



R&M: Critical to Success in a Technology Reliant World

Robert Gold

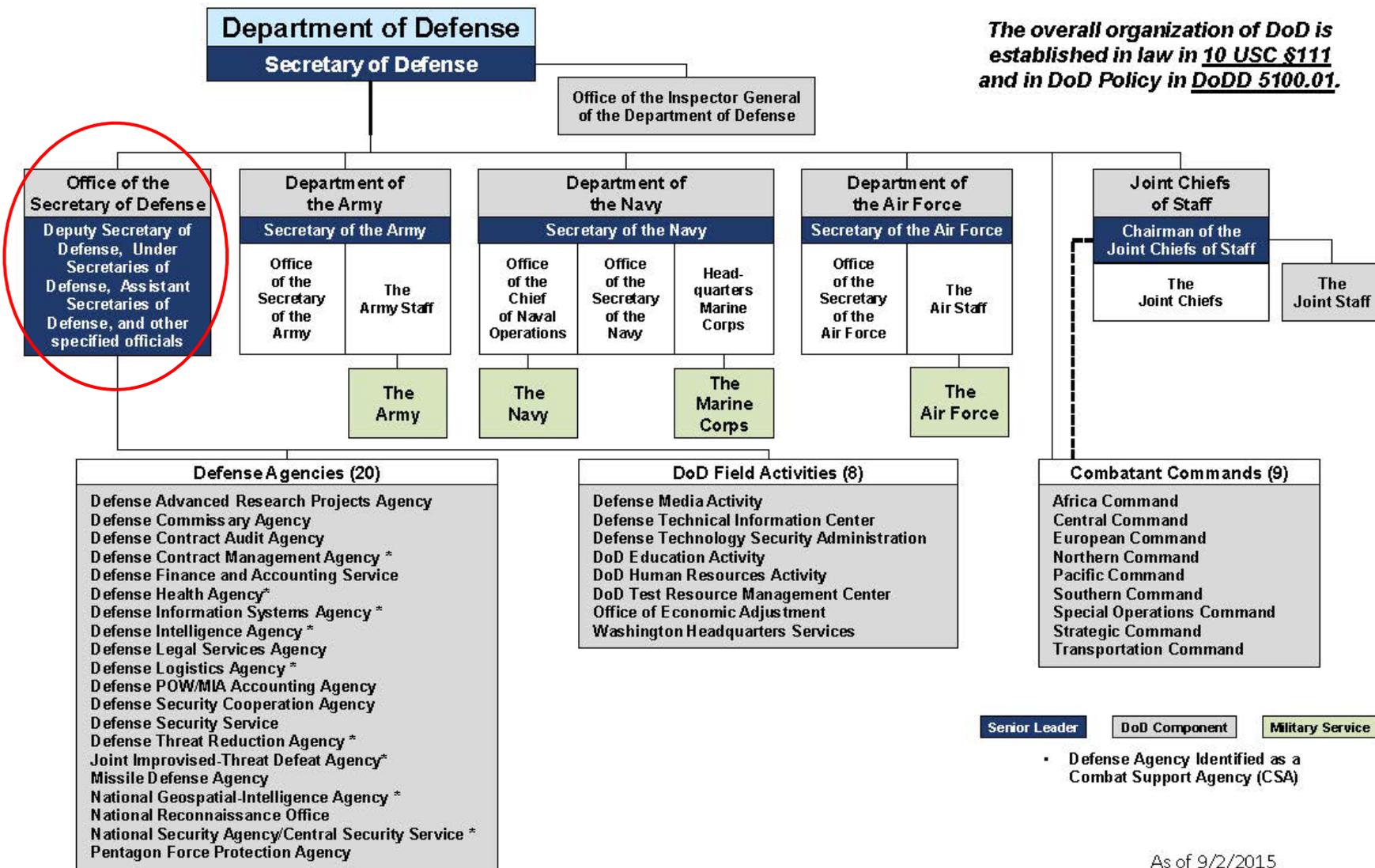
**Director, Engineering Enterprise
Office of the Deputy Assistant Secretary of Defense
for Systems Engineering**

