

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 repeated 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.

5.2.2 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/MAR 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 MARs 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 MARs observed in production acceptance tests are within the acceptance limits specified by the R&M acceptance test.
    - 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, SE 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 estimates, 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 SE 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.

5.2.3 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.
  - 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.

5.3 Test and Evaluation

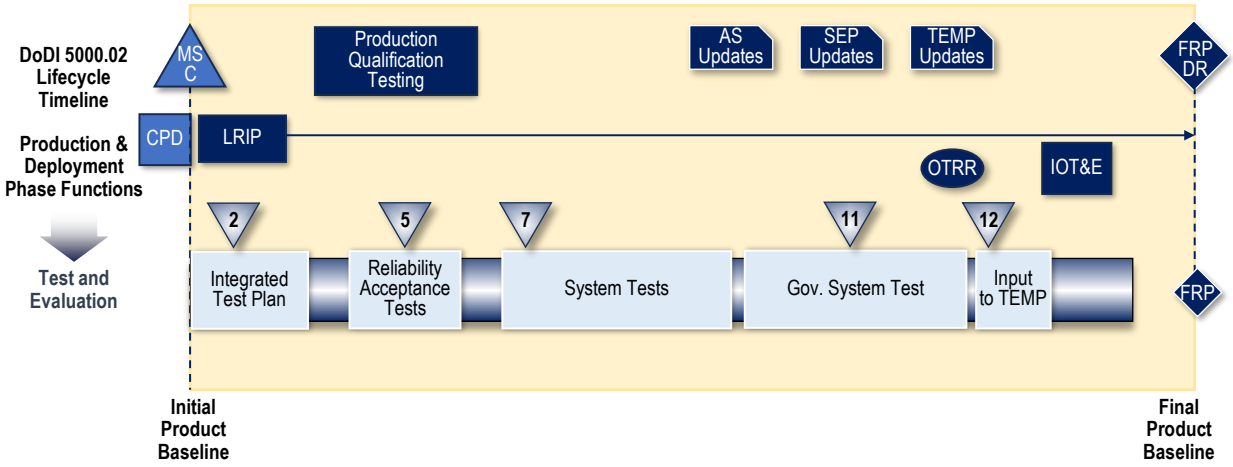


Table 5-4 lists the primary R&M activities associated with the Test and Evaluation functional area in the P&D phase.

Table 5-4. 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.

5.3.1 Review Integrated Test Plan 2

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 needs evidence that the system will satisfy the field operational thresholds for R&M reflected in the requirements document, evidence 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 – Conducted 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 – Conducted 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 – Conducted to determine equipment conformance to specified failure-rate/failure-mode/MAR 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 conducted in either of two ways, depending on the size, complexity, and quantity of production items. Formal reliability demonstrations can be conducted for large, complex systems, or failure-rate acceptance testing can be conducted 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 – Conducted 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.
  - 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.

5.3.2 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:

- *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 the contractor to adjust 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.

5.3.3 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.
    - 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.

5.3.4 Provide R&M Input to TEMP

Update the TEMP for the 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.
- *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.
- *Specification*s – 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.

5.4 PROCUREMENT

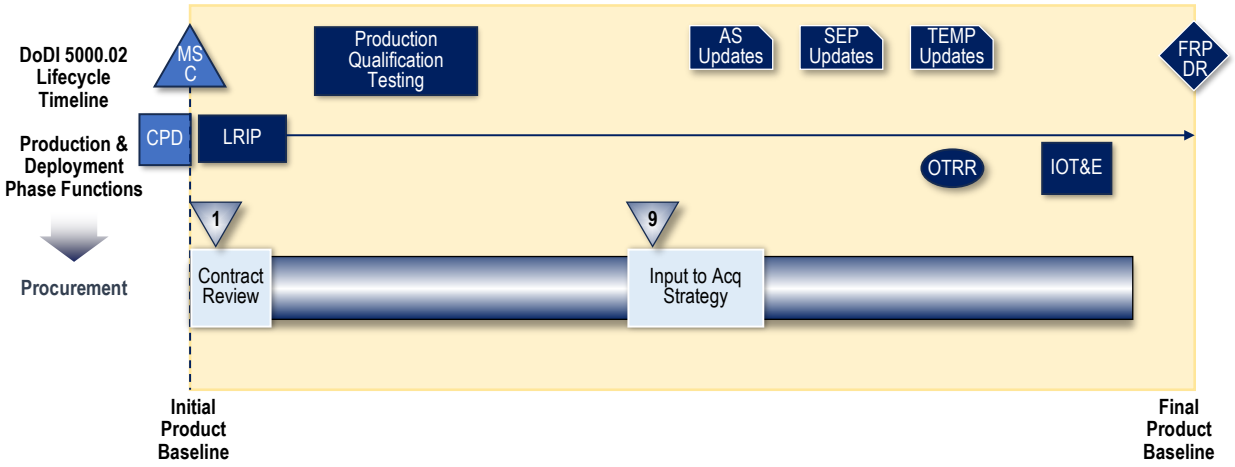


Table 5-5 lists the primary R&M activities associated with the Procurement functional area in the P&D phase.

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

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

5.4.1 Review P&D Phase Contract 1

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 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 following criteria.

- *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.

5.4.2 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 requirements development documented 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 Acquisition Strategy: 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 Acquisition Strategy: Data

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

Input to Acquisition Strategy: 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.

5.5 PRODUCT SUPPORT

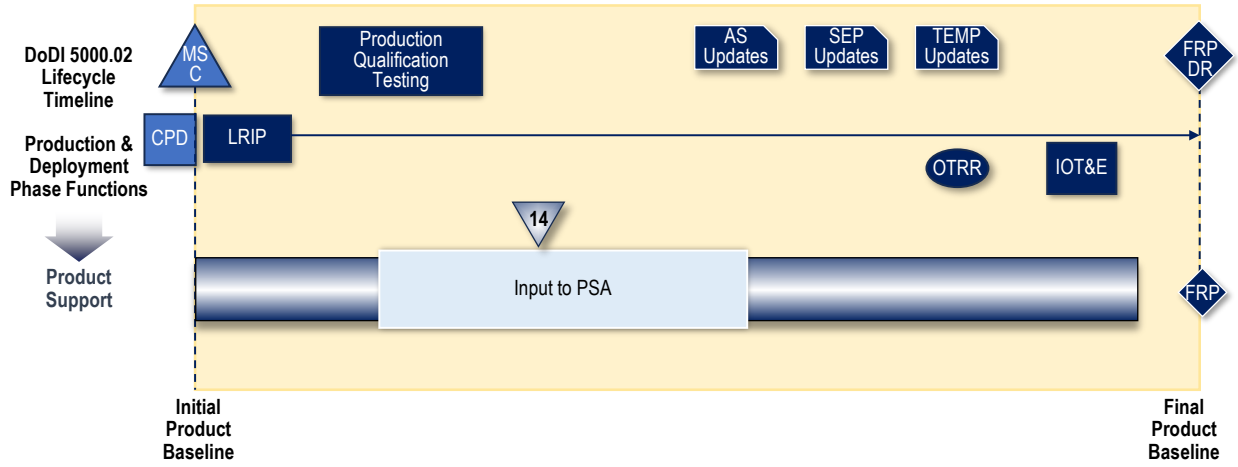


Table 5-6 lists the primary R&M activities associated with the PS functional area in the P&D phase.

