Essential Elements of a Reliability and Maintainability Engineering Program

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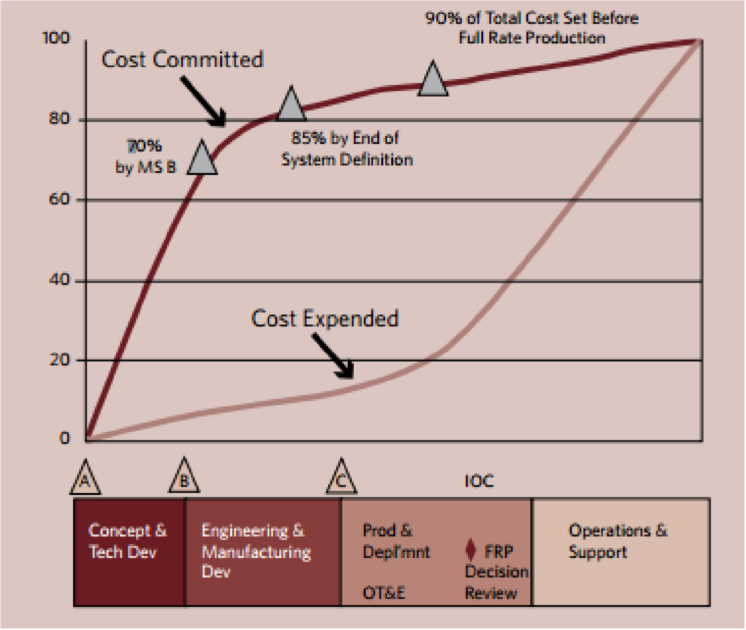
Agenda

- Need for R&M Engineering
- Key Objectives
- Policy
- Essential Elements
- Summary

Need for R&M Engineering
R&M and O&S Costs

- **Benefits of an Effective R&M Engineering Program:**
  - For the Weapons System/Equipment:
    - Reduced life-cycle costs
    - Decreased Operations and Support (O&S) costs
    - Increased mission capabilities
    - Increased readiness
  - For the Program Manager and DoD:
    - Minimize O&S cost increases & schedule delays
    - Reduce R&M risks associated with Milestone Reviews
    - Reduce R&M risks associated with Initial Operational Test and Evaluation (IOT&E)



Early application of R&M Engineering is essential to influencing the Operations and Support (O&S) cost of the program

Key Objectives

- Management commitment and attention
- Well defined mission oriented requirements
- Understand difference between operational and acquisition measures of R&M
- R&M design and test activities correctly applied and tailored to all acquisition phases
- Realistic schedule associated with R&M disciplines
- Sustained reliability growth and maintainability maturation
- R&M activities monitored for effective implementation
- R&M assessments to inform decisions at key program reviews and milestones

Policy
DoDI 5000.02 Enclosure 3 Overview

DoDI 5000.02

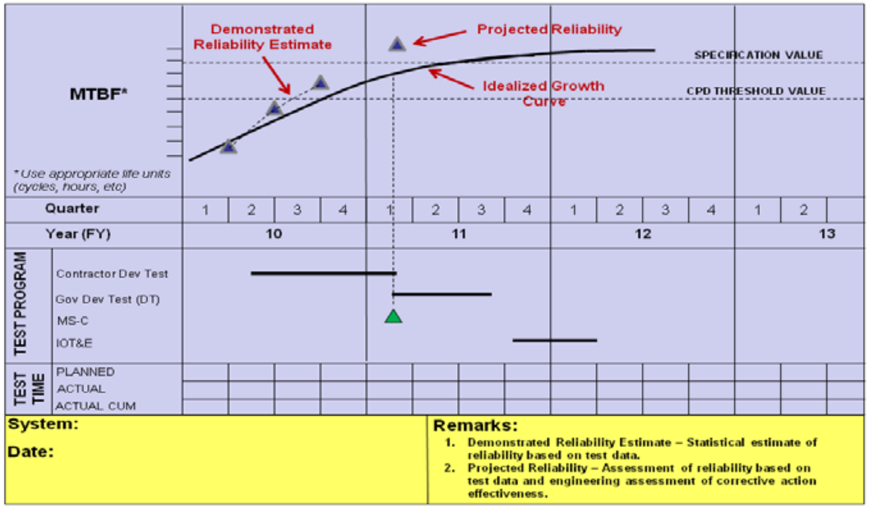

Department of Defense
INSTRUCTION

- **Engineering Activities**
  - R&M allocations, block diagrams and predictions
  - Failure definitions and scoring criteria
  - Failure Mode, Effects and Criticality Analysis (FMECA)
  - Built-in Test (BIT) and maintainability demonstrations
  - Reliability Growth testing at system/subsystem level
  - Failure Reporting, Analysis and Corrective Action System (FRACAS)

