Implementing the Materiel Availability KPP in DoD Acquisition Programs—Balancing Life Cycle Costs with Warfighter Needs

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Introduction

- **Domain Expert for Reliability, Availability, and Maintainability (RAM) in OSD AT&L SSE:**
  - OUSD AT&L SSE: Office of the Under Secretary of Defense; Acquisition, Technology, and Logistics; Software and Systems Engineering
    - HCSE: Human Capital and Specialty Engineering
    - ASETS: Acquisition Systems Engineering and Test Support
- **DoD 5000.02, dated 8 December 2008, provides for:**
  - Operation of the JCIDS Process including robust Systems Engineering
    - PSRs
    - Nunn-McCurdy Certifications
    - JAT, DST, OIPT Support, etc.
- **Mandatory Sustainment KPP in CJCSM 3170.01D (March 2009)**
  - KPP: Availability
    - KSA: Reliability
    - KSA: Ownership Cost
- **Operational versus Life-Cycle Based Metrics**
  - Traditional development efforts end at full rate production decision
  - Costs of sustainment are set by system design
  - Programs have become both unreliable and expensive to sustain
- **Implementation covered in RAM-C Report Manual**

Current Situation
—and How We Got Here

Mistakes have been made!

Background: Defense Science Board Report on Developmental Testing (cont.)

- **Congressional Testimony (March 3, 2009) by Mr. Pete Adolph (Chairman of DSB Team):**
  - Loss of Core Acquisition Personnel in DoD:
    - 500,000 in 1990
    - 200,000 in 2009
  - "Concurrent with acquisition reform, the general practice of reliability growth during development was de-emphasized and, in most cases, eliminated. This departure from a widely recognized best practice may not have been a direct result of acquisition reform, but may instead be related to the loss of key personnel and experience, **as well as short-sighted attempts to save acquisition funds at the expense of increased sustainment and life cycle costs**."
- **Dr. Paul Kaminski**
  - "…further underscored the importance of early system engineering effort in that, prior to the key Milestone A and B decisions, we find that those decisions **impact somewhere between 75 percent and 85 percent of the total lifecycle costs**. So the time to address those issues is up front before those decisions are made."

Background: Defense Science Board Report on Developmental Testing (cont.)

- **Acquisition workforce reductions mandated by 1996 thru 1999 Defense Authorization Acts**
  - Loss of experienced management and technical personnel throughout government and industry
  - Service acquisition test organizations were affected:
    - Army essentially eliminated their military DT component and made government DT discretionary
    - Navy reduced DT workforce by 10%
    - Air Force transitioned DT conduct and control to the contractor while significantly reducing test personnel (~15%) and program office engineering support (up to 60%)

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Background: Defense Science Board Report on Developmental Testing (cont.)

- **Programs complexity increasing significantly**
  - Software lines of code increases, off-board sensor data integration, system of systems
- **Elimination or reduction of Military Standards from contracts**
  - Use of commercial specifications and standards encouraged under Acquisition Reform
- **De-emphasis of Reliability Growth**
  - Industry recommendations in the 1970's had caused the Services to implement Reliability Growth as an integral part of development

> "Lack of failure prevention during design leading to low initial MTBF and reduced growth potential are the most significant reasons for systems failing to meet operational reliability requirements"

Background: Program Support Review Reliability Findings

- **Unrealistic Reliability requirements**
  - Requirements not measurable, quantifiable, reasonable, etc…
    - “as good as or better than current system…” – impacts translation of user needs into technical requirements
  - User R&M requirements not underpinned by sound rationale
    - Failure to document mission context or mission profile
  - Maturation timeframes or maturity at IOC not defined
  - Inconsistent use of R&M measures makes comparison of programs difficult

Background: Program Support Review Reliability Findings

- **Maturing "suitability" (e.g., RAM)… not always a priority**
  - Little effort to design-in reliability and maintainability
    - Inadequate allowance of resources (time, money, people)
    - Scope of effort to design-in RAM not aligned with schedules and resources
  - Optimistic growth rate assumptions
    - Over optimistic view of starting reliability (prior to growth)
    - Lack of understanding of statistical confidence issues
  - DT&E not always tested under realistic OT&E (e.g., OMS/MP) conditions
    - Reliability growth strategy incompatible with demonstration requirements
    - Supply chain and maintainers not operationally representative in DT&E
  - No interim measures for suitability to gauge progress/growth
  - Log Demos to evaluate IETMs and diagnostics effectiveness are not timely or comprehensive; Most are conducted too close to IOT&E

Background: Other Considerations

- **Performance based contracts allowed contractors to determine how to reach reliability requirements—often with disastrous results for the warfighter**
- **There is an inherent disincentive for contractors to spend acquisition funds on improving Reliability**
  - Partially due to the lucrative nature of contractor support and sparing
- **Acquisition program managers are not held accountable for post-FRP support costs**
  - But are held accountable for Average Per Unit Cost (APUC)—leading to restricting the expenditure of “discretionary” funds (like those required for Reliability Demonstration and Growth)

Background: Defense Science Board Report on Developmental Testing

- **May 2008 Defense Science Board Report on Developmental Tests & Evaluation**
  - Commissioned by AT&L in 2007

> "In recent years, there has been a dramatic increase in the number of systems not meeting suitability requirements during IOT&E. Reliability, Availability and Maintainability (RAM) deficiencies comprise the primary shortfall areas."

Program	Service	ACAT	IOT&E Result		Reason
FY 2001					
[redacted]	USAF	II	Effective	Not Suitable	Reliability, Maintainability, Availability
[redacted]	Navy	1D	Effective	Not Suitable	Reliability, Availability, Maintainability (RAM), Human Factors, BIT
[redacted]	USAF	1C	Effective only with legacy fuses	Not Suitable	Integration with delivery platforms
[redacted]	Army	1D	Effective	Suitable	
FY 2002					
[redacted]	USAF	1C	Effective with deficiencies	Not Suitable	RAM, Safety, Human Factors
[redacted]	Navy	1D	Effective	Suitable	
[redacted]	Army	1C	Effective	Suitable	
[redacted]	Navy	1C	Effective	Not Suitable	RAM, excessive administrative and logistic repair time impacted RAM
FY 2003					
[redacted]	USAF	1D	Effective	Not Suitable	
[redacted]	Navy	1D	Effective	Suitable	Several requirement thresholds were not met but overall system effective and suitable

Figure 1. DoD IOT&E Results FY 2001-2003.