Table 5-6. R&M PS Activity – P&D Phase

R&M Activities	Description
14 Input to PSA	Input to product support, e.g., reevaluate maintenance procedures, training plans, to achieve or improve R&M and operational requirements

Other R&M activities in the P&D phase related to PS include the following:

- Review ECPs, operational mission/deployment changes, and variations for impact on R&M & sustainment. Verify that Parts Management Program requirements for limiting reliability risk and "lessons learned" are used during all design change efforts.
- Performance of the PSP, which is fielded to support initial operational capability. is measured against availability, reliability, and cost metrics. Remediation plans should be developed to address any identified issues or "deficiencies" identified through testing and executed prior to acceptance.
- R&M demonstrations and tests performed for acceptance are monitored as are those performed for production surveillance on a sampling basis. Review and approve deficiency reports and the assessment of R&M performance. Deficiency reports include:
    - Product Quality Deficiency Reports (PQDR) used to identify, report, and resolve conditions impacting the warfighter.
    - Hazardous Material Reports (HMRs) identify hazardous chemicals and other materials and instructions for safe handling during maintenance.

  - Technical Publication Deficiency Reports (TPDRs) used to report critical, major, and minor discrepancies in technical manuals found by the using activity.

- The R&M engineer prepares and periodically reviews and updates the R&M requirements defined in production specifications and evaluates proposed changes to determine its effect on R&M characteristics of the design. The reviews and updates have the following objectives.
  - Verify R&M characteristics, maintenance concept, repair policies, and maintenance procedures by test and evaluation. Identify BIT and technical manual improvement opportunities via FRACAS and field data assessment.
  - Update R&M predictions, the FMECA, RCM, and other analyses based on P&D phase testing and LRIP field data reports. Coordinate with PSMs to verify that this data is used in the models previously developed to assess impacts on PS.

In addition, tasks under the other functional areas provide important inputs to and support PS.

5.5.1 Provide Input to Product Support Analysis

The interface between R&M engineering and PS continues in the P&D phase. Maintenance procedures, provisioning requirements, training plans, packaging design, test equipment, and other SE requirements can all be re-evaluated on the production system and updated to satisfy more nearly the R&M and operational readiness requirements. From an R&M perspective, the PM and PSM should ensure that the specific maintenance procedures and provisioning plans developed are validated based on data derived from production tests, demonstration tests, operational evaluation, and subsequently, field reports on the production system. These managers should also ensure that the impact of these plans and procedures on system R&M is validated, i.e., they demonstrate conformance to expectations derived from the tradeoff studies on which they are based.

During P&D, the PSM with the assistance of logistics specialists, the R&M engineer, and other members of the program team, will:

- Update the PSS.
- Update the PS plan and PSA by providing inputs based on testing and analysis conducted during P&D.

Provide Input to Product Support Analysis: Procedure

The R&M engineer validates the PS plans, or verifies the validation, as follows.

- *Maintenance Plan* — Validate the R&M data and verify adequacy of maintenance plans, test, and SE requirements for the production design based on production test data, demonstration

test data, operational evaluation, and field experience data as they become available, to accomplish the following:

- Verify that the failure modes and effects used in maintenance engineering analysis and SE planning are consistent with the R&M analyses and failure data derived from test time accrued on the current production design configuration.
- Verify the data on which maintenance and SE requirements have been defined is still valid and thus confirms the selection of test points, sensor designs (for performance monitoring and fault indication) and design of ATE and other SE.
- Verify that R&M data accrued from tests of the production design confirms the adequacy and continued need for design features contemplated by the maintenance concept, including ATE, "throwaway" modules, and redundancy with on-line repair, and confirm earlier predictions of failure detectability and false alarm rate associated with fault indication and performance monitoring.
- Verify that time-to-failure distributional parameters initially predicted are still valid as a basis for the preventive maintenance system for the equipment.
- Verify that maintenance-induced R&M degradation problems have been identified and are adequately described for corrective action through a change in either maintenance procedures or test equipment design.
- Evaluate the impact of maintenance plans and procedures, including daily system operability tests, on operational R&M and availability.

- *Provisioning Plan* — R&M data derived from production tests and demonstrations should be used to update the spares provisioning plans developed earlier based on use of production-representative articles. The acquisition manager should review these plans, which become the basis for actual procurement of initial spares, to verify consistency with usage rate data derived in the R&M analyses. Usage rate for spares and spare parts is based on the "removal" rate of these items from the equipment during corrective and preventive maintenance, which includes, but is not limited to, those verified as actual failures.
  - Verify that test data and field data have been used as the basis for estimation of spare parts and components required to support the system under the planned verified maintenance concept.
  - Verify the specification requirements for replacement parts and components on the provisioning list have the same R&M control provisions as proposed for production procurement.
  - Verify that Parts Management Program requirements for limiting reliability risk and “lessons learned” have been used during all design change efforts including change proposals, Diminishing Manufacturing Sources and Material Shortages (DMSMS) solutions, product improvement efforts, or any other hardware change effort.

  - Verify that provisioning plans include replacement hardware for planned periodic sampling and laboratory test programs, operational readiness exercises, etc., that provide inputs for R&M assessment and control.

- *Maintenance Plan* – The PSM and R&M engineer analyze RCM analysis and in-service data and develop updates to the scheduled maintenance plan, CBM+, and related capabilities to continuously improve maintenance effectiveness and efficiency. Finally, the PSM supports the Full Rate Production (FRP) decision review and preparedness for Initial Operating Capability (IOC) and Full Operating Capability (FOC).
- *Maintenance Procedures* — Using production test and maintenance experience, reassess R&M sensitivity of the system to variations in procedures for operation, checkout, maintenance, and handling, and verify that these are clearly identified in applicable operation and maintenance manuals for the system. Based on data derived from production tests, demonstration tests, operational evaluation, and subsequently, field reports on the production system, verify and validate[21] specific maintenance procedures.
  - Verify that field personnel test procedures and instructions described in these manuals on the LRIP production-representative models, to identify and eliminate ambiguous or erroneous instructions that could degrade performance or R&M.
  - Verify that procedures for turn-on/off checkout, operation, and performance monitoring of the system are sufficiently comprehensive, clearly defined, and simply presented, so that R&M and other performance characteristics achieved in design cannot be seriously degraded by operator error induced by inadequate or unclear procedures.
  - Verify that procedures for corrective and preventive maintenance cover all malfunction symptoms and failure modes and provide clear, direct procedures for diagnosing, correcting, and verifying correction of malfunctions.
- *PHS&T Design* — Re-evaluate PHS&T designs and design interfaces to ensure compatibility with production configuration, and revalidate, by test, the adequacy of production PHS&T design to provide the specified protection against the following R&M degradation factors:
  - Shock and vibration exposure in transportation and handling
  - Exposure to extreme thermal ambient in transportation and storage
  - Relative humidity in the storage environment

[21] Verification focuses on ensuring system-level requirements are met. In contrast, Validation focuses on ensuring the system performs the way it was designed and intended.