- **Preliminary Reliability, Availability, Maintainability – Cost (RAM-C) Report in support of Milestone (MS) A and updated for Dev RFP Release Decision Point, MS B, and MS C**
  - Provides early (Pre-MS A) reliability, availability, maintainability and ownership cost feasibility assessments of alternative concepts
    - Includes early formulation of maintenance & support concepts
  - Provides an audit trail that documents and supports JCIDS thresholds
  - Ensures correct balance between the sustainment metrics (Availability-KPP, Reliability-KSA, and Ownership Cost-KSA)
  - Provides early risk reduction by ensuring requirements are realistic and correct

Policy
DoDI 5000.02 Enclosure 3 Overview

- ## Reliability Growth Strategy
  - Documents system-level reliability growth curves in the SEP beginning at MS A and updated in the Test & Evaluation Master Plan (TEMP) beginning at MS B
  - Establishes intermediate goals for reliability growth curves that will be tracked through fully integrated system-level test and evaluation events until the threshold is achieved
  - Requires MS C PMs and Operational Test Agencies to assess reliability growth required to achieve the reliability threshold during Initial Operational Test and Evaluation



- ## Tracking and Monitoring
  - Requires PMs to report status of reliability objectives and/or thresholds as part of the formal system engineering review process
  - Incorporates Reliability Growth Curves into the Defense Acquisition Executive Summary (DAES) review process

Policy
JCIDS Sustainment KPP

- **The Sustainment KPP is a mandatory KPP intended to ensure an adequate quantity of the capability solution will be ready for tasking to support operational missions.**
- **At a minimum, the sustainment KPP consists of:**
  - Materiel Availability KPP
  - Operational Availability KPP
  - Reliability KSA
  - O&S Cost KSA
- **The supporting Reliability KSA and Operating and Support (O&S) Cost KSA ensure that the Sustainment KPP is achievable and affordable in its operational environment.**
- **The KPP and supporting KSAs ensure early sustainment planning, enabling the requirements and acquisition communities to provide a capability solution with optimal availability and reliability to the warfighter at an affordable life cycle cost.**

Essential Elements

- Operational Thresholds (Sustainment KPP)
- R&M Engineering Activities
- Performance Requirements
- Acquisition Documentation
- Schedule Considerations
- R&M Technical Monitoring
- Reliability Growth Strategy

Operational Mode Summary/Mission Profile (OMS/MP)

- **Required by DoDI 5000.02**
- **An OMS/MP projects the anticipated mix of ways a system will be used for each moment of time to include both peacetime and wartime. It also includes the percentage of time the system will be exposed to each type of environmental condition and movement terrain.**
- **The <u>Combat Developer</u> produces the OMS/MP following development of the system CONOPS and uses the OMS/MP (and FDSC) to conduct an analysis to determine the maintenance and support concepts describing the levels of maintenance and the maintenance activities that will be conducted at each level.**
- **Reliability growth testing and R&M demonstration testing should be reflective of the OMS/MP**

Table 1 - Marine Corps and Army Joint Major Combat Operation (MCO) Scenario with Mission Tasks *

Operational Mode Summery (OMS)	Mission Profiles (MP)	
	Offense	
Full Spectrum Element MCO War Game Phases	Littoral/Air Assault	Movement to conta
Duration (hours)	5.7	11.4
Distance (miles)	4.6	128.9
Engine Operations (hours)		
Dynamic Operation or Movement Time	0.9	6.4
Static Operation or Idle Time	1.2	1.6
Total Operating Time (Dynamic + Static)	2.1	8.0
Systems & Engine Off Time	1.8	3.4
Auxiliary Power or Battery Power (hours)		
Silent Watch Operating Time	1.8	0.0
Exportable Power	2.1	8.0
Cycles (Numbers)		
Engine on/off Cycles	1	2