Program	Service	ACAT	IOT&E Result		Reason
FY 2004					
[redacted]	Navy	II	Effectiveness unresolved	Suitable	Testing was not adequate to determine effectiveness.
[redacted]	Army	1D	Effective	Suitable	
[redacted]	Navy	1D	Effective with restrictions	Not suitable	Effective for short duration missions; not effective for all missions and profiles. Not suitable due to RAM.
[redacted]	Navy	1C	Effective	Suitable	
[redacted]	Army	1D	Effective	Not Suitable	RAM and safety concerns.
FY 2005					
[redacted]	Army	1C	Effective	Not Suitable	RAM; communications system less suitable than did not meet Information Exchange Requirements for Block I.
[redacted]	USAF	1D	Effective	Not Suitable	RAM; needed more maintenance resources and spare parts; BIT
[redacted]	Navy	1C	Not Effective		Not effective against moderately hardened targets; mission planning time was excessive.
[redacted]	Army	1C	Effective	Suitable	
[redacted]	Army	1C	Effective	Suitable	
[redacted]	Navy	1D	Effective	Suitable	
[redacted]	Navy	II	Effective	Suitable	

Figure 2: DoD IOT&E Results FY 2004-2005.

Program	Service	ACAT	IOT&E Result		Reason
CY 2006					
[redacted]	Army	1C	Effective	Suitable	Effective and suitable in the OIF/OEF environment but needs further testing outside of the OIF/OEF environment.
[redacted]	Navy	1AM	Effective	Not Suitable	Operational Test Agency, COTF, reported effective, not suitable. BLRIP not complete.
[redacted]	Navy	II			Test suspended due to reliability problems.
[redacted]	Navy	II	Not Effective	Not Suitable	Block 1A Upgrade does not make the operationally effective and suitable but does enhance ability
[redacted]	USAF	1C	Effective single ship; Not effective in formation	Suitable with shortfalls	Effective single ship; not effective in formation air land / air drop; not effective in non permissive threat environment. Shortfalls in suitability due to maintainability issues
[redacted]	USAF	1D	Effective with limitations	Suitable with limitations	Limited effectiveness and suitability due to reliability and deficiencies in software used to predict optimum fuzing solutions.

Figure 3: DoD IOT&E Results for 2006.

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DSB Report on DT: Suitability

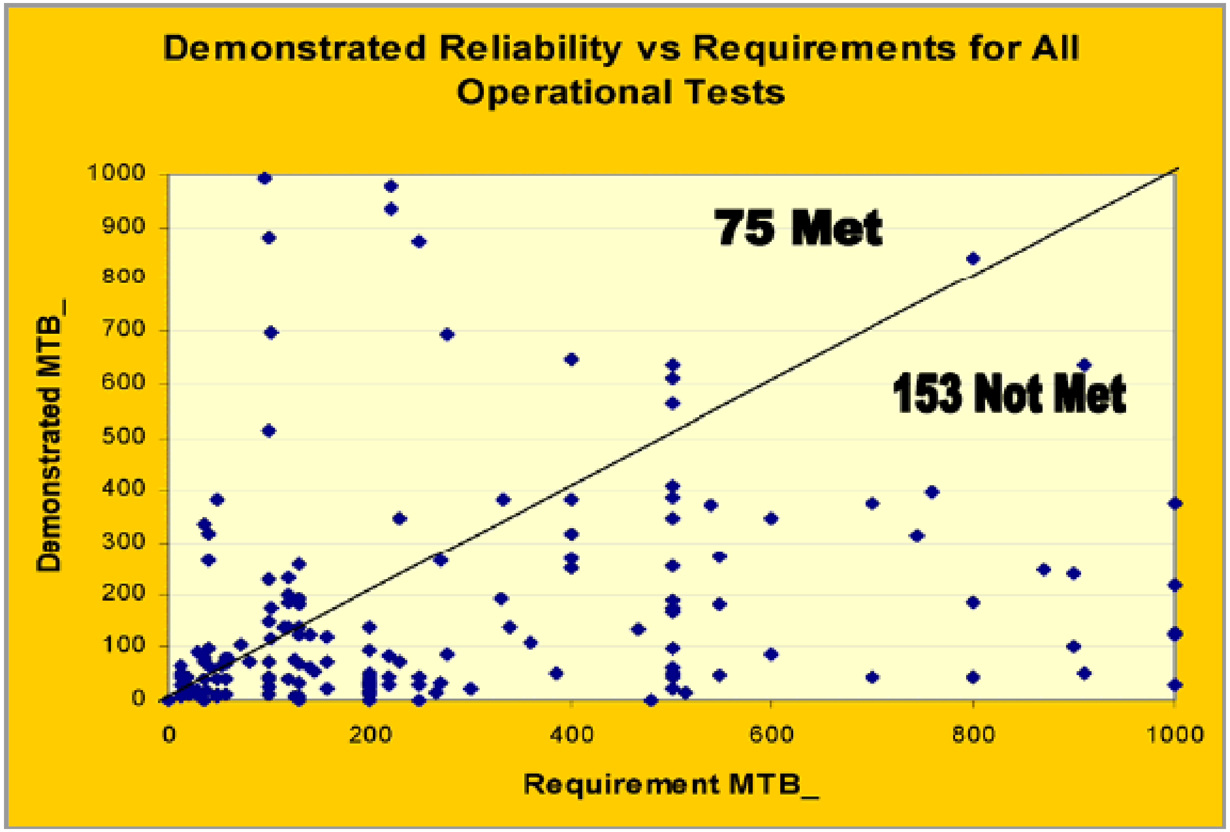

Figure 4: Army Systems Failing Reliability during Operational Testing (1997-2006).