Provide Input to Product Support Analysis: Data Requirements

The R&M engineer requires data at this review point, including data from:

- *Logistics Planning Report* — overall LCSP updated from the EMD phase. Plan elements include the following.
  - Maintenance engineering analysis report
  - Maintenance plan
  - Operation and maintenance manuals
  - Spares provisioning plan
  - PHS&T requirements analysis and design criteria
- *Contractor Logistics Validation Plan* — plans and procedures for evaluating and verifying effectiveness of specific elements of the logistics plan in relation to the production design.
- *Specifications* — production specifications, drawings, and lists pertaining to the system, including spares and replacement parts included on the provisioning list.
- *R&M Assessment*— results of failure rate, failure-mode and MAR analyses performed as engineering functions on the current production design configuration.
- *Logistics Evaluation Reports* — results of validation tests performed in accordance with approved plans, to include the following:
  - Operating procedures evaluation report with basic data and analysis pertaining to proposed operating instructions.
  - Maintenance procedures evaluation report with basic data and analysis pertaining to the proposed maintenance instructions.
  - Maintenance analysis report containing complete updated analysis of failure rate and mode, and MAR confirming the selection of maintenance procedures, test equipment, and maintenance SE required to support the system in the field.
  - PHS&T verification report containing test results accrued on production systems. Feedback of operational experience data from field activities should be analyzed and included in the report.

Provide Input to Product Support Analysis: Review Criteria and Decision Alternatives

Acceptability of R&M considerations in maintenance engineering analysis and logistics planning becomes evident as engineers compile and analyze data from production tests, R&M demonstrations, operational evaluation, and field experience. If criteria outlined previously show evidence of not being satisfied during the period of field introduction, the program should take one of the following alternatives.

- *Conditional Approval* — Determine causes of observed logistics planning deficiencies and, if correctable in the current production contract period, initiate appropriate corrective action.
- *Disapproval* — If not correctable in the current contract period, disapprove the logistics plan and advise of the disparity between the achievable R&M under the current logistics support plans and the R&M thresholds in the CDD, with a full description of the problem and a realistic estimate of the cost, time, and risk factors involved in its correction.

P&D Checklist for Product Support

Table 5-7 is a checklist for ensuring the needed R&M inputs to PS are made prior to the end of the P&D phase.

Table 5-7. Checklist for R&M Inputs to Product Support During P&D

R&M INPUT TO PRODUCT SUPPORT CHECKLIST		ADEQUATE		REMARKS
		YES	NO	
(1)	R&M aspects of logistics support elements evaluated and validated.			
(2)	Maintenance engineering analysis verified by test; R&M impact of maintenance concept, repair policies, and maintenance procedures identified.			
(3)	Spares provisioning plans based on removal rates observed in demonstration tests.			
(4)	Operation and maintenance manuals prepared, updated with current production design configuration, verified by test, and available for distribution.			
(5)	Packaging design compatible with the item protection requirements and proven acceptable by demonstration test under specified conditions of handling, storage, and transportation.			
(6)	Design changes made during the P&D phase to correct performance and design deficiencies are assessed and monitored to verify the improvement and impact on the Sustainment KPP.			

5.6 Full-Rate Production Decision Review

5.6.1 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. It is the critical transition point in the life cycle at which the design is considered suitable and stable. R&M suitability of the production system should first be demonstrated by test, then verified by operational test and evaluation for field use.

The RAM-C should be updated to reflect current performance metrics versus requirements and total impact to life cycle costs. This supports the FRP decision and is attached to or included in the LCSP. If the RAM-C and LCSP shows there are significant problems, further development and corrective actions may be required to ensure the metrics are achieved.

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 accrued from production tests and field operational experience.

5.6.2 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 from deficiency reports, R&M improvement programs, manufacturing processes, mission abort drivers, or safety issues/mishaps.
- *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.

5.6.3 R&M Recommendation

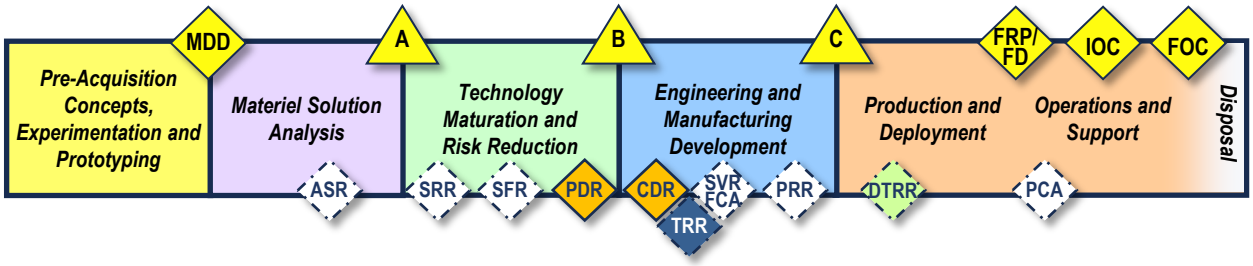
On the basis of the review, make specific recommendations, with justification, for disposition of the program by one of the following alternatives:

- *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 through demonstration or test.

6 R&M in the Operations and Support Phase



Objectives of the Operations and Support Phase

The 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 practicality of incorporating improvements from technological advances or maintaining and updating the design and support structure.

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 each Service MDCS 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:

- Maintain R&M KPPs and KSAs throughout production.
- Ensure product support strategies are sufficient to maintain system effectiveness during operations.
- Optimize cost and performance through Identification of R&M and product support issues and implementation of corrective actions.

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 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 PM 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., 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 6-1 and Table 6-1. The activities should reflect the continuation of the iterative design-evaluate-redesign-reevaluate doctrine practiced in previous phases.