**Reliability and Maintainability Symposium
Tucson, AZ | January 25, 2016**



Organization of the DoD

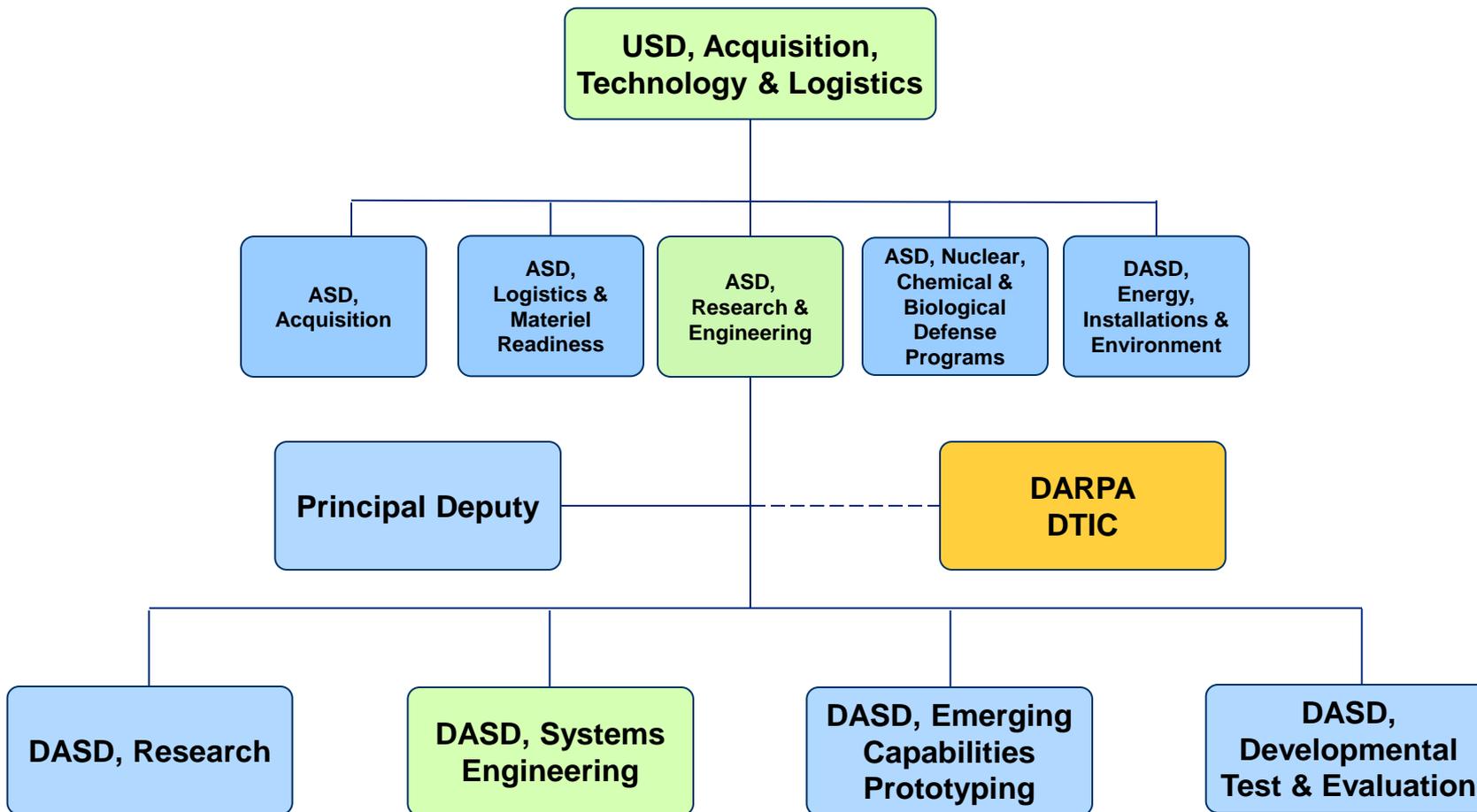
The overall organization of DoD is established in law in 10 USC §111 and in DoD Policy in DoDD 5100.01.



As of 9/2/2015



Organization of USD(AT&L)





DASD, Systems Engineering Mission



Public Law 111-23 (Weapon Systems Acquisition Reform Act) establishes *Deputy Assistant Secretary of Defense, Systems Engineering (DASD(SE))* as principal systems engineering advisor to the SECDEF and the USD(AT&L)

Systems Engineering focuses on engineering excellence – the creative application of scientific principles:

- To design, develop, construct and operate complex systems
- To forecast their behavior under specific operating conditions
- To deliver their intended function while addressing economic efficiency, environmental stewardship and safety of life and property

DASD(SE) Mission: Develop and grow the Systems Engineering capability of the Department of Defense – through engineering policy, continuous engagement with component Systems Engineering organizations and through substantive technical engagement throughout the acquisition life cycle with major and selected acquisition programs.

A Robust Systems Engineering Capability Across the Department Requires Attention to Policy, People and Practice

- *US Department of Defense is the World's Largest Engineering Organization*
- *Over 108,000 Uniformed and Civilian Engineers*
- *Over 39,000 in the Engineering (ENG) Acquisition Workforce*



DASD, Systems Engineering



Acting Deputy Assistant Secretary of Defense
and Principal Deputy, Systems Engineering
Kristen Baldwin

Homeland Defense
Capability
Development
Robin Hicks



Major Program Support
James Thompson

*Supporting USD(AT&L) Decisions with Independent
Engineering Expertise*

- Engineering Assessment / Mentoring of Major Defense Programs
- Program Support Assessments
- Overarching Integrated Product Team and Defense Acquisition Board Support
- Systems Engineering Plans
- Systemic Root Cause Analysis
- Development Planning/Early SE
- Program Protection



Engineering Enterprise
Robert Gold

*Leading Systems Engineering Practice
in DoD and Industry*

- Systems Engineering Policy and Guidance
- Technical Workforce Development
- Specialty Engineering (System Safety, Reliability and Maintainability, Quality, Manufacturing, Producibility, Human Systems Integration)
- Security, Anti-Tamper, Counterfeit Prevention
- Standardization
- Engineering Tools and Environments