- **Only 75 of 228 Army programs met their Reliability requirements from 1997 to 2006**

Other Considerations (One Man's Opinions)

- **Performance based contracts allowed contractors to determine how to reach reliability requirements—with disastrous results**
  - There is an inherent disincentive for contractors to spend acquisition funds on improving Reliability due to the lucrative nature of contractor support and sparing
  - Acquisition program managers are not held accountable for post-FRP support costs

"…short-sighted attempts to save acquisition funds at the expense of increased life cycle costs."—DSB Report on DT&E

Program Support Review Reliability Findings

- **Unrealistic Reliability requirements**
  - Requirements not measurable, quantifiable, reasonable, etc…
    - "as good as or better than current system…" – impacts translation of user needs into technical requirements
  - User R&M requirements not underpinned by sound rationale
    - Failure to document mission context or mission profile
  - Maturation timeframes or maturity at IOC not defined
  - Inconsistent use of R&M measures makes comparison of programs difficult
- **Maturing "suitability" (e.g., RAM)… not always a priority**
  - Little effort to design-in reliability and maintainability
    - Inadequate allowance of resources (time, money, people)
    - Scope of effort to design-in RAM not aligned with schedules and resources
  - Optimistic growth rate assumptions
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Examples of Issues Found During AOTRs
(Not systemic across all reviews)

- **Immature technologies**
- **Lack of quantitative user requirement lead to subjective evaluation**
- **Lack of measures to assess resolution of Critical Operational Issues**
- **Inadequate Stakeholder involvement during development phase**
- **DT&E not always conducted in all IOT&E regimes and environments**
  - KPPs not always demonstrated in DT&E
- **Not meeting reliability thresholds**
- **Poor logistics support planning; Immature IETMs and training**
- **LFT&E conducted too late to impact design**
- **Budget vice not event-driven schedules**
  - Pressures to meet IOT&E and IOC dates
- **Planning and resources for FOT&E not identified**

IOT&E Results

- **57% (20 of 35) of DoD programs from FY2001 to FY2007 entered IOT&E and failed to meet Operational Effectiveness and/or Suitability requirements**
  - 12 of the 20 (60%) failed to meet effectiveness requirements
  - 17 of the 20 (85%) were either not operationally suitable or suitability was the cause of test suspension
  - 11 of the 17 (65%) cited Reliability as the cause of failure or suspension

Materiel Availability KPP Established to Relate Logistics Reliability to Ownership Cost

- **May 2007: CJCSI 3170.01F and CJCSM 3170.01C**
  - Included Materiel Availability KPP
    - Supported by Materiel Reliability and Ownership Cost KSAs
  - Mandatory for JROC Interest Programs

on validation. The sponsoring component will validate the KPPs for non-JROC Interest CDDs and CPDs. A single KPP can be developed provided it complies with the congressional direction pertaining to force protection and survivability.

(1) Survivability KPP. Survivability attributes are those that contribute to the survivability of a manned system. This includes attributes such as speed, maneuverability, detectability, and countermeasures that reduce a system's likelihood of being engaged by hostile fire, as well as attributes such as armor and redundancy or critical components that reduce the system's vulnerability if it is hit by hostile fire.

(2) Force Protection KPP. Force protection attributes are those that contribute to the protection of personnel by preventing or mitigating hostile actions against friendly personnel, military and civilian. This may include the same attributes as those that contribute to survivability, but the emphasis is on protecting the system operator or other personnel rather than protecting the system itself. Attributes that are offensive in nature and primarily intended to defeat enemy forces before they can engage friendly forces are not considered force protection attributes. Attributes that protect against accidents, weather, natural environmental hazards, or disease (except when related to a biological attack) are also not part of force protection.

(3) Exemptions. Document sponsors who determine that the survivability and/or force protection KPPs do not apply will include rationale in the CDD/CPD explaining why they are not appropriate. The JROC must concur in this recommendation for JROC Interest documents.

b. Sustainment KPP. A Sustainment KPP (Materiel Availability) and two mandatory supporting KSAs (Materiel Reliability and Ownership Cost) will be developed for all JROC Interest programs involving materiel solutions. For non-JROC Interest programs, the sponsor will determine the applicability of this KPP. During the CBA, the relevant sustainment criteria and alternatives will be evaluated to provide the analytical foundation for the establishment of the sustainment KPP and KSAs.

(1) Mandatory KPP. Materiel Availability is a measure of the percentage of the total inventory of a system operationally capable (ready for tasking) of performing an assigned mission at a given time, based on materiel condition. This can be expressed mathematically as (number of operational end items/total population). Materiel Availability also indicates the percentage of time that a system is operationally capable of performing an assigned mission and can be expressed as (uptime/(uptime + downtime)). Determining the optimum value for Materiel Availability requires a comprehensive analysis of the system and its planned use, including the planned operating environment, operating tempo, reliability alternatives, maintenance approaches, and supply chain solutions. Materiel Availability is primarily determined by system

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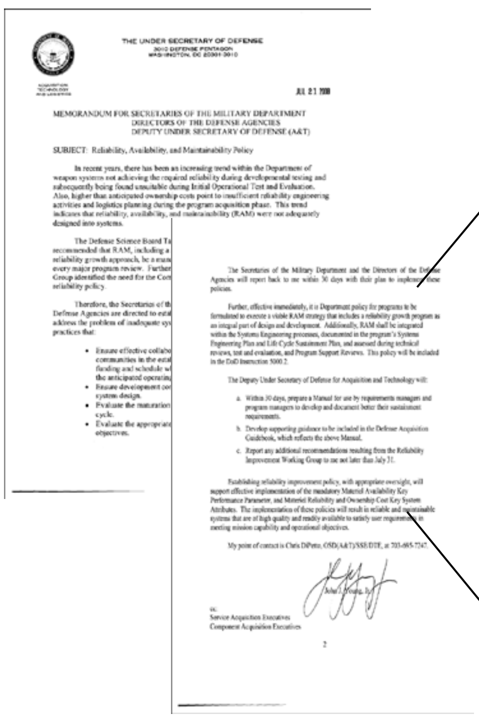
RAM Policy Memo

- **July 2008: Reliability, Availability, and Maintainability Policy Requires RAM be integrated into the Systems Engineering process**



Further, effective immediately, it is Department policy for programs to be formulated to execute a viable RAM strategy that includes a reliability growth program as an integral part of design and development. Additionally, RAM shall be integrated within the Systems Engineering processes, documented in the program's Systems Engineering Plan and Life Cycle Sustainment Plan, and assessed during technical reviews, test and evaluation, and Program Support Reviews. This policy will be included in the DoD Instruction 5000.2.

The Deputy Under Secretary of Defense for Acquisition and Technology will:

a. Within 30 days, prepare a Manual for use by requirements managers and program managers to develop and document better their sustainment requirements.

b. Develop supporting guidance to be included in the Defense Acquisition Guidebook, which reflects the above Manual.