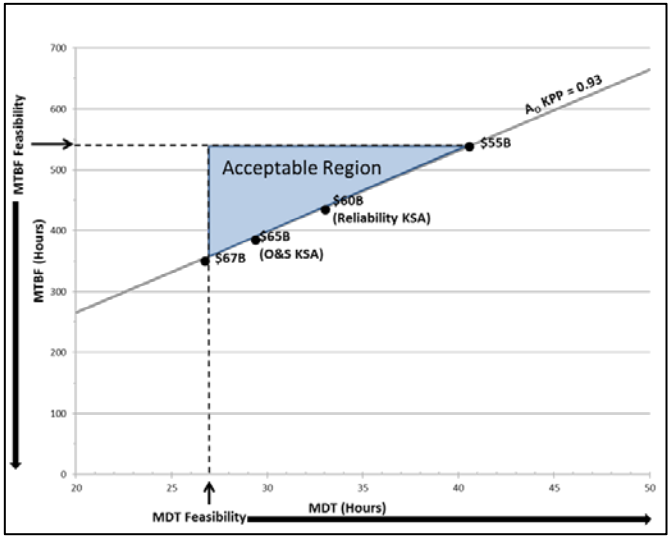
Vehicle and Trailer Percent Payload for RAM Testing

Payload On-Board the JLTV FOV	Payload On-Board Trailer			
	No Trailer	Empty Trailer	Half Loaded Trailer	Fully Loaded Trailer
Empty JLTV (CW + Crew - All Payload)	1%	2%	1%	5%
Half Loaded JLTV (GVW + Crew - 1/2 Payload)	35%	1%	8%	3%
Fully Loaded JLTV (GVW + Crew)	24%	2%	3%	15%

Reliability, Availability, Maintainability – Cost (RAM-C)

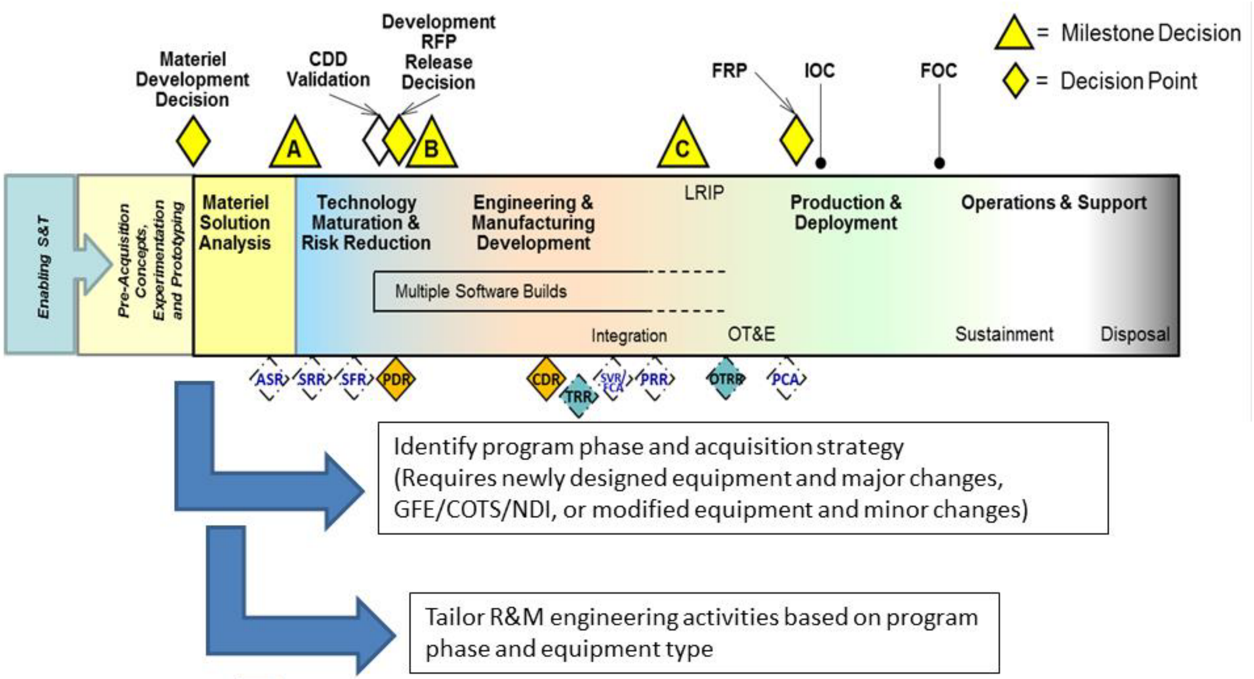
- **A RAM-C analysis provides the rationale behind the development of the JCIDS sustainment requirements along with underlying assumptions.**
  - Ensures sustainment metrics are valid (correct balance between the Availability-KPP, Reliability-KSA, and Operations and Support Cost-KSA)
  - Provides early (Pre-MS A) reliability, availability, maintainability and ownership cost feasibility assessments of alternative concepts
  - Includes early formulation of maintenance & support concepts
  - Provides an audit trail that documents and supports JCIDS thresholds
  - Provides early risk reduction by ensuring requirements are valid and feasible