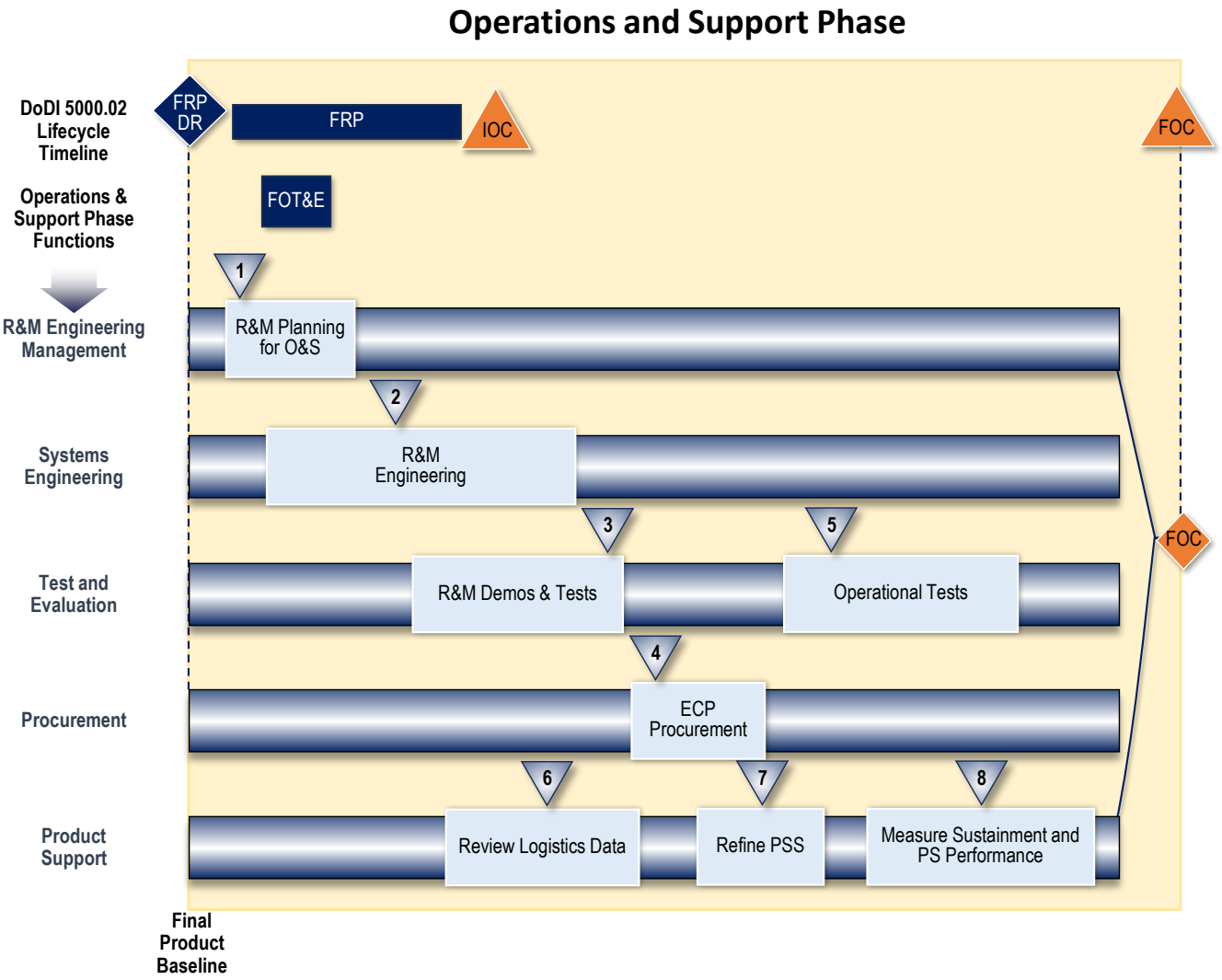


Figure 6-1. O&S Phase R&M Activities by Functional Area

Table 6-1. R&M Activities in the O&S Phase

R&M Activity	Functional Area	Paragraph
1 Develop R&M planning for O&S	R&M Engineering Management	6.1.1
2 Perform R&M engineering	Systems Engineering	6.2.1
3 Conduct R&M demonstrations and tests	Test and Evaluation	6.3.1
4 Support ECP procurement	Procurement	6.4.1
5 Support Service operational tests	Test and Evaluation	6.3.2
6 Review logistics data	Product Support	6.5.1
7 Refine the PSS	Product Support	6.5.2
8 Measure sustainment and PS performance	Product Support	6.5.3

6.1 R&M Engineering Management

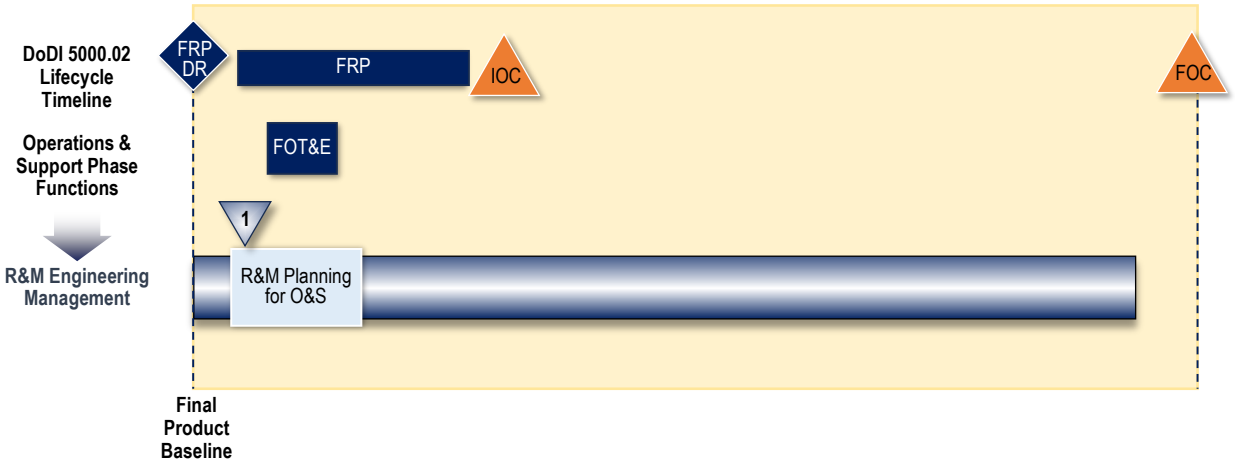


Table 6-2 lists the primary R&M activity associated with the R&M Engineering Management functional area in the O&S phase.

Table 6-2. R&M Engineering Management Activity – O&S Phase

R&M Activity	Description
1 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.

6.1.1 Develop R&M Planning 1

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.

The Government R&M engineer verifies that Parts Management Program requirements for limiting reliability risk are used during the selection of parts and materials for any design changes that take place during the EMD phase due to obsolescence and DMSMS issues or for any other required change.

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 each Service MDCS or other reporting systems. Enter the data into the continuing 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. Assess R&M operational measures against R&M KPPs and KSAs, 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 performance 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; estimates; FMECA, SFMEA) to reflect any design or process changes under consideration or to reflect any previously unaccounted-for or undocumented failure modes that have occurred in the field.
    - Following are some examples of types of engineering analysis that might prove useful:

- Top Degrader Analysis prioritizing R&M issues using composite score analyses considering reliability, maintainability, cost, criticality, and safety
- FRACAS analyzing root causes of top degraders and developing corrective actions to mitigate or eliminate the failure modes
- Failure rate analysis to update predictions, block diagrams, FMECAs, and other early assessments
- Updates to product support strategies based on updated failure rate analysis
- RCM updates to ensure failure management strategies are updated for actual performance measurements

- Cost Analysis/BCA – 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. Failure analysis reports should include details of the forensic techniques of discovering failure mechanisms and should document evidence of findings.
- 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 deployment environment 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 support 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 each Service MDCS and other data sources covering the period of interest, to include:
  - System/mission reliability.
  - System maintainability.
  - Failure-rate/root cause failure mode.
  - Operational availability.
  - 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 each Service MDCS 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, software, and engineering analyses identifying the specific root cause and consequence of failure.
  - R&M operations and support feedback – Surveys and direct lines of communications from users and maintainers with issues they are seeing during operation and repairs.
  - 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.
  - 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.
- *Parts and Materials Selection and Control* – Evaluate procedures for the selection and control of parts and materials for use in any design changes during the O&S phase, 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.