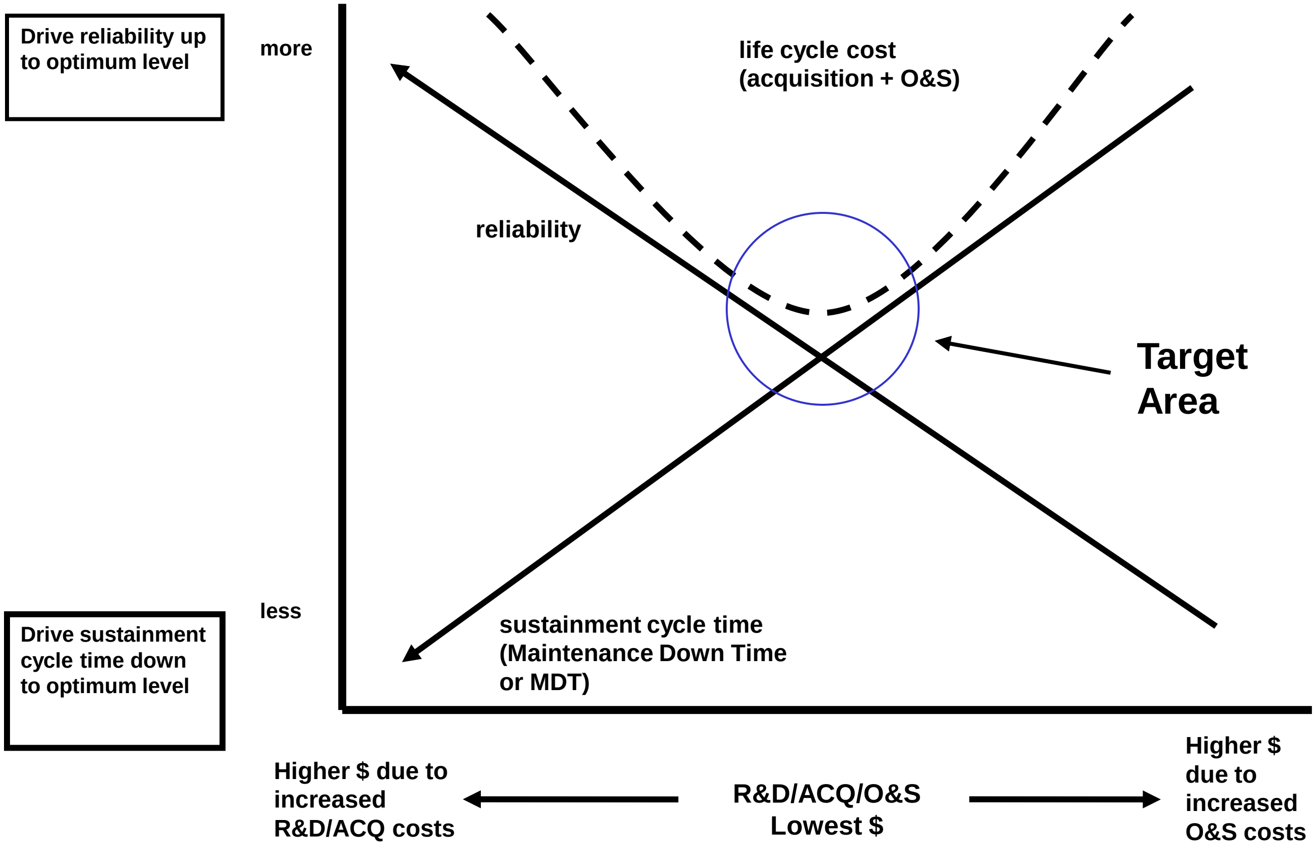
c. Report any additional recommendations resulting from the Reliability Improvement Working Group to me not later than July 31.

Establishing reliability improvement policy, with appropriate oversight, will support effective implementation of the mandatory Materiel Availability Key Performance Parameter, and Materiel Reliability and Ownership Cost Key System Attributes. The implementation of these policies will result in reliable and maintainable systems that are of high quality and readily available to satisfy user requirements in meeting mission capability and operational objectives.

Defense Acquisition Guidebook Design Considerations

Achieving the "best value" solution is an iterative task performed within the framework of Systems Engineering.

Trade Off Considerations



- **The Sustainment KPP ensures the program considers reliability and O&S costs equally during system design and development**

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Sustainment KPP: Materiel Availability

- **Materiel Availability (A_M) is a system design metric**
  - Applies to all items that have been delivered at any point in time—entire inventory (Active + Inactive)
    - A_O applies only to the Active Inventory—and usually to a subset of that!
  - A_M is optimized—not maximized
    - A_O is a direct measure of operational effectiveness and, as such, it is usually best when maximized
    - A_M is a function of how the system is intended to be fielded
      - Proper implementation requires tradeoffs between operational AND non-operational factors:
        - » Operational factors include A_O, Mission Reliability, Logistics Reliability, MDT
        - » Non-Operational factors include Total Inventory, Active Inventory, Sustainment Strategy (repair levels, spares availability, delays, etc.), Ownership Cost
- **A_M includes two Key System Attributes (KSAs):**
  - Materiel Reliability
  - Ownership Cost
- **SSE AS has developed a handbook for implementation of the Sustainment KPP**
  - RAM-C Report Manual
  - Presently in coordination
    - Army non-concurral based on A_M not being immediately under the full control of the combat commander

What is RAM, really?

- **Definitions (Adapted from Reliability Statistics by Dovich):**
  - Reliability:
    1. The duration or probability of failure-free performance under stated conditions.
    2. The probability that a system can perform its intended function for a specified interval under stated conditions.
       - For non-redundant designs, the definitions are equivalent. For designs including redundancy, definition 2 reflects the "mission" reliability.
  - Availability:
    - A measure of the degree to which a system is in the operable and committable state AT THE START of the mission when the mission is called for at an unknown (random) time.

      {Emphasis Added!!!!}
  - Maintainability:
    - The measure of the ability of a system to 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.

Reliability, Availability, and Maintainability $\rightarrow$ RAM

Measures of RAM

- **Mean Time Between Failures (MTBF):**
  - The mean number of life units during which all parts of the item perform within their specified limits during a particular measurement interval under stated conditions
  - Applies to REPAIRABLE items only
- **Mean Time To Failure (MTTF):**
  - The mean number of life units to failure of the item under stated conditions
  - Applies to NON-REPAIRABLE items only
- **Mean Time Between Maintenance (MTBM):**
  - The mean number of life units before maintenance events (scheduled or unscheduled) *necessitating that the system be taken offline* are required
    - A measure of reliability taking into account maintenance policy
    - Note: Standard definitions of MTBM do not specifically limit analysis to actions which take the system offline. In view of the Sustainment KPP, definition of MTBM to cover only this specific subset of actions is required to support implementation of the Materiel Availability KPP.