**Providing technical support and SE leadership and oversight
In support of planned and ongoing acquisition programs**



DASD(SE) Key Responsibilities



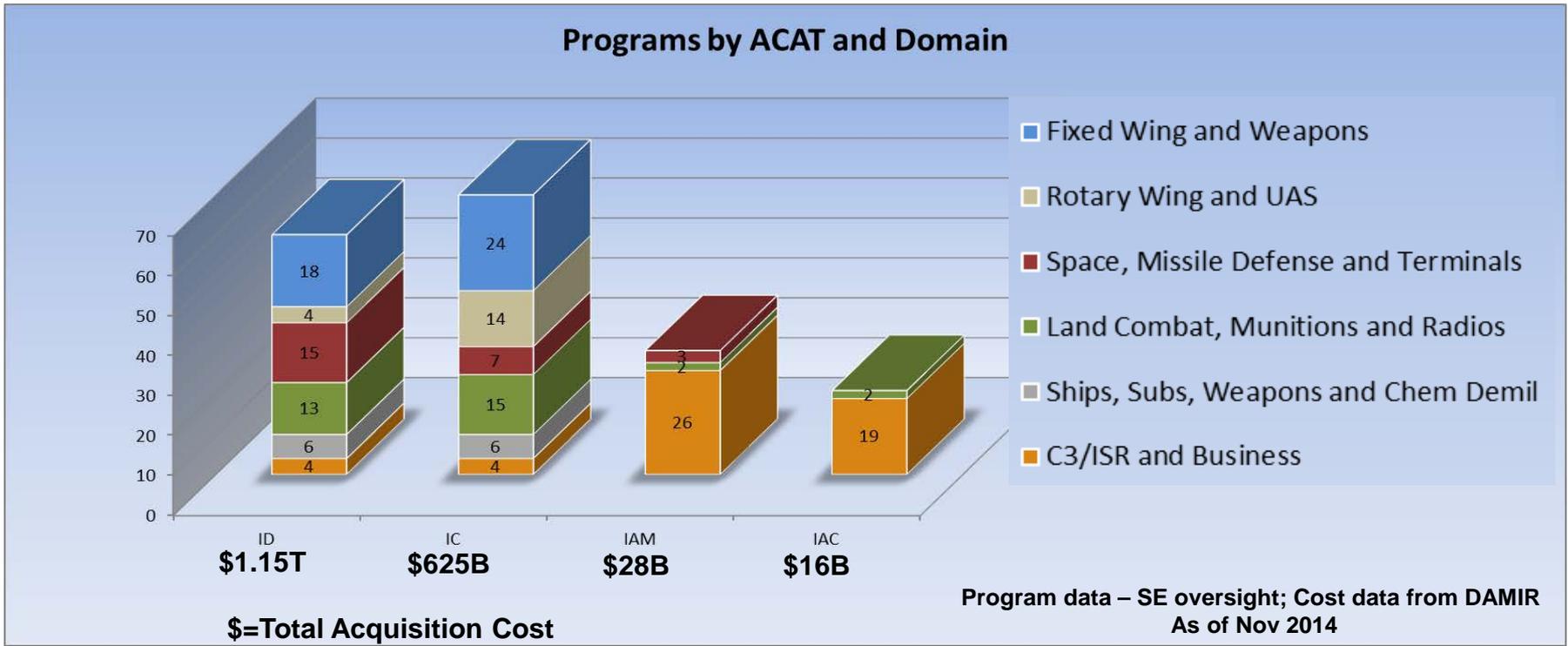
- **Program Engagement**
 - Serve as principal engineering advisor to the SECDEF and USD(AT&L) in support of critical acquisition decisions
 - Provide continuous engineering oversight and mentoring of Major DoD Programs to identify, assess, and mitigate engineering risk; focus on helping ensure program success
 - Serve as approval authority for Systems Engineering Plans for all Major DoD Programs
 - Certify completeness of Preliminary Design Reviews and Critical Design Reviews for all Major DoD Programs
- **Policy and Guidance**
 - Develop engineering, manufacturing, reliability, program protection, and modeling and simulation policy and guidance for the DoD
 - Serve as Defense Standardization Executive – approve military standards and coordinate DoD engagement on non-military standards
- **Technical Workforce Development**
 - Provide functional leadership for the Non-Construction (Engineering) and the Acquisition (ENG and PQM) workforce
- **Engineering Research and Development**
 - Sponsor the DoD Systems Engineering Research Center (SERC) University Affiliated Research Center (UARC)
 - Sponsor the MITRE National Security Engineering Center (NSEC) Federally Funded Research and Development Center (FFRDC)

Reference: DoDI 5134.16, Deputy Assistant Secretary of Defense for Systems Engineering



DASD(SE) Portfolio

- Perform system engineering oversight of **182 programs** with acquisition costs of **\$1.8T**