Draft CDD, CDD or CPD			Feasibility Results	
Parameter		Threshold	Composite Model Estimate	Predecessor (Legacy) System
KPP	Materiel Availability	0.65	0.67	0.58
KPP	Operational Availability	0.80	0.80	0.73
KSA	Mission Reliability	46	40	18
KSA	Logistics Reliability	3.5	4.2	2.5
APA	Maintenance Burden	9.0	8.0	15
APA	Corrective Maintenance	0.5	0.5	1.0
KSA	O&S Cost	$423.7M	$471.4M	$722.6M



R&M Engineering Activities

- **Acquisition Strategy, Program Type, and Phase determine the R&M engineering activities needed for a cost-effective R&M Program**
  - Acquisition Strategy: Use of NDI/COTS, new development
  - Program Type (Aircraft, avionics, support equipment, missile, target, etc.)
  - Phase (MSA, TMRR, EMD, Production)



Tailoring Guidance

R&M Engineering Activity	MSA	TMRR	EMD	P&D	O&S	New Design "Major" Change	Modified "Minor" Change	NDI/COTS
Program Requirements								
R&M and BIT Program	✓	✓	✓	✓	✓	✓	✓	✓
R&M and BIT Organization		✓	✓	✓		✓	✓	
Subcontractor R&M and BIT Requirements		✓	✓	✓		✓	✓	✓
Trade Studies	✓	✓	✓			✓	✓	✓
Market Survey		✓	✓					✓
Spares Reliability Provisions			✓	✓	✓	✓	✓	
Design Analyses								
Mission Profile Definition	✓	✓	✓			✓	✓	✓
Environmental Effects Analysis		✓	✓			✓	✓	✓
Reliability Math Models, Allocations, and Predictions	✓	✓	✓			✓	✓	✓ (1)
Maintainability and BIT Allocations, Predictions and Analysis	✓	✓	✓			✓	✓	✓ (2)
FMECA and Reliability Critical Items		✓	✓			✓	✓ (4)	✓ (3)
Worst Case / Sneak Circuit Analysis			✓			✓		
Thermal Analysis and Survey			✓			✓	✓	✓
Parts, Material and Processes Program		✓	✓	✓		✓	✓	
Documentation/Data Items	✓	✓	✓	✓	✓	✓	✓	✓
Tests								
Subsystem/Equipment Level Reliability Growth Test		✓	✓	✓		✓		
Subsystem/Equipment Level BIT Assessment Tests			✓			✓		
System-Level Reliability, Maintainability and BIT Demo			✓			✓	✓	✓
Manufacturing Screening			✓	✓		✓	✓	
System Test Monitoring			✓	✓		✓	✓	✓
FRACAS		✓	✓	✓	✓	✓	✓	✓