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 and mechanisms from contractors, subcontractors, and suppliers, as appropriate to the contract.

6.2 Systems Engineering

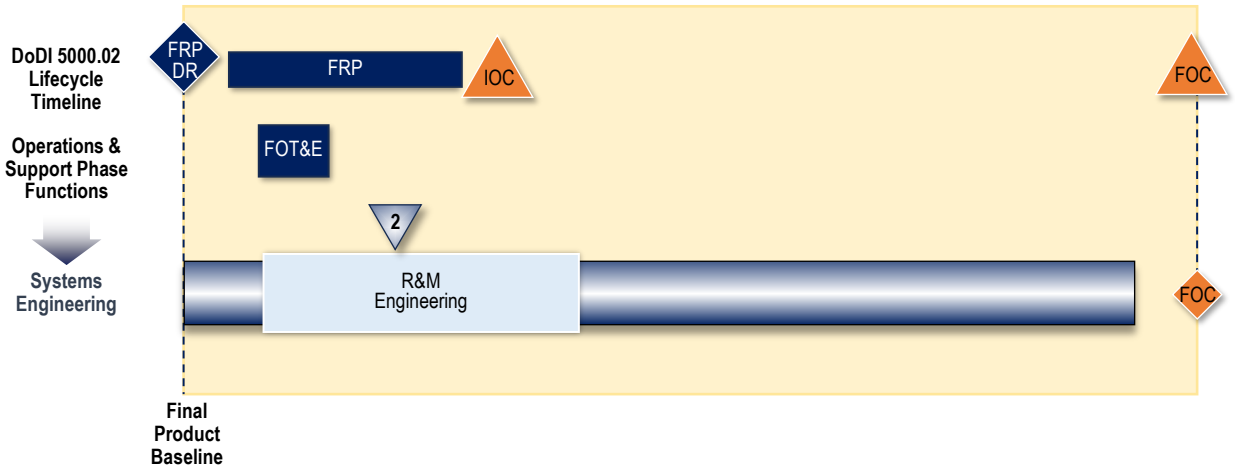


Table 6-3 lists the primary R&M activities associated with the activities for the Systems Engineering functional area in the O&S phase.

Table 6-3. R&M Systems Engineering Activities – O&S Phase

R&M Activity	Description
2 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.

6.2.1 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
- The update of previously performed R&M analyses based on these changes to reflect new system configurations.

Alternative original equipment manufacturer (OEM) repair procedures and/or consideration of overhaul criteria of high failure rate parts within components for increased time since repair. 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.

Some Service R&M practitioners have noted that a major roadblock to successful FRACAS and proper failure mode identification is lack of OEM repair data. If available, OEM repair report data may improve failure modeling as part of FRACAS.

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 re-procurement. 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 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 estimate analysis and verification methods. Evaluate relative life cycle costs/BCA, 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., estimate, 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.*

6.3 Test and Evaluation

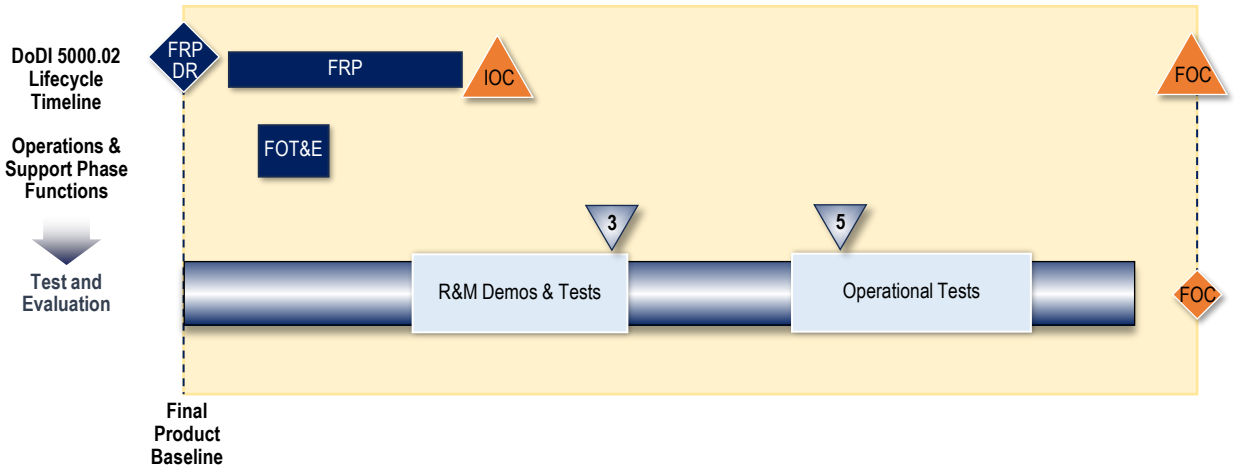


Table 6-4 lists the primary T&E R&M activities in the O&S phase.

Table 6-4. R&M T&E Activities – O&S Phase

R&M Activity	Description
3 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.
5 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.

6.3.1 Conduct R&M Demonstrations and Tests 3

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 and 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 each Service MDCS 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 and 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.
- *Test Incident Reports* – To capture details of test incidents that may not be available in test reports.

R&M Demonstrations and 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).

6.3.2 Support Service Operational Tests 

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 each Service MDCS, 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.
  - 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 MDCS 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, test incident reports, 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.
- *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.