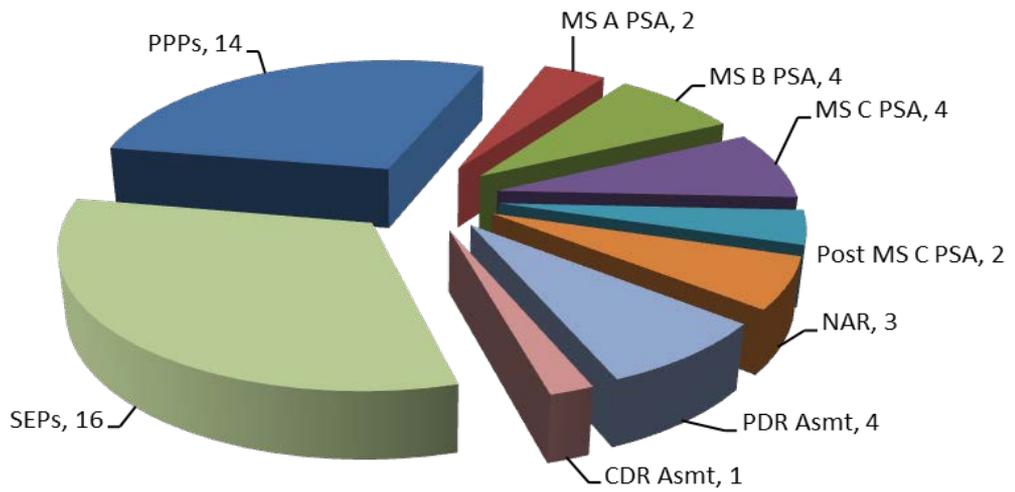


SE FY 2015 Program Engagement

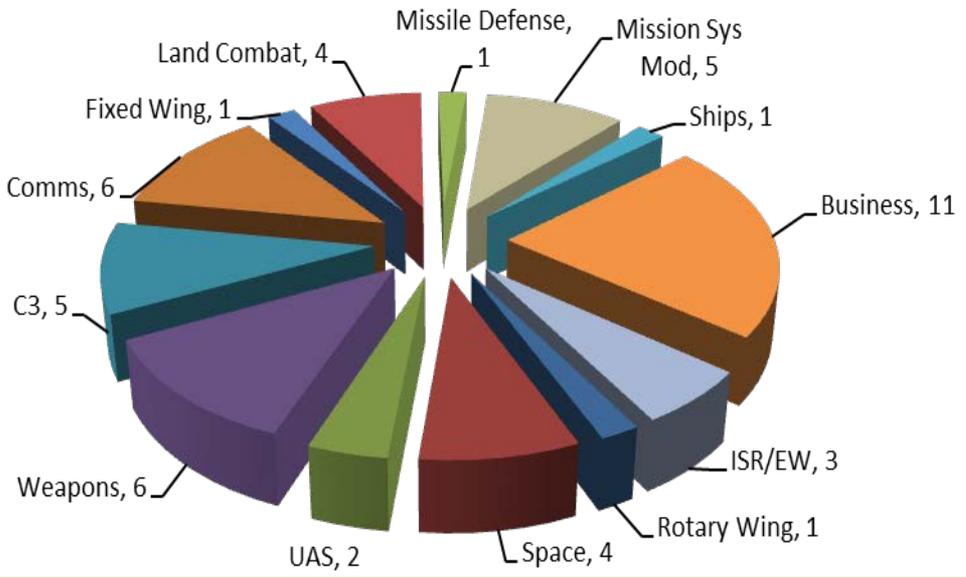
Fiscal Year 2015

- Program Support Assessments: 12
- Non-Advocate Reviews: 3
- PDR/CDR Assessments: 5
- SEP Approvals: 16
- PPP Approvals: 14

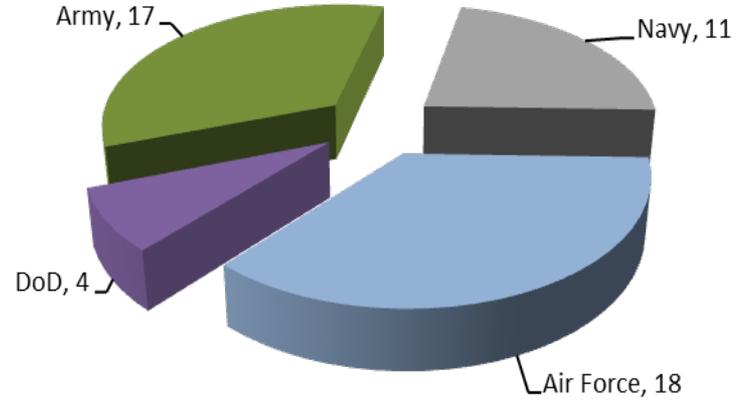
Decision Support Reviews



Domain



Military Department





Why R&M Engineering is Critical to the DoD Mission



DoD Mission: Develop and deliver incredibly effective but increasingly complex weapon systems to our soldiers, sailors, marines, and airmen to ensure technological superiority over our adversaries

- **DoD R&M Engineers:**
 - Help program managers identify and mitigate risks
 - Shape technical planning and management
 - Support knowledge-based decision making
 - Provide technical depth of acquisition policy and processes
 - Provide a balanced solution for affordable and capable systems
- **R&M Engineering is needed to ensure defense systems are:**
 - High-quality
 - Affordable
 - Supportable
 - Effective to sustain
- **Developing complex weapon systems requires:**
 - Technical competency
 - Critical and strategic thinking
 - Knowledge of various product domains
 - Knowledge of other engineering disciplines



R&M: Critical to Success in a Technology Reliant World



Effective R&M Engineering needed to Design, Develop and Deliver DoD's Complex Weapon Systems



Benefits of an Effective R&M Engineering Program

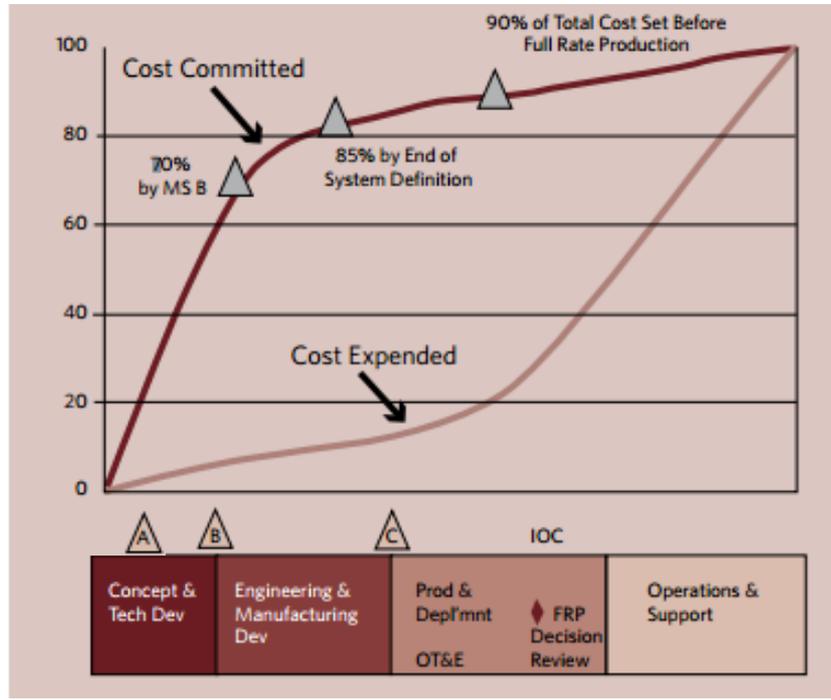


- **For the Weapons System/Equipment:**

- Reduced life-cycle costs
- Decreased logistics costs
- Increased mission capabilities
- Increased readiness

- **For the Program Manager and DoD:**

- Minimize cost increases and schedule delays
- Reduce R&M risks associated with Milestone Reviews
- Reduce R&M risks associated with Initial Operational Test and Evaluation (IOT&E)





Essential Elements of an Effective R&M Engineering Program



- **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**



DoDI 5000.02 (2015) Enclosure 3 SE, R&M Overview



- **R&M 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)