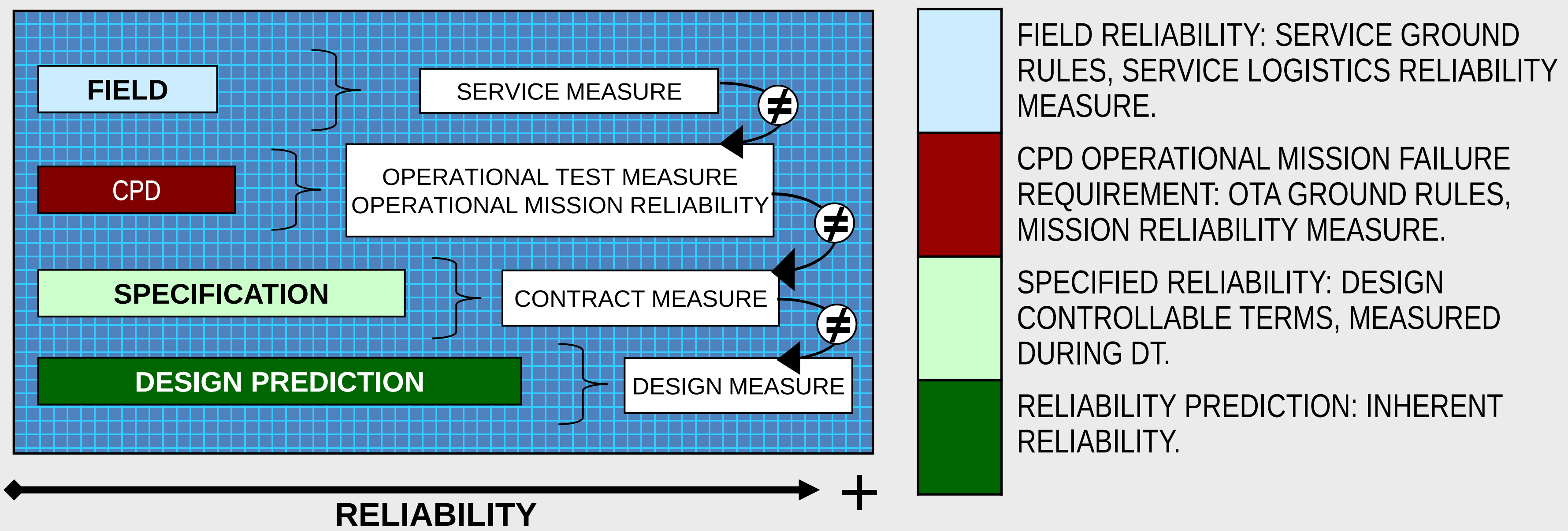
Notes:
1. Excludes parts count or stress analysis prediction, analysis generally limited to equipment end-item.
2. Maintainability analysis generally limited to equipment end-item.
3. Applicable to the interfaces of COTS/NDI equipment.
4. Applicable to the modified portions and interfaces.

Performance Requirements

- **Performance Requirement considerations**
  - R&M are performance requirements that directly affects readiness, support and total ownership costs
  - Contractually specified R&M requirements are traceable to the CDD/CPD
  - R&M Operational Test thresholds = CDD/CPD R&M thresholds
- **Establishing quantitative requirements**
  - Unrealistic requirements increase program cost, schedule, and performance risk
  - Translated to contractually specified operational measures of reliability
  - Operational Test failure definition and scoring criteria need to be established early-on

Translation of Performance Requirements

Relative Relationship of Reliability Measures



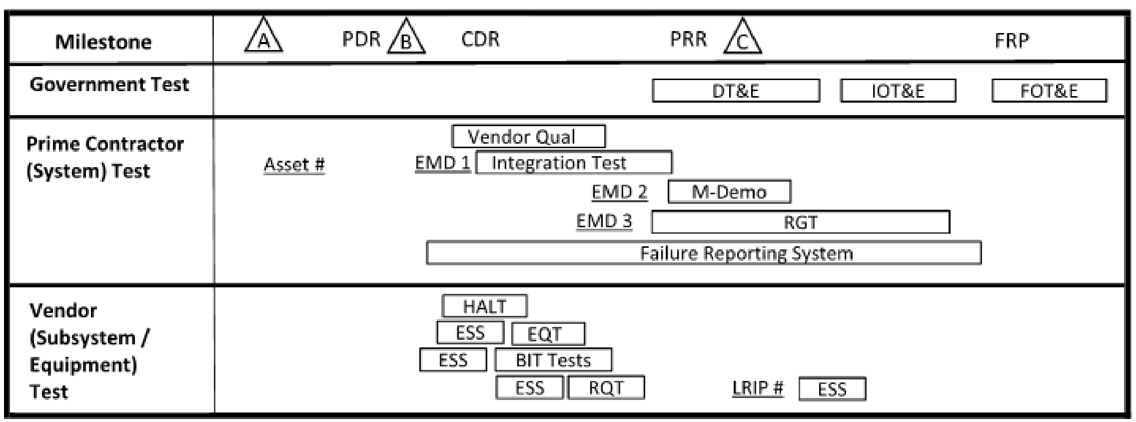
Contract specification requirements should have a good design margin to ensure achieving the stated CDD/CPD thresholds

