Reliability Growth Modeling

Defense Acquisition University

Certification Training | Knowledge Sharing | Continuous Learning | Mission Assistance

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Please recall…

$$N_{D,SYS} = T_{D,SYS} + \hat{\rho}_{SYS}$$

$$LCB_{\gamma} = \frac{2T_{D,SYS}}{\chi^2_{2n_{D,SYS}+2,\gamma}}$$

$$T_{Gi} = \frac{1}{\left[\lambda\beta M_{G,i}\right]^{\left[\frac{1}{(\beta-1)}\right]}} \quad (\beta \neq 1)$$

$$\text{Prob} = 1 - e^{-\left(\frac{t_I * MS}{M_I}\right)}$$

$$M(t) = \frac{1}{\omega(\beta t^{\beta-1})}, \quad 0 < t \leq T$$

$$\frac{1}{\omega} = (M(T))\beta T^{\beta-1}$$

$$M(t) = (M(T))\left(\frac{t}{T}\right)^{\alpha}, \quad 0 < t \leq T.$$

$$\text{Prob}(A; \alpha, T, M(T)) = (1 - e^{-\mu})^{-1} \sum_{n=1}^{\infty} \left[\text{Prob}\left(\frac{\chi^2_{2n}}{z^2_{\gamma}} \geq \frac{1}{2\mu d}\right)\right] e^{-\mu}\left(\frac{\mu^n}{n!}\right)$$

$$\text{Type I} = 1 - \text{Prob}(A; \mu_G, d_G)$$

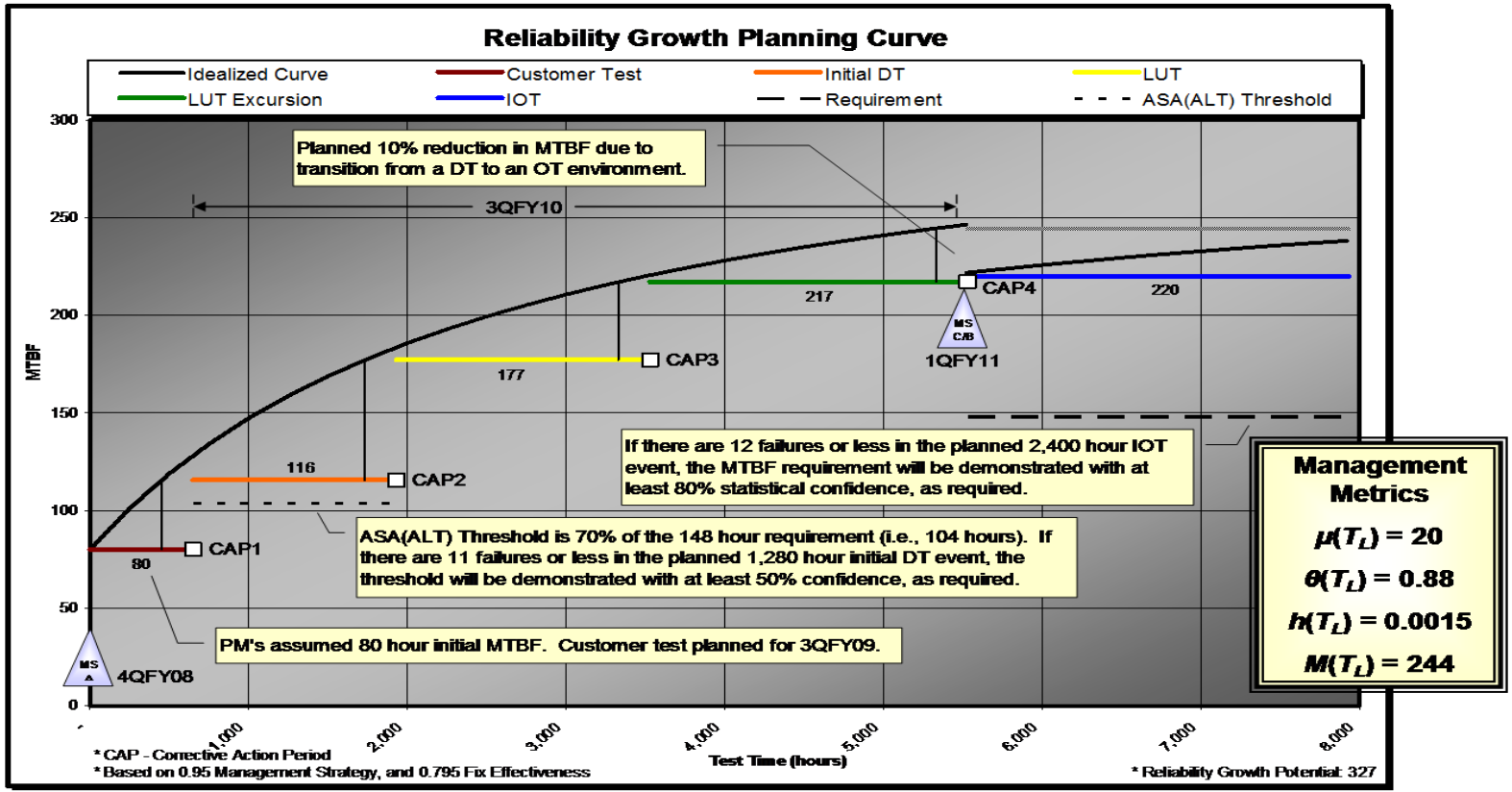
$$d_G = M_G/TR \text{ and } \mu_G = T/\{(1-\alpha_G)M_G\}$$

$$M_G/TR = d_G = \left\{\frac{M_I}{(1-\alpha_G)t_I^{\alpha_G} TR}\right\} T^{\alpha_G}$$

$$E(N) = \mu_G = (t_I^{\alpha_G}/M_I)T^{1-\alpha_G}$$

$$\beta = \left(\frac{1}{T}\right)\left(\frac{1 - \frac{M_1}{M_G}}{MS \cdot \mu_d - \left(1 - \frac{M_1}{M_G}\right)}\right)$$