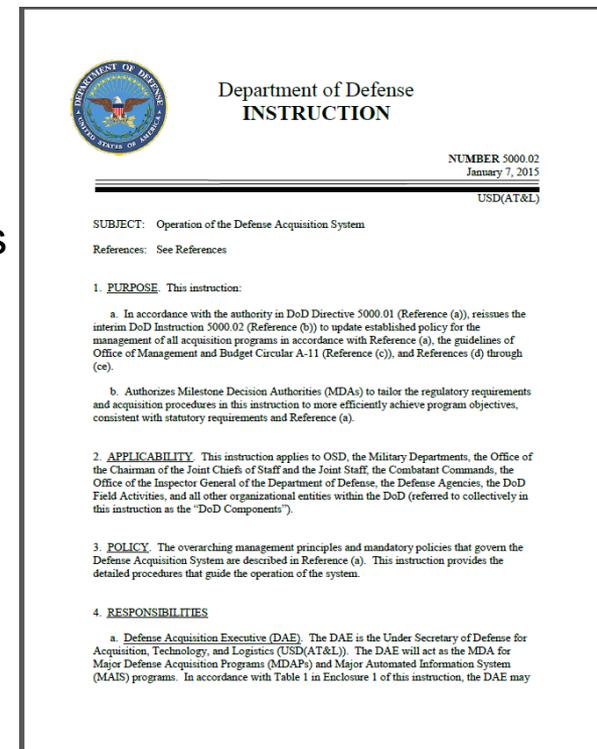
- **Reliability, Availability, Maintainability- Cost (RAM-C) Rationale Report**

- **Reliability Growth Strategy**

- System-level reliability growth curves in the SEP beginning at Milestone A

- **Tracking and Monitoring**

- Incorporates reliability growth curves into the Defense Acquisition Executive Summary (DAES)





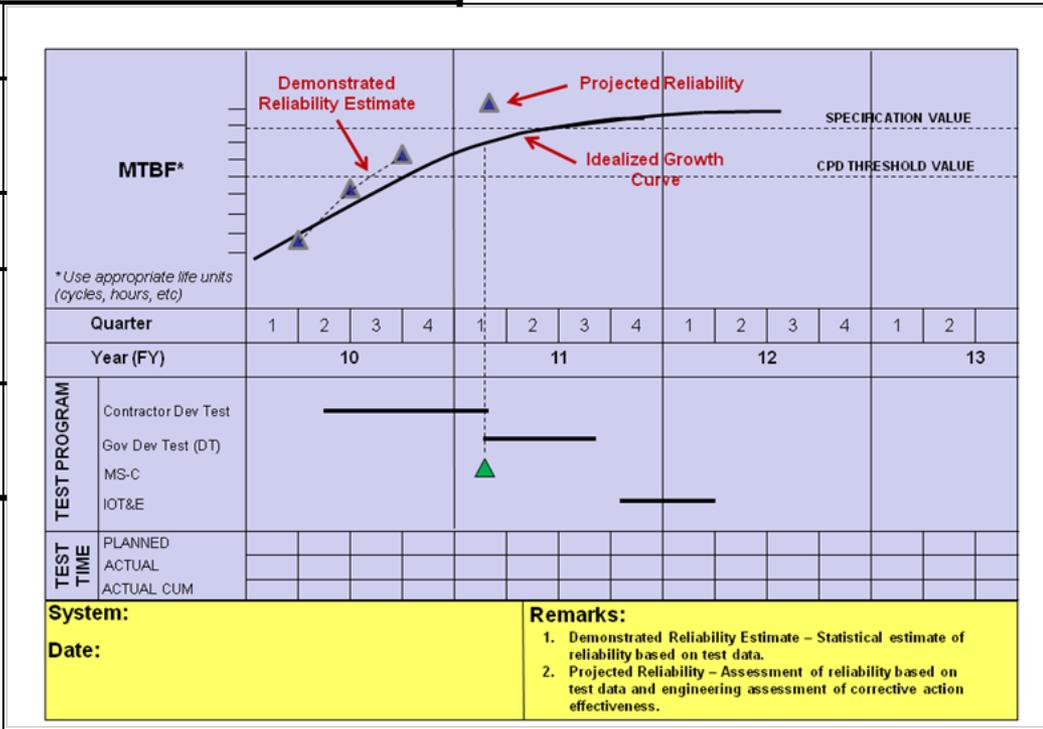
Systems Engineering Plan – R&M Portions



Describe planning and timing for R&M Engineering Activities

R&M Engineering Activity	Planning and Timing
R&M Allocations	
R&M Block Diagrams	
R&M Predictions	
Failure Definitions and Scoring Criteria	
Failure Mode, Effects, and Criticality Analysis (FMECA)	
Maintainability and Built-in Test Demonstrations	
Reliability Growth Testing at the System and Subsystem Level	
Failure Reporting, Analysis, and Corrective Action System (FRACAS)	

Accomplished in time to influence system design. Initial reliability-critical parts and critical risks were identified during TD/TMRR. Corrective maintenance task requirements were also identified. Completed in support of PDR efforts to identify critical parts and risks, maintenance task requirements and will be updated and matured in support of CDR.





Lessons Learned and Opportunities



- **R&M Quantitative Operational Thresholds**
- **Translation of Operational Thresholds to Design Requirements**
- **Planning R&M Engineering Activities**
- **R&M Engineering Analysis and Data**
- **Digital Models Engineering Across the Life-Cycle**
- **Engineering Workforce**
 - R&M Engineering Learning Architecture
 - R&M Engineering Curriculum Development