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Measures of RAM—Continued

- **Maintenance Downtime (MDT):**
  - Mean time required to perform maintenance
    - Includes supply time, logistics time, administrative delays, active maintenance time, etc.
- **Administrative Delay Time (ADT):**
  - That element of downtime during which no maintenance is being accomplished due to administrative delay
- **Logistics Delay Time (LDT):**
  - That element of downtime during which no maintenance is being accomplished due to logistics delay
- **Administrative/Logistics Delay Time (ALDT):**
  - Mean value of ADT + LDT
- **Mean Time To Repair (MTTR):**
  - Mean active maintenance time
    - Usually repair action specific due to variability of repair times (replacing an engine takes much more time than changing a tire)

Math Basics Required: Metrics

- The symbol λ represents the failure rate
- MTBF (or MTTF) = $\frac{1}{\lambda}$
- Availability Measures

$$\text{Inherent Availability} = \frac{\text{MTBF}}{\text{MTBF} + \text{MTTR}}$$

$$\text{Operational Availability} = \frac{\text{MTBM}}{\text{MTBM} + \text{MDT}} \text{ or } \frac{\text{Uptime}}{\text{Uptime} + \text{Downtime}}$$

$$\text{Materiel Availability} = \frac{\text{Active Inventory}}{\text{Active Inventory} + \text{Inactive Inventory}} \text{ or } \frac{\text{Uptime}}{\text{Uptime} + \text{Downtime}}$$

Note: Operational Availability and Materiel Availability both have uptime/(uptime + downtime) definitions but the uptime and downtime definitions are different for each measure!

New RAM Policy

New RAM Policy: Origins of Sustainment Key Performance Parameter (KPP)

- **JCIDS process detailed in DoD 5000.02**
- **Incorporated into JCIDS 3170.01 series in May 2007**
- **Refined in new JCIDS 3170.01 versions in March 2009**
- **Availability KPP**
  - Materiel Availability
  - Operational Availability (Added in March 2009)
    - May require multiple values
- **Reliability Key System Attribute (KSA)**
  - Mission Reliability
    - May require multiple values!
  - Logistics (Basic) Reliability
- **Ownership Cost KSA**

New RAM Policy: July 21st RAM Policy Memo

- **DDR&E SE maintains that a viable RAM strategy requires consideration of sustainment and fielding issues during system design**
  - Mandated in new Acquisition Reform Law (WASARA)
- **Note the policy intentionally calls for a "…reliability growth program…" and not simply a growth curve**

> "Effective immediately, it is Department policy for programs to be formulated to execute a viable RAM strategy that includes a reliability growth program as an integral part of design and development."

Applicable RAM Metric Relationships

- **Operational Availability:** $$A_O = \frac{MTBM}{MTBM + MDT}$$
- **Maintenance Down Time:** $$MDT = MTTR + \overline{ADT} + \overline{LDT}$$
- **Available Tradeoffs:**
  - **A_O is improved by:**
    - Decreasing MDT
    - Increasing MTBM
  - **MDT is decreased by:**
    - Reducing MTTR
    - Reducing average ADT
    - Reducing average LDT
  - **MTBM is increased by:**
    - Increasing MTBF
    - Decreasing need for scheduled maintenance requiring system to be taken offline

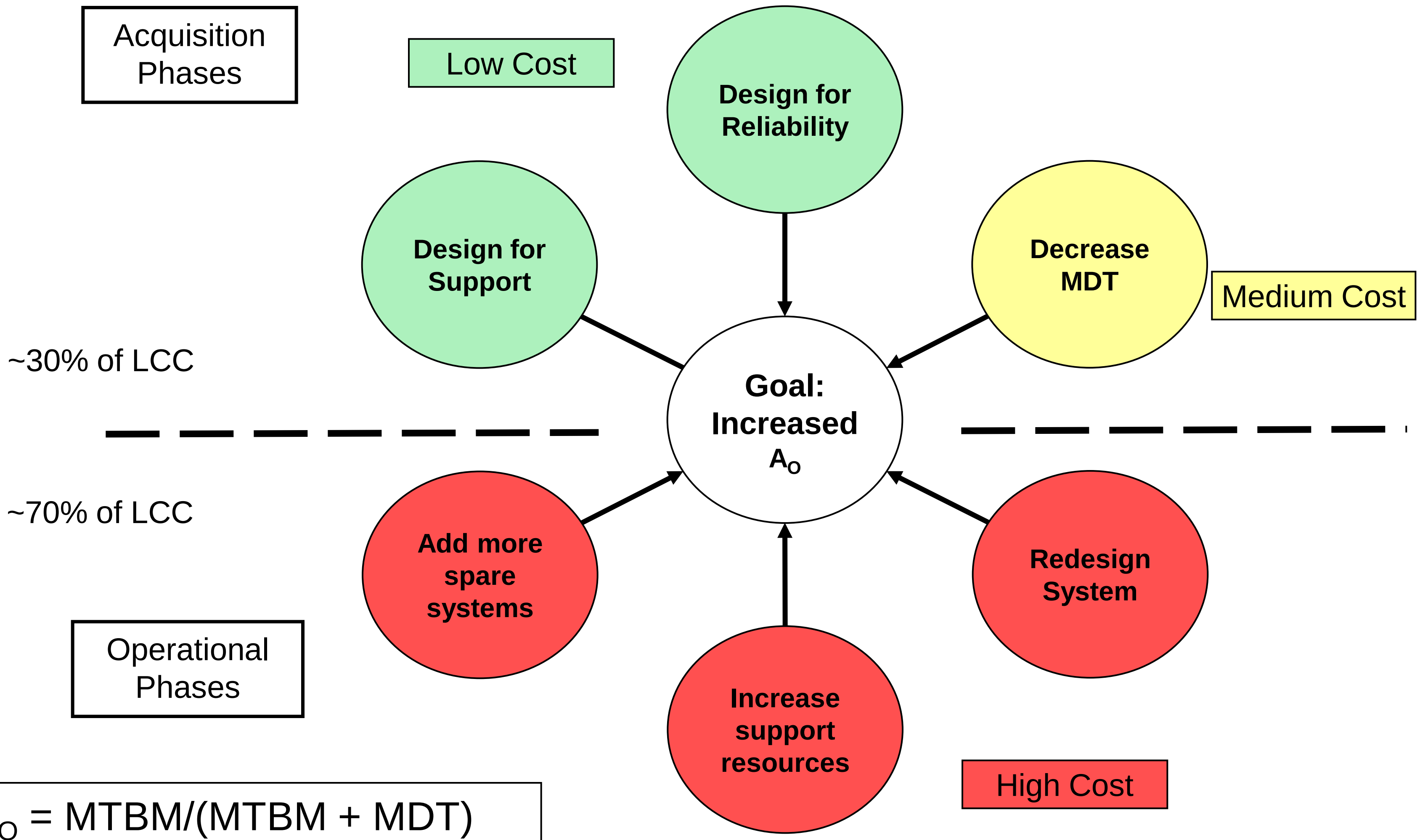
MDT is Decreased by…

- **Decreasing Mean Time To Repair**
  - Adding Maintainers (Increases Cost)
  - Designing for Maintainability (Cost Neutral to Slightly Increased)
- **Decreasing Average Administrative Delay Time**
  - Increasing efficiency of request for repair system (Cost Neutral)
- **Decreasing Average Logistics Delay Time**
  - Increasing spares availability
    - Pre-position spares to decrease shipping time (Increases Cost)
    - Acquire extra spares (Increases Cost)
    - Adding Maintenance Locations (Increases Cost)
  - Improving efficiency of spares distribution system (Cost Neutral)