PM2 Product – RG Curve



Overview

Implement a robust Reliability and Maintainability (R&M) Program

Stakeholders

- Milestone Decision Authority (MDA)
- Acquisition chain of command
- Program office
- Developmental test agencies
- Operational test agencies

R&M Program

- The Program Manager is responsible for the R&M program
- The R&M program is an integral part of the systems engineering process
- The R&M program includes robust reliability testing

Reliability growth monitoring and reporting

- Status of R&M objectives and/or thresholds reported
  - Formal design review process
  - Systems engineering technical reviews
  - Other reviews
- RGCs are also used to report reliability growth status at DAES reviews

R&M PROGRAM ENGINEERING ACTIVITIES

- R&M allocations
- Block diagrams and predictions
- Failure definitions and scoring criteria;
- FMECA (Failure Mode, Effects And Criticality Analysis)
- Maintainability and BIT (built-in test) demonstrations
- Reliability testing at the system and subsystem level
- FRACAS (Failure Reporting, Analysis, and Corrective Action System) maintained through design, development, production, and sustainment

RAM-C Report

- Reliability, Availability, Maintainability and Cost Rationale (RAM-C) Report
  - Preliminary report required for MDAPs in support of the **Milestone A** decision
- RAM-C Report provides a quantitative basis for reliability requirements, and improves cost estimates and program planning.
- Attached to the SEP at Milestone A
- Updated in support of
  - Development RFP Release Decision Point,
  - Milestone B
  - Milestone C

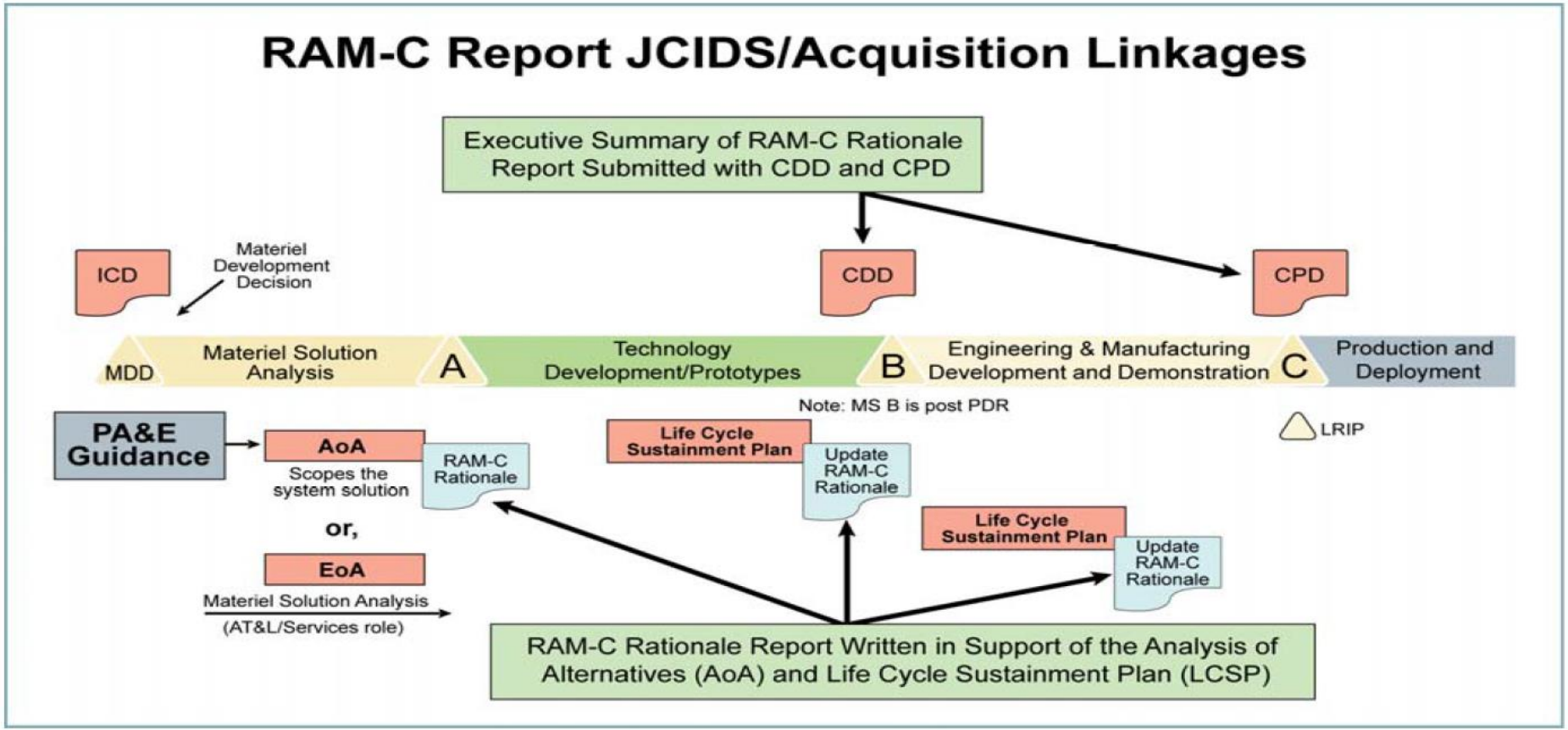