R&M Quantitative Operational Thresholds

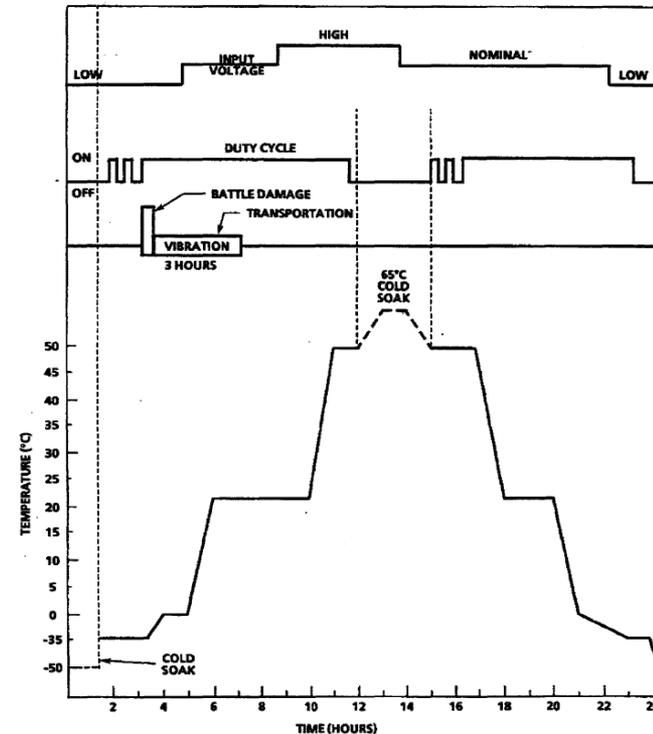


Lessons Learned

- **Thresholds need to be validated and assessed for feasibility**
 - R&M and Cost thresholds should support the availability parameters
 - Thresholds need to be consistent with the Operational Mode Summary/ Mission Profile (OMS/MP), Concept of Operations (CONOPS), and maintenance concept
 - To assess feasibility, a model of the composite system based on comparison data and current state of the art should be developed

DoD Emphasis

- **An R&M requirements analysis should:**
 - Provide early R&M, availability, and cost feasibility assessments of alternatives
 - Ensure a definition of failure is established and supports the operational mission i.e. what constitutes a failure
 - Ensure correct balance between availability, reliability, and ownership cost
 - Provide early risk reduction by ensuring requirements are valid and feasible





Translation of Operational Thresholds to Design Requirements



Lessons Learned

- In most cases, R&M thresholds and design requirements should be established with design margin
- Justification should be provided when parameters change i.e., from operational mission failure or system abort to logistics reliability
- Definitions of failure should include:
 - System boundaries
 - Government-Furnished Equipment (GFE) and Contractor-Furnished Equipment (CFE) as part of the system level requirements
 - Required functionality and allowable levels of degradation
 - Applicable events (e.g. pre-flight, post-flight)

DoD Emphasis

- Ensure translation of R&M thresholds to contract specification requirements are described and are consistent with the planning documents i.e., OMS/MP, CONOPs, and Design Reference Mission Profile (DRMP)



Planning R&M Engineering Activities

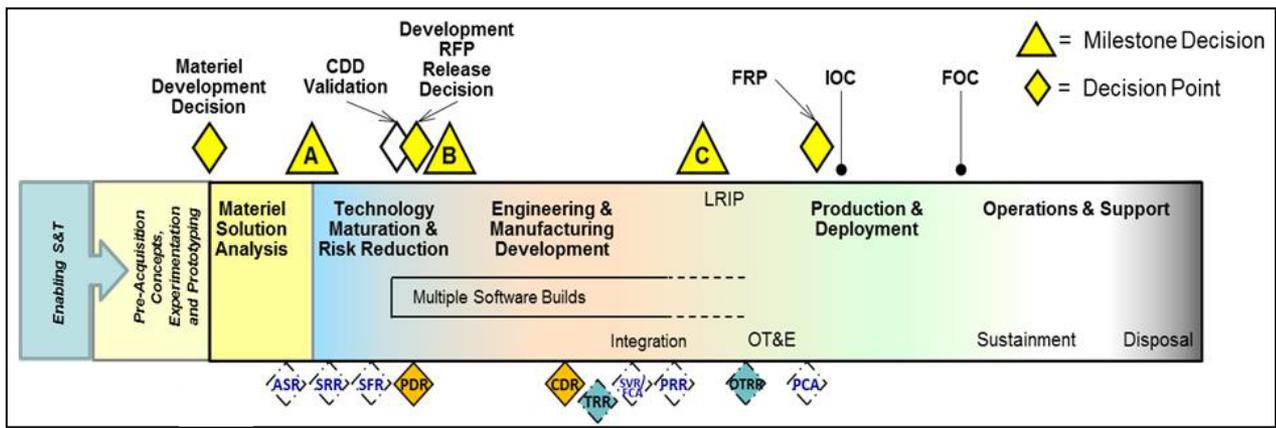


Lessons Learned

- R&M Engineering activities need to be structured based on acquisition strategy e.g., Use of Non-Developmental Items (NDI)/Commercial Off The Shelf (COTS), new development

DoD Emphasis

- R&M engineering activities should be tailored based on equipment type
- Different R&M engineering activities apply to the various phases of the program depending on the phase being addressed and supported