Program Acquisition Documentation

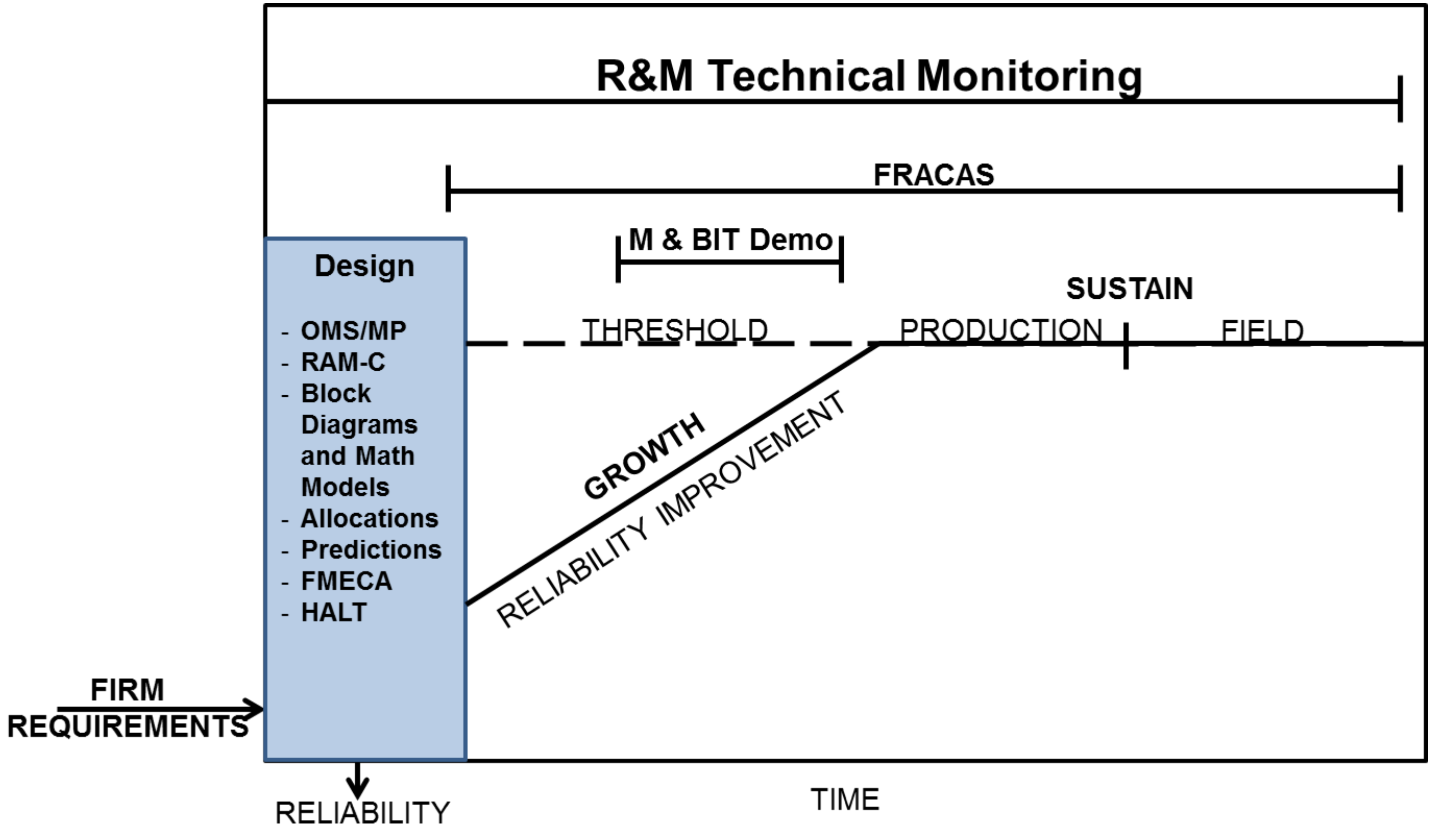
- **R&M inputs are required for:**
  - AS
    - o Describes the R&M engineering strategy for the program
  - SEP (including RAM-C Rationale Report)
    - o Integrates the R&M engineering activities in the systems engineering program
    - o Describes overall reliability growth strategy (system/subsystem level testing, RGC)
  - TEMP
    - o Includes an appropriate test strategy for the verification of the program's R&M requirements
    - o Includes planning and tracking of reliability growth, system and subsystem level R&M demonstration/test events, test support activities and R&M data measurement requirements
  - Performance Specification
    - o Contains R&M quantitative requirements and verification methods
  - Statement of Work (SOW)
    - o Includes appropriately tailored R&M engineering activities