MTBM is Improved by…

- **Increasing Reliability**
  - Incorporating Redundancy Into the Design
    - Increases Cost, Weight, Logistics Failures
  - Using Best Practices
    - Reliability Growth Testing (Slight Cost Increase)
    - Using High Reliability Parts (Slight Cost Increase)
    - Implementing a Failure Reporting and Corrective Action System (Cost Neutral)
    - Executing a Failure Modes, Effects, and Criticality Analysis (Cost Neutral)
    - Design for Reliability (Cost Neutral)
    - Physics of Failure Analysis (Cost Neutral)
- **Decreasing Scheduled Maintenance Requirements (Cost Neutral)**

Approaches to Improve Operational Availability (A_O)



$$A_O = MTBM/(MTBM + MDT)$$

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A_O vs. A_M

A_O vs. A_M: What is Materiel Availability?

- **Materiel Availability (A_M) is a system design metric**
  - Applies to all items that have been delivered at any point in time—Active + Inactive
  - A_O applies only to the Active Inventory—and usually to a subset of that!
- **A_M is optimized—not maximized**
  - A_O is a direct measure of operational effectiveness
    - Usually best when maximized
  - A_M is a function of how the system is intended to be fielded
    - Any value is acceptable
      - A missile system where only 5% of the missiles are fielded at any one time might have a valid A_M of 0.05!

A_O vs. A_M: What is Materiel Availability? (cont.)

- **Definitions:**
  - For End Items or Assemblies procured with spares (includes one-shot devices) :

$$A_M = \frac{\text{Number Ready for Tasking}}{\text{Total Number Acquired}}$$

  - For Systems procured as part of an end item:

$$A_M = \frac{\text{Uptime}}{\text{Uptime} + \text{Downtime}}$$

A_O vs. A_M: What is Materiel Availability? (cont.)

- **Proper implementation requires tradeoffs between operational AND non-operational factors:**
  - Operational factors include:
    - A_O
    - Mission Reliability
    - Logistics Reliability (aka Basic Reliability)
    - Maintenance Down Time (MDT)
  - Non-Operational factors include:
    - Total Inventory
    - Active Inventory
    - Sustainment Strategy (repair levels, spares availability, delays, etc.)
    - Ownership Cost

A_O vs. A_M: What is Materiel Availability? (cont.)

- **DDR&E SE has developed a handbook for implementation of the Sustainment KPP**
  - RAM-C Rationale Report Manual
    - Called for in the July 21st memo
  - Signed May 31, 2009
    - Army non-concurral based on A_M not being immediately under the full control of the combat commander
    - Added A_O as additional consideration in newest version of 3170.01 series manuals

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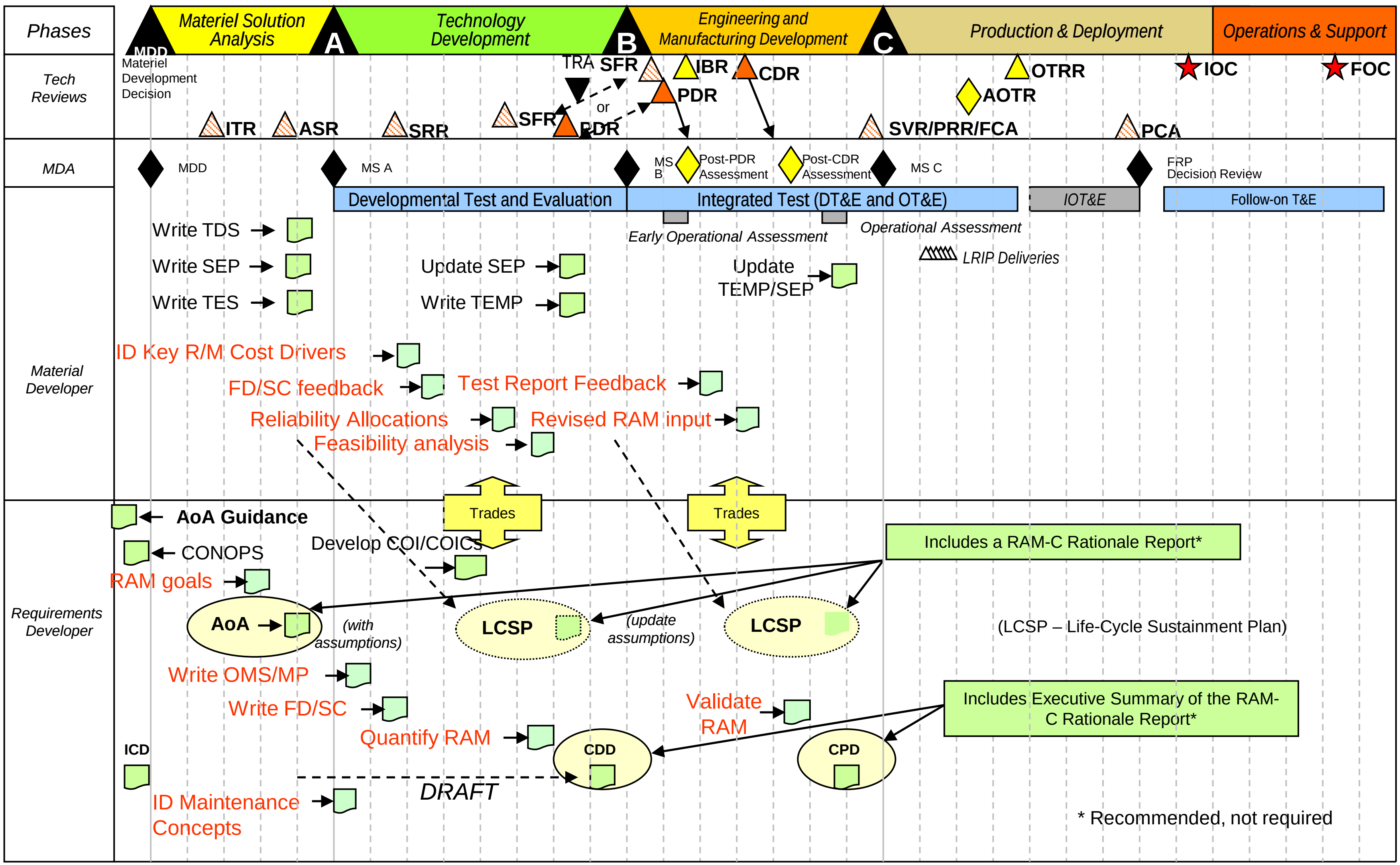
Guidance in RAM-C Manual