6.4 PROCUREMENT

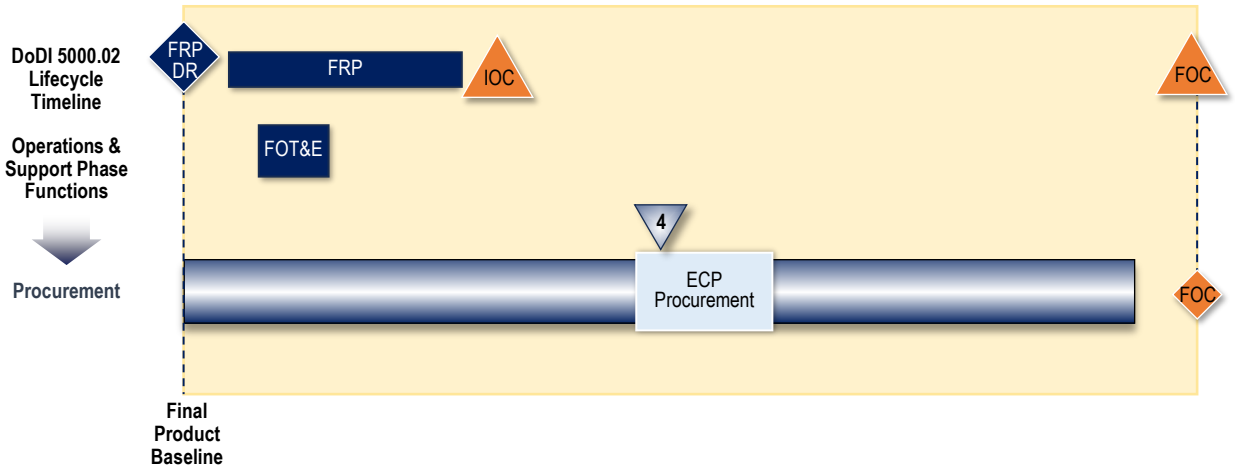


Table 6-5 lists the primary procurement R&M engineering activities in the O&S phase.

Table 6-5. R&M Procurement Activities – O&S Phase

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

6.4.1 Support ECP Procurement 4

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 MDCS 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.
- *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 MDCS data analysis, and R&M assessments are called out in the contract.

6.5 Product Support

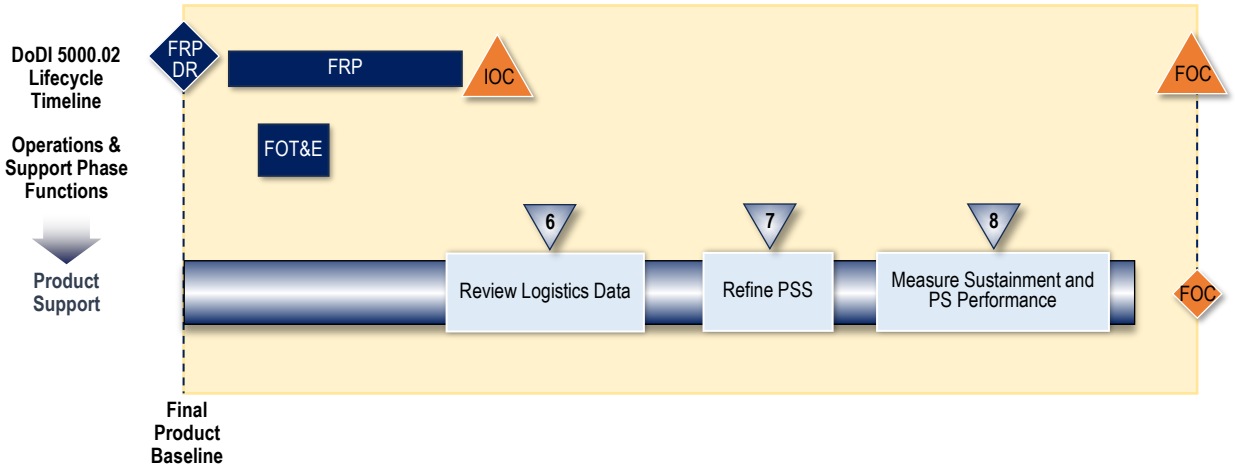


Table 6-6 lists the primary PS R&M engineering activities in the O&S phase.

Table 6-6. R&M PS Activities – O&S Phase

R&M Activity		Description
6	Review logistics data	Review logistics data for potential deficiencies in R&M design or maintenance procedures
7	Refine the PSS	Refine the PSS based on data from maintenance activities and failure reporting
8	Measure sustainment and PS performance	Measure sustainment and PS performance and implement corrective actions as needed to improve readiness

In addition to these tasks, tasks in the other functional areas provide inputs to and support PS.

- R&M engineering tasks include:
  - Ensuring the operational features and characteristics (including R&M) achieved for the system in EMD are maintained under control throughout production and experienced consistently in the field under operational conditions.
  - Ensuring the PSP elements are adequate to support the system and achieve the Sustainment KPP in the operational environment (a primary objective at IOC).
- An important T&E task is conducting sustainment reviews (SRs), which are required by 10 USC 4323. These reviews are conducted to assess the PSS, performance, and O&S costs of the covered system.

In the O&S phase, the PSM assesses the effectiveness of the sustainment approach in terms of the KPP and KSAs as a basis for evaluating and revising the PSS. Changes may be required due to changes in operational requirements (operational tempo, operational environment, mission changes), sustainment challenges (infrastructure and/or capabilities), funding constraints, or political shifts. Each change requires an evaluation of the product support strategy via the PS BCA process.

During O&S, support systems and services have been delivered and fully integrated into the operational environment. Depot maintenance begins to be performed. Sustainment and PS performance is regularly measured against sustainment metrics and corrective actions taken. Product improvement, modifications, and upgrades are planned.

6.5.1 Review Logistics Data 

Review of logistics data involves analyzing the data. Analysis of logistics data reveals deficiencies in R&M design and maintenance procedures potentially to be corrected by ECPs. Coordinating these possibly separate corrective actions is mutually beneficial to each and is essential to controlling both. Design changes for R&M improvement can seriously impair maintenance under the existing maintenance plan and can completely alter existing spares provisioning requirements. Conversely, an uncoordinated change in maintenance procedures can have a degrading effect on operational R&M.

The R&M engineer and logistics specialists can evaluate the effectiveness of logistics planning by analyzing field data, specifically studying system downtime for maintenance to identify errors in maintenance procedures, shortages of replacement spares or repair parts, inadequate test equipment, malfunctioning ATE, and complex and time-consuming daily system operability test procedures. Any one of these can have serious degrading effects on R&M.

Analysis of field data provides a measure of logistics planning effectiveness in meeting the maintenance support needs of the deployed system. This analysis will identify problem areas or deficiencies in maintenance planning, test equipment design, maintenance instructions, maintenance training, and spares provisioning, which the acquisition manager will assign to his participating product support team for appropriate corrective action.

Finally, logistics data is vital to the conduct of Sustainment Reviews, required by statute for any covered system.