Schedule Considerations

- **It takes finite time to conduct R&M testing, engineer corrective actions, and incorporate them into equipment:**
  - Incorporate changes in hardware and software between developmental and operational test
  - Make effective use of applied R&M design/test disciplines (i.e. RDGT, HALT, M-Demos, etc.) to sustain reliability growth and maintainability maturation
  - Maximize use of production representative units for both developmental and operational testing
- **No hardware or software design maturity occurs without sufficient time**



R&M Technical Monitoring



- **Design and Manufacturing Monitoring**
  - Post Award Reviews
  - Technical Reviews
  - Test Readiness Review
- **Test Monitoring**
  - RDGT
  - HALT
  - M & BIT Demo
  - System Level Testing

R&M Technical Monitoring must be continuous throughout the life-cycle of the program

Reliability Growth Strategy

- **Reliability Growth Through External Experience and Lessons Learned**
  - Historical data, publications, technical experience of personnel, lessons learned, and information from currently operating systems
- **Reliability Growth Through Design Techniques**
  - Design simplification, redundancy, margins of safety, probabilistic design, physics of failure techniques, and derating
- **Reliability Growth Through Engineering Analysis**
  - Block diagrams, predictions, and Failure, Mode, Effects, and Criticality Analysis (FMECA), Fault Tree Analysis, Design Reviews
  - Saves test time and resources
- **Reliability Growth Through Testing**
  - Design verification tests, conventional reliability growth tests, accelerated life tests (ALT), HALT, environmental and functional qualification tests, environmental stress screens, FRACAS
- **Reliability Growth Through Production Experience**
  - Quality assurance and control
- **Reliability Growth Through Operational Experience**
  - Monitoring fielded systems; Least desirable, but inevitable in most cases

Summary

- Reliable, maintainable systems are NOT normally produced by routine development
- Well-defined mission oriented reliability requirements are critical
- Application of appropriately tailored engineering activities are needed to produce reliable and maintainable systems
- R&M design disciplines require vigorous pursuit and must be imposed on the contract
- R&M analyses can predict equipment behavior needed to reduce risk
- Timeliness is essential in analysis

R&M by Design and Not by Chance

Systems Engineering: Critical to Defense Acquisition










Defense Innovation Marketplace
http://www.defenseinnovationmarketplace.mil

DASD, Systems Engineering
http://www.acq.osd.mil/se

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R&M Engineering Activities

Activity	Description	Purpose	Benefit
Operational Mode Summary/Mission Profile (OMS/MP)	Provides an accurate representation of actual mission characteristics, pertinent environments, and functions	To develop realistic functional and environmental design requirements for all equipment	Ensures effective design requirements are used, and that ensuing tests use realistic environments
Environmental Study	Detailed evaluation of the environment the system will operate in	Determine the impact the operating environment has on reliability; basis for future test profiles	Establishes system environmental design limits and test profiles
Allocations	Apportions numeric targets to lower level assemblies	Provides IPTs with R&M targets	Management tool to attain top level R&M requirements
Block Diagram and Math Models	Describes relationships of elements that make up the design	Create the necessary models for allocation and predictions	Identifies critical elements and need for redesign or redundancy
Predictions	Numeric R&M analysis of the item	Predicts inherent R&M to determine if requirement can be met	Establishes if design can meet the requirements
FMECA	Analysis of each failure mode to determine the resulting effects on system performance	Identifies critical part and single point failures for redesign opportunity	Systematic identification of failures that negatively impact mission success and safety
FRACAS	A closed loop process that documents failures and establishes trends and corrective actions	Process to identify corrective actions for failures experienced during system development	Essential to mature reliability
Design Reviews	Series of reviews to assess the Contractor's design progress	Forum used to make known current progress of R&M efforts	Program vehicle to raise R&M issues to the highest levels in order to obtain resolution
Maintainability and BIT Demo	Exercises the BIT functions on all equipment and systems in the laboratory and on the actual system	Determines whether required M & BIT performance are achieved	Matures M and BIT by finding and correcting problems in both HW and SW
Equipment/Subsystem RDT/HALT	Application of environmental stresses to identify and eliminate failure modes	To mature the system design	Matures reliability to achieve system requirements