R&M Engineering Analysis and Data

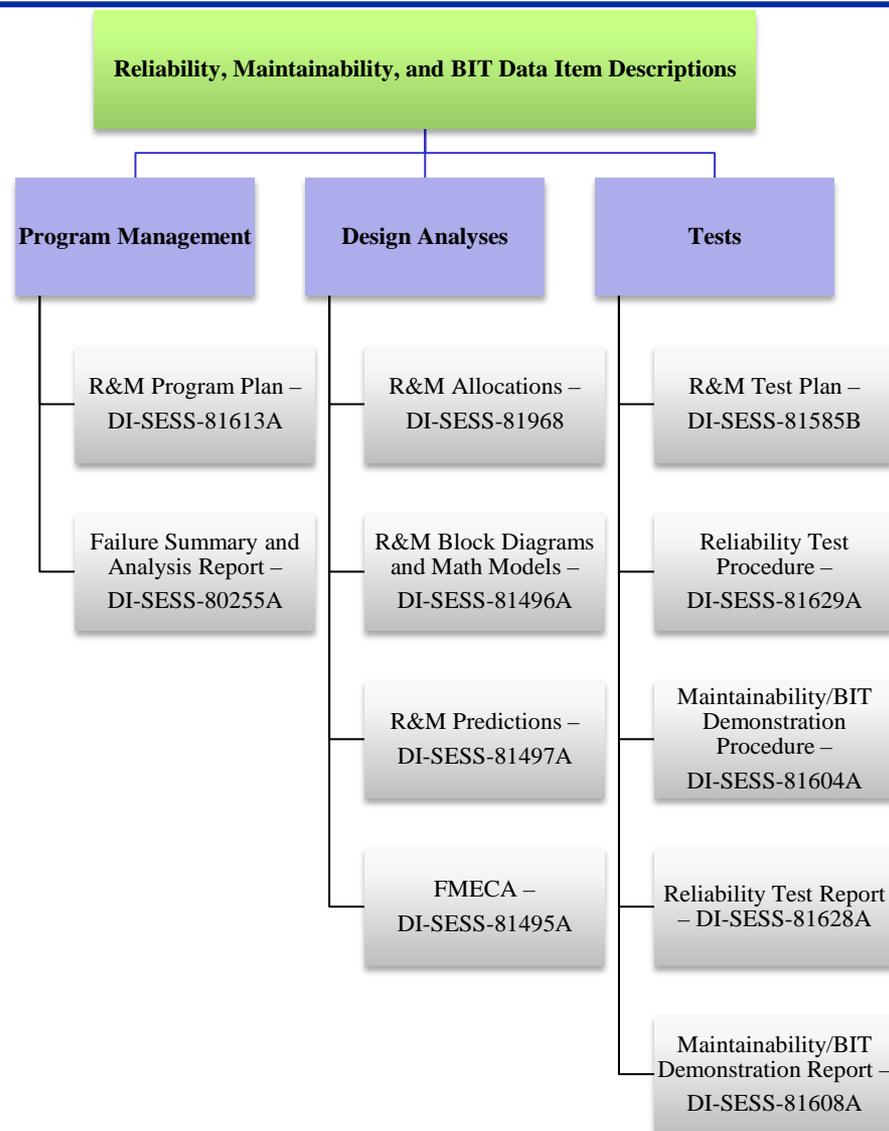


Lessons Learned

- R&M engineering analyses must be conducted in a timely manner to influence the design
- Data Item Descriptions (DIDs) for reliability, maintainability, and testability updated and combined to increase efficiencies

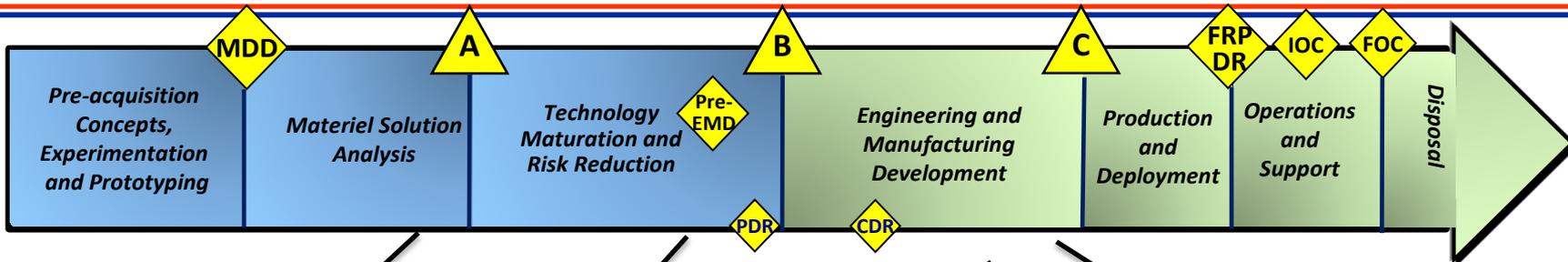
DoD Emphasis

- Developing tailoring guidance based on engineering activity by phase and equipment type to support effective R&M engineering analysis



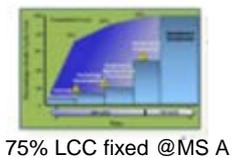


Digital Models Engineering Across the Lifecycle

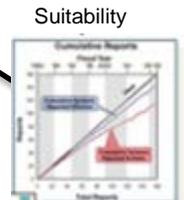
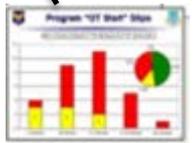
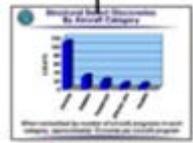
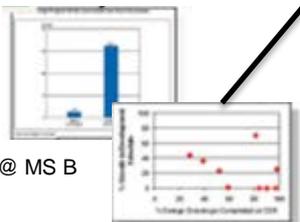


Concept & Analysis

- Physics-Based Models
- Operational Engagement Model
- L-V-C Simulator



Technology Mature @ MS B



Operations & Sustainment

Agile sustainment Aircraft "Digital Twin"

Concept & Analysis

Design & Development

- Architecture
- 3D solid modeling
- Component/system integration
- Process Workflow
- 3D Parts Rendering
- Manufacturing Logistics

- Interoperability
- Mission Utility
- Affordability

- Quantified Margins & Uncertainty
- Subsystem Integration
- Merge Data and Models

- Operability
- Reliability
- Suitability

- Reduce O&S Cost

Test & Evaluation

Integrated modeling, testing, and statistical engineering

Manufacturing

Agile manufacturing

Training

L-V-C Sustainment

Agile sustainment Aircraft "Digital Twin"