RAM-C Manual: Report Timeline



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RAM-C Manual: Phased Requirements and Measurements

Metric	Milestone	How Measured	Responsible Activity	When Measured	Program Phase Metric
Availability Materiel Availability (A_M)	A	Comparative Analysis with Legacy Systems and/or Engineering Assessment	Program Manager (PM) or Program Sponsor if PM not assigned	Pre Alternative System Review (ASR) for all candidate systems Post ASR for preferred system selected	$\frac{\text{(number of operational end items)}}{\text{(total number of end items acquired)}}$ or $\frac{\text{uptime}}{\text{uptime} + \text{downtime}}$ Value is "as planned" given the expected system use and support concept
Operational Availability (A_O) KPP	B	Demonstrated through testing plus modeling and simulation where needed	Test and Evaluation Activity	During DT and Early User Tests (EUT)	Scored failure rate per FD/SC • MTBF if all failures classified as critical and MTBM otherwise MDT modeled from MTTR, LDT, and ADT • MDT estimates from early in program; Replaced by data as available
	C	Demonstrated through testing and analysis of early fielded system performance	Test and Evaluation Activity and Program Manager	During DT, DT/OT and Limited User Tests/Operational Assessment	Scored failure rate per FD/SC • MTBF if all failures classified as critical and MTBM otherwise MDT modeled from MTTR, LDT, and ADT values
	FRP and Beyond	Demonstrated through analysis of fielded system performance	OTA and Program Manager	During IOT and throughout system life cycle	$\frac{\text{(number of operational end items)}}{\text{(total number of end items acquired)}}$ or $\frac{\text{uptime}}{\text{uptime} + \text{downtime}}$

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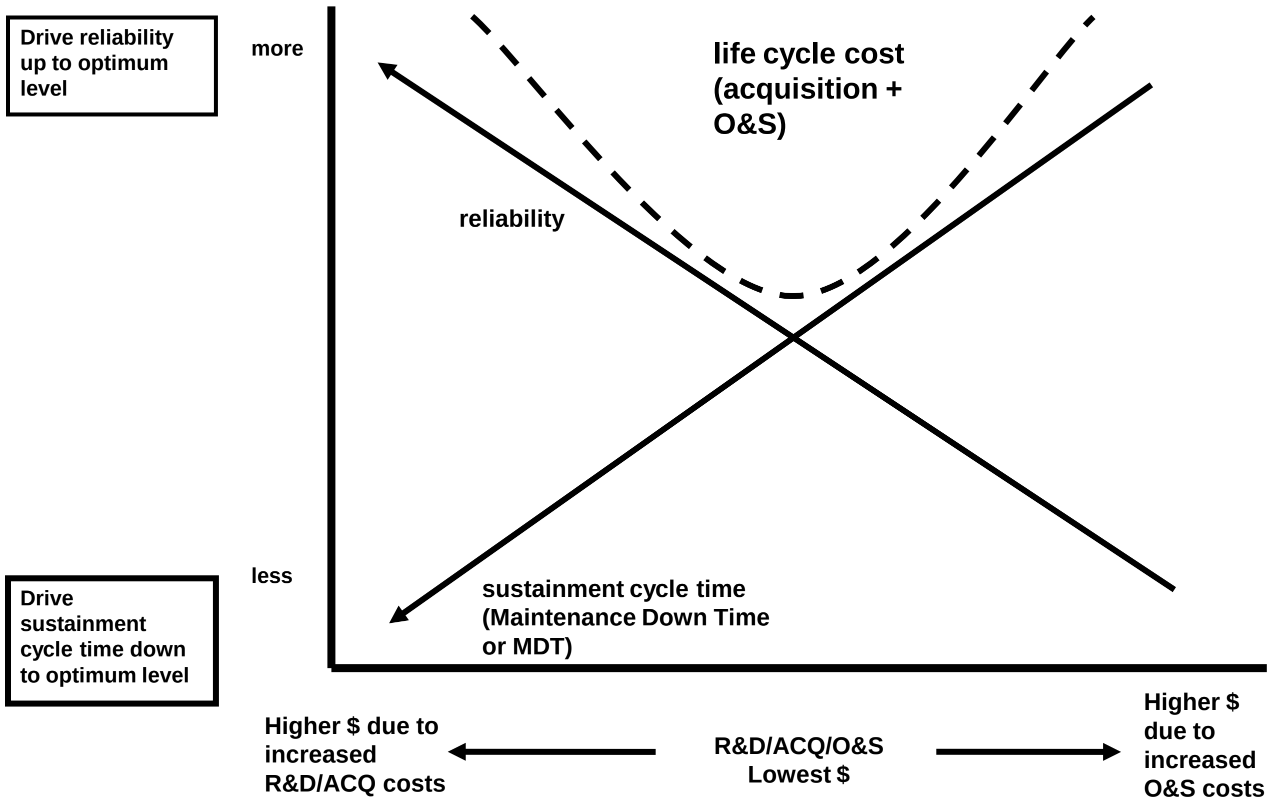
RAM-C Manual: Phased Requirements and Measurements (cont.)

Metric	Milestone	How Measured	Responsible Activity	When Measured	Program Phase Metric
Reliability (R_M) (KSA)	A	Comparative Analysis with Legacy Systems and/or Engineering Analysis	Program Manager or Program Sponsor if PM not assigned	Pre ASR for all candidate systems Post ASR for preferred system selected	MTBF/MTBM derived from warfighter's stated needs and translated into contract level testable values.
	B	Demonstrated through testing, analysis, and modeling/ simulation	Test and Evaluation Activity	During DT and EUT	Scored failure rate per FD/SC • MTBF if all failures classified as critical and MTBM otherwise
	C	Demonstrated through testing, analysis, modeling/ simulation, and analysis of early fielded system performance	Test and Evaluation Activity and Program Manager	During DT, DT/OT, and LUT)/ Operational Assessment	Scored failure rate per FD/SC • MTBF if all failures classified as critical and MTBM otherwise
	FRP and beyond	Demonstrated through analysis of fielded system performance	OTA and Program Manager	During IOT and throughout system life cycle	Scored failure rate per FD/SC • MTBF if all failures classified as critical and MTBM otherwise

RAM-C Manual: Phased Requirements and Measurements (cont.)

Metric	Milestone	How Measured	Responsible Activity	When Measured	Program Phase Metric
Ownership Cost (OC) (KSA)	A	Comparative analysis with legacy systems or documented analysis when legacy systems unavailable	Program Manager (PM) or Program Sponsor if PM not assigned	Pre Alternative System Review (ASR) for all candidate systems Post ASR for preferred system selected	Initial, rough approximation based on projected energy and maintenance costs for assumed inventory and operating tempos and “placeholders” for Sustaining Support and Continuing System Improvements.
	B	Results of prototype testing; projected requirements for Sustaining Support and Continuing System Improvements as described in the Cost Analysis Requirements Description (CARD)	Program Manager with inputs from test and evaluation activity and contractors	During DT and Early User Tests (EUT)	For energy and maintenance, refined estimate based on demonstrated results in testing. Estimates for Sustaining Support and Continuing System Improvements, as described in the CARD, are refined based on analysis of test results and similar, legacy systems
	C	Demonstrated through testing and analysis of early fielded system performance	Program Manager with inputs from test and evaluation activity and contractors	During DT, DT/OT and Limited User Tests/Operational Assessment	Further refined estimates for all four OC elements, based on SDD test results and validated requirements for Sustaining Support and Continuing System Improvements
	FRP and Beyond	Demonstrated through analysis of fielded system performance	OTA and Program Manager	During IOT and throughout system life cycle	Updates based on actual energy consumption, maintenance, Sustaining Support and Continuing System Improvements costs.

RAM-C Manual: Trade-offs Required for Sustainment KPP



- **The Sustainment KPP ensures the program considers reliability and O&S costs equally during system design and development**

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RAM-C Manual: Stakeholder Tasks and Responsibilities

Stakeholder	Tasks/Responsibilities
Combat Developer	o Primary responsibility for drafting sustainment requirements and rationale articulated in the RAM-C Report. o Drafts the Operational Mode Summary/Mission Profile and Fault/Failure Definition and Scoring Criteria o Develops the maintenance and support concepts articulated in the CONOPS, CDD, and CPD o Solicit warfighter insights/inputs into sustainment requirements, fault/failure definition and scoring criteria, and maintenance/support concepts
Program Manager (Program Sponsor if PM not yet Assigned)	o Supports the combat developer in providing expert engineering and supportability analysis in developing sustainment requirements detailed in the applicable JCIDS document (CDD and CPD) o Responsible for implementing design for R&M and to demonstrate it through M&S, analysis, and event driven component, subsystem, and system level testing o Ensures development of the Product Support Elements (IETMs, provisioning, training, support equipment, etc.) required to implement the support concept o Establishes Performance-Based Agreement (PBA) with Product Support Integrators/Providers

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RAM-C Manual: Stakeholder Tasks and Responsibilities

Office of the Under Secretary of Defense (OUSD)	o Provides management and technical oversight as appropriate o PA&E provides Analysis of Alternative Guidance o CAIG will conduct assessment of RAM-C reports when conducting independent cost estimates in support of Milestone Reviews
Joint Staff	o Staffs and approves requirements in accordance with the JCIDS process
DoD Component (Lead Service)	o As directed, conduct the Analysis of Alternatives and include the results of sustainment analysis in the briefings and final report
Test and Evaluation Activities	o Provides appropriate input into the statement of requirements to ensure they are articulated in measurable and testable terms while also providing input into the validity and clarity of assumptions o Confirms sufficiency of test assets and schedule to support the RAM evaluation efforts including system reliability and maintenance o Verifies test program includes sufficient time for retest of any needed corrective actions o Evaluate A_M and R_M

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RAM-C Manual: Failure Definition and Scoring Criteria (FD/SC)

Document	Purpose	Contents
Failure Definitions	**To establish the guidelines used to classify the cause and effect of test incidents prior to test start**	▪ Mission Essential Functions must be determined and recorded • Mission essential functions are the minimum operational tasks that the system must be capable of performing in order to accomplish the assigned mission • Descriptions of mission essential functions should be in operational terms that relate to mission requirements • The equipment operator should be able to readily identify the loss of a mission essential function
Scoring Criteria	**Test scoring results are used to determine reliability estimates for the system at the applicable point in time**	▪ Scoring criteria must be applicable to the sustainment requirements ▪ Charging of incidents must be grouped as to the reason/cause of the incident (i.e. hardware, software, operator error, accident, etc.) ▪ Includes a classification process that ensures the consistent analysis of all test events including (at the minimum): • No-Test • Correctable Maintenance • Operational Mission Failure • Essential Maintenance Action • Unscheduled Maintenance Action • Identification of the Chargeable Event • Rating of the Hazard/Severity of the failure/incident

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RAM-C Manual: Operational Modes Summary and Mission Profile (OMS/MP)

Document	Purpose	Contents
Operational Mode Summary	To provide a description of the anticipated mix of ways a system will be used in carrying out its operational role	▪ Documented system usages to be used as fundamental inputs to the design process and as the basis for test and evaluation efforts ▪ All primary missions listed in the mission profile must be covered ▪ Includes relative frequency of the various missions or the percentage of the systems to involved in each mission ▪ Details percentage of time the system will be exposed to each type of environmental condition during the system life
Mission Profile	Provision of a time phased description of the operational events and environments an item experiences from beginning to end of a specific mission	▪ Identification of the tasks, events, durations, operating conditions, and environments the system encounters during each phase of the mission ▪ Must include typical mission scenarios ▪ Should identify mission tasks or operational events that must be completed to successfully accomplish the mission ▪ States specific amounts of operation (e.g. hours, rounds, miles, cycles, etc.) for each mission essential functions within the mission ▪ Shall be consistent with doctrine and tactics ▪ May use a timeline or any other appropriate format

Summary

- **RAM must return to being a key design consideration during system development—and the new Acquisition Reform legislation mandates this!**
- **Sustainment costs are mostly set during system design**
- **The Sustainment KPP is intended to establish necessary trade space**