Logistics Data: Procedure

Using field data, the R&M engineer performs or verifies performance of the following R&M-coordinated logistics support evaluation and improvement tasks:

- *Maintenance Planning* - A key part of the LCSP is the maintenance plan, which includes preventive maintenance plans and programmed Depot Maintenance Plans. Update these plans throughout O&S as new data is collected and analyzed. Conduct quality reviews, approve and issue maintenance plan updates and maintenance planning data for the users for acquiring the IPS Element products needed to sustain the weapon system and associate equipment. Review the RCM Analysis, Maintenance Plan and Maintenance Concept for in-service equipment when one or more of the following events occur:
  - Significant changes occur in the operational scenario.
  - Maintenance significant drivers change as monitored through proactive sustained maintenance planning.
  - Product support falls short of the design requirement adversely impacting readiness or costs.
  - Class-1 ECP changes in legacy systems or equipment.
  - Real-world experience is gained from operating and supporting the fielded system.
- *Maintenance Engineering Analysis* — Identify causes of excessive maintenance downtime or maintenance errors; evaluate corrective action requirements; and determine R&M impact of the proposed changes in the following areas:
  - Major revision in basic maintenance policies and concepts, or level of repair provisions.
  - Modification of corrective maintenance procedures and technical manuals.
  - Alteration of test equipment design or calibration procedures.
  - Modification of daily system operability test procedures, checkout procedures or operational success/failure criteria for "readiness" definition.
  - Relocation or redesign of test points, monitoring sensors, and false alarm indicators to improve failure detection efficiency.
- *Spares Provisioning Analysis* — Identify causes of excessive maintenance downtime attributable to any of the following factors, define the changes required to correct the deficiencies, and evaluate R&M impact of these proposed changes:
  - Inadequate spares or repair parts provisioning due to unrealistic replacement rate data.
  - Inadequate reliability in spares or repair parts packaging for the handling, storage, and transportation environments to which exposed in the logistics support cycle.
- *PHS&T Evaluation* — Evaluate R&M adequacy of PHS&T design for delivery of systems and for storage, handling, and transportation incident to replenishment of spares for maintenance at all maintenance levels; and for return of repairable items removed from deployed systems.

Logistics Data: Data Requirements

Review and evaluation of R&M-coordinated maintenance and logistics improvements are dependent on acquisition of the data from the following documents and analysis.

- *Logistics Support Assessment Report* — report of field data analysis identifying maintenance and logistics support deficiencies in the following areas:
  - Maintenance planning
  - Support and test equipment
  - Technical data — operation and maintenance instructions
  - Spares and repair parts provisioning
  - PHST design adequacy in its intended application
- *Maintenance Engineering Analysis* — maintenance analysis based on field data, with an evaluation of R&M impact due to proposed changes in any of the following areas:
  - Relocation of test points, monitoring points, and sensor locations for system test and checkout during maintenance.
  - Redesign of test equipment, built-in test equipment, and ATE.
  - Redefinition of maintenance policy or procedures (e.g., reconsideration of throwaway vs. repair policy).
  - Redefinition of maintenance (e.g., go/no-go) criteria.
  - Redefinition of personnel skill levels and training requirements.
- *Provisioning Change Proposals* — proposed changes or improvements in provisioning plans for spares and repair parts, with an evaluation of R&M impact to be expected with the approval of such changes.
- *Logistics Support Impact Analysis Report* — assessment of impact on maintenance and logistics plans and procedures, due to changes under consideration for system R&M or performance improvement, with an evaluation of the changes in maintenance plans and logistics support provisions required because of these changes.

Logistics Data: Review Criteria And Decision Alternatives

Approval of changes for maintenance and logistics support enhancement, Service Life Extension Programs (SLEPS), or any other reason can be justified from R&M points of view when analyses and test data verify that the proposed changes can be introduced without degrading current R&M, or jeopardizing improvement potential available in changes currently pending.

6.5.2 Refine the PSS

The PSS is refined leveraging the best value mix of organic and contractor support for logistics processes, services and products.

Refine the PSS: Procedure

Refining the PSS during O&S requires the following activities.

- Performance Monitoring and Evaluation:
  - Track key performance indicators (KPIs). Monitor metrics related to availability, R&M, and support cost to assess the effectiveness of the current strategy.
  - Collect and analyze data. Gather data from maintenance activities, failure reporting, and other sources to identify trends and areas for improvement.
  - Conduct regular reviews. Periodic reviews with stakeholders to discuss performance data, identify issues, and propose adjustments to the strategy.
- Update of the PS BCA.
  - Re-evaluate cost and benefit analysis. Regularly re-evaluate the PS BCA to ensure the strategy remains cost-effective and aligns with operational needs.
  - Consider alternative support options. Explore different approaches to product support, such as transitioning between commercial, organic, and partnered support providers.
  - Assess the impact of changes. Analyze the potential impact of proposed changes to the strategy on cost, performance, and other relevant factors.
- Update of the LCSP.
  - Reflect changes in requirements. Incorporate changes in operational requirements, performance goals, and budget constraints into the LCSP.
  - Adjust support arrangements. Modify the product support arrangements to reflect the updated strategy and ensure that support providers are aligned with the new requirements.
  - Implement necessary changes. Implement the agreed-upon changes to the PSS and ensure that they are effectively communicated and implemented.
- Continuous Improvement.
  - Seek feedback. Regularly solicit feedback from users, maintainers, and other stakeholders to identify areas for improvement.
  - Embrace lessons learned. Document lessons learned from past experiences and use them to refine the strategy for future products and projects.

- Stay informed. Keep abreast of industry best practices and emerging technologies to ensure that the strategy remains current and relevant.

By continuously monitoring performance, conducting updates of the PS BCA and LCSP, and embracing a culture of continuous improvement, an organization can refine the PSS during the O&S phase to ensure that their products continue to meet the needs of their users in a cost-effective and efficient manner.

Refine the PSS: Data Requirements

- Metrics related to availability, R&M, and support cost.
- Operational data from Service MDCs.
- Supply system data (order fulfillment rates, cost per unit, inventory levels, demand rates, etc.).
- Manufacturing data (work measurement, variances, defect rate, etc.).
- Changes in operational requirements, performance goals, and budget constraints.
- Feedback from users, maintainers, and other stakeholders

Refine the PSS: Review Criteria and Decision Alternatives

Approval of changes to the PSS based on changes to the LCSP, PS BCA, or any other reason can be justified from R&M points of view when analyses and test data verify that the proposed changes can be introduced without degrading current R&M, or jeopardizing improvement potential available in changes currently pending.

6.5.3 Measure Sustainment and PS Performance 

During O&S, the PM will measure, assess, and report system readiness using sustainment metrics (Materiel Availability, Materiel Reliability, O&S cost, and other sustainment metrics important to the warfighter). Operational needs, changes in training requirements, technological advances, evolving threats, process improvements, fiscal constraints, plans for follow-on systems, changes to the industrial base, or a combination of these influences that occur during O&S may warrant revising the PSS.

On the basis of measuring sustainment and PS performance:

- PS package and sustainment processes are refined and adjusted based on performance and evolving operational needs.
- Initiatives to ensure and improve affordable system operational effectiveness are implemented.

Measure Sustainment and PS Performance: Procedure

PS packages are dependent on variables such as operating doctrine, changes in technology, as well as commercial and Government repair capabilities. As a result, a consistent metric to measure the maturity of the implementation process is useful in conveying the progress across the various communities. The Sustainment Maturity Levels (SMLs) concept may be used by the PSM to assess the program's progress in implementing the PSS, including the design and resultant PS Package to achieve the sustainment metrics consisting of the Sustainment KPP, KSAs, and lower-level metrics that drive sustainment performance. The SML concept addresses the full range of support options, from traditional organic based to full commercial based product support without prescribing a specific solution. In addition, the SML approach can be applied across major sub-systems to provide a common, consistent, repeatable means of articulating and understanding the product support package maturity.

Achieving SMLs along an indicated timeline helps the PSM evolve the program's PS approach to achieve the best value support solution. Achieving the "up front" levels help in designing support actions to reduce total cost of ownership (TOC) and ensure the PS package is being developed using supportability analysis concepts such as FMECA, FTA, RCM Analysis, LORA, and MTA) Using an SML construct can also help ensure the PSS can be continuously improved based on actual data collected during the testing and operations phases. (Refer to Appendix G of the PSM Guidebook for additional details)

Measure Sustainment and PS Performance: Data

Data used for measuring sustainment and PS performance should be obtained from authoritative data sources such as Service MDCSs, Advancing Analytics (ADVANA), Enterprise Visibility and Management of O&S Cost (EVAMOSC), Navy VAMOSC, Air Force Total Ownership Cost (AFTOC), Operating and Support Management Information System (OSMIS), and Component Enterprise Resource Planning (ERP) tools that, as much as possible, rely on automated data collection.

Data include:

- Materiel and Operational Availability.
- R&M (failure data, demand rates, mean downtime, repair times, etc.).
- O&S costs (spares, consumables, labor, SE. training, technical manuals, etc.).
- Supply system data (order fulfillment rates, cost per unit, inventory levels, demand rates, etc.).

Measure Sustainment and PS Performance: Review Criteria And Decision Alternatives

- Implement corrective actions when measured sustainment and PS performance indicate trends diverging from the required performance outcomes defined in the Acquisition Program Baseline (APB) and the PSS.
- Revise the PSS to reflect changes in operational needs, training requirements, technology, threats, processes, fiscal constraints, industrial base, or a combination of these influences that occur during O&S.

6.6 In-Service Reviews

6.6.1 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.

6.6.2 Procedure

Using Service MDCS data and data from depots, laboratories, and other sources of field experience, evaluate the effectiveness of the R&M improvements.

- *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.
- *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.

6.6.3 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 more than 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.

ACRONYMS

AAF	Adaptive Acquisition Framework
Acq Strat	Acquisition Strategy
ACTD	Advanced Concept Technology Demonstration
ADM	Acquisition Decision Memorandum
AI	Artificial Intelligence
AoA	Analysis of Alternatives
APB	Acquisition Program Baseline
ASOT	Authoritative Source of Truth
ASR	Alternative System Review
ATE	Automated Test Equipment
BCA	Business Case Analysis
BIT	Built-in Test
CBM+	Condition Based Maintenance Plus
CDD	Capability Development Document
CDE	Common Defect Enumeration
CDR	Critical Design Review
CDRL	Contract Data Requirements List
CFE	Contractor-Furnished Equipment
CONOPS	Concept of Operations
COTS	Commercial Off-The-Shelf
CTP	Critical Technical Parameter
DAES	Defense Acquisition Executive Summary
DAG	Defense Acquisition Guidebook
DASD(SE)	Deputy Assistant Secretary of Defense for Systems Engineering
D-DIL	Denied, Degraded, Intermittent, and Limited
DE	Digital Engineering
DID	Data Item Description
DMSMS	Diminishing Manufacturing Sources and Material Shortage
DMU	Digital Mockup
DoD	Department of Defense
DoDI	DoD Instruction
DoW	Department of War
DRMP	Design Reference Mission Profile
DSOR	Depot Source of Repair Analysis
DT&E	Developmental Test and Evaluation
ECP	Engineering Change Proposal

EMD	Engineering and Manufacturing Development (phase)
FCA	Functional Configuration Audit
FDSC	Failure Definition and Scoring Criteria
FMEA	Failure Mode and Effects Analysis
FMECA	Failure Mode, Effects, and Criticality Analysis
FOT&E	Follow-on Operational Test and Evaluation
FRACAS	Failure Reporting, Analysis, and Corrective Action System
FRP	Full-Rate Production
GFE	Government-Furnished Equipment
GOTS	Government Off-the-Shelf
HALT	Highly Accelerated Life Test
HMR	Hazardous Material Report
HSI	Human Systems Integration
ICD	Initial Capabilities Document
IMP	Integrated Master Plan
IMS	Integrated Master Schedule
IOT&E	Initial Operational Test and Evaluation
IPS	Integrated Product Support
JCIDS	Joint Capabilities Integration and Development System
KPI	Key Performance Indicator
KPP	Key Performance Parameter
KSA	Key System Attribute
LCC	Life Cycle Cost
LCSP	Life Cycle Sustainment Plan
LORA	Level of Repair Analysis
LRIP	Low-Rate Initial Production
M&Q	Manufacturing and Quality
MAR	Maintenance Action Rate
MARS	Multivariate Adaptive Regression Splines
MCS	Mission Critical System
MDAP	Major Defense Acquisition Program
MDCS	Maintenance Data Collection System
MDD	Materiel Development Decision
ML	Machine Learning
MSA	Materiel Solution Analysis (phase)
MTA	Maintenance Task Analysis
MTTR	Mean Time to Repair
OEM	Original Equipment Manufacturer
O&S	Operations and Support (phase)

OMS/MP	Operational Mode Summary/Mission Profile
OTA	Operational Test Agency
OTRR	Operational Test Readiness Review
P&D	Production and Deployment (phase)
PCA	Physical Configuration Audit
PDR	Preliminary Design Review
PHS&T	Packaging, Handling, Storage, and Transportation
PLM	Product Lifecycle Management
PM	Program Manager
PQDR	Product Quality Deficiency Report
PR	Procurement Request
PS	Product Support
PSA	Product Support Analysis
PSI	Product Support Integrator
PSM	Product Support Manager
PSP	Product Support Provider
PSS	Product Support Strategy
R&M	Reliability and Maintainability
RAM-C	Reliability, Availability, Maintainability, and Cost
RCM	Reliability Centered Maintenance
RDGT	Reliability Development Growth Test
RDP	Release Decision Point
RFI	Request for Information
RFP	Request for Proposal
RGC	Reliability Growth Curve
SCRM	Supply Chain Risk Management
SE	Support Equipment
SE	Systems Engineering
SEP	Systems Engineering Plan
SFR	System Functional Review
SML	Sustainment Maturity Level
SORA	Source of Repair Analysis
SOW	Statement of Work
SRR	System Readiness Review
SRR	System Requirements Review
SSA	Software Support Activity
SSE	System Safety Engineering
T&E	Test and Evaluation
TAAF	Test, Analyze, and Fix

TEMP	Test and Evaluation Master Plan
TM	Technical Manual
TMRR	Technology Maturation and Risk Reduction (phase)
TOC	Total Cost oof Ownership
TPDR	Technical Publication Deficiency Report
TPM	Technical Performance Measure
TRR	Test Readiness Review
VAULTIS	Visible, Accessible, Understandable, Linked, Trustworthy, Interoperable, Secure
USC	United States Code
WBS	Work Breakdown Structure

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