DoD Emphasis: Enabling rapid development and continuity from concept to disposal



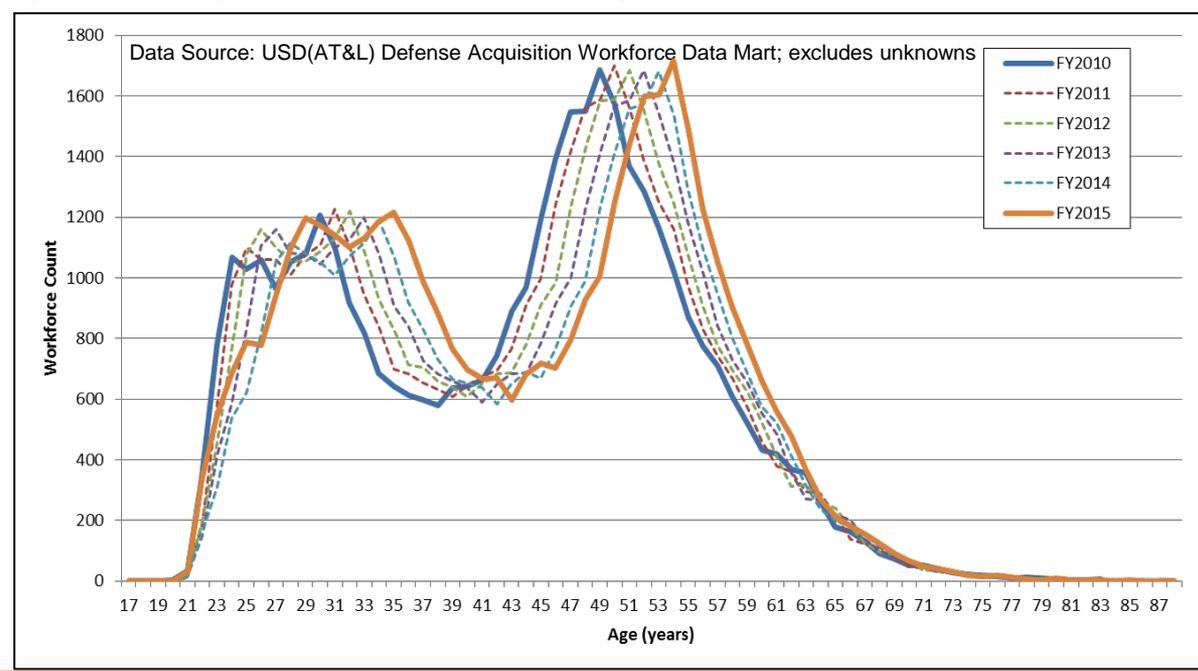
Engineering Workforce

Lessons Learned

- While the numbers of mid to senior engineers have maintained, there has been an increase in junior engineers

DoD Emphasis

- Developing an R&M Engineering Learning Architecture for the practitioner
- Structuring an R&M Engineering Curriculum to train both the practitioner and the engineering workforce at large

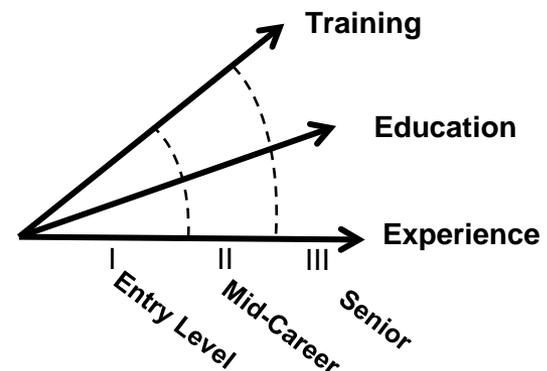




R&M Engineering Learning Architecture



- **Purpose: to provide career development guidance for the R&M Engineer**
- **R&M Learning Architecture – consolidation of desired:**
 - Associated Training Available to the DoD community
 - Education
 - Experiences
- **Defined set of guidance for three levels (senior, mid, entry)**
- **Organizes desired experiences and training within:**
 - R&M Engineering/Acquisition
 - R&M Design Analysis
 - R&M Product Support Planning
 - R&M Test
 - R&M Procurement





R&M Engineering Curriculum Development



- **Update Continuous Learning Module for R&M**

- Learning Objectives developed
- Course design complete – 5 separate courses
- Lesson Scripts under development
- Deployment date scheduled for late FY16

CLE-301 Reliability & Maintainability Module Design

Modules	1	2	3	4	5	
Titles	R&M Requirements	R&M Planning	R&M Design Analysis	Program & Technical Reviews	Evaluate R&M Effectiveness	
Tasks	ICD, CDD, CPD, TDS, SEP, TEMP analyze and provide input	Plans, DIDs, Test Results review and monitor	Develop Specs, FRACAS, FMECA, FDSC	MS A, B, & C, Tech Reviews	Data to analyze design change or corrections, and future increments	
Competency No. & Phase	1 MSA, 3 TMRR, 9 MSA	2 MSA, 3 TMRR, 9 MSA	2 MSA, 3 EMD, 9 MSA	14 TMRR	6 PD, 13 PD, 14 TMRR	
Sub-Competencies	1.1.1	2.1.1	2.1.4	3.1.1	14.1.1	14.2.2
	1.1.2	2.1.2	9.1.1	3.1.3	14.1.2	14.2.3
	1.1.3	2.1.3	9.2.1	3.1.5	14.1.3	14.2.4
	1.1.4	2.1.5	9.2.2	3.2.5	14.1.4	14.2.5
	3.1.1	3.1.6	9.2.3		14.2.1	14.2.6
	3.2.2	9.1.3	9.2.4		14.3.1	13.1.1
	9.1.2	9.1.4	9.2.5		14.3.2	6.1.1
		9.1.5	9.2.6		14.3.3	
		9.2.7		14.3.4		
		9.2.8		14.3.5		
				14.3.6		

- **Develop RAM-C Rationale Report Process Course**

- Learning Objectives developed
- Contracting support for Course Development
- Deployment date scheduled for FY17

- **Develop R&M Topic Studies Course**

- Learning Objectives developed
- Case studies under development by Systems Engineering Research Center contract
- Deployment date scheduled for late FY16





Summary



- **Reliable, maintainable systems are NOT normally produced by routine development**
- **Well-defined mission oriented reliability requirements are critical**
- **Application of appropriately tailored disciplines 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**
- **Essential element of Systems Engineering**
- **Critical to success in a technology reliant world**

R&M by Design and Not by Chance



R&M Engineering: Critical to Defense Acquisition



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



Systemic Observations Engineering Activities



Activity	Description	Purpose	Benefit
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. Determine the impact the operating environment has on reliability	Ensures effective design requirements are used, and that ensuing tests use realistic environments. 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
M 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

*R&M Activity in SEP Table 4.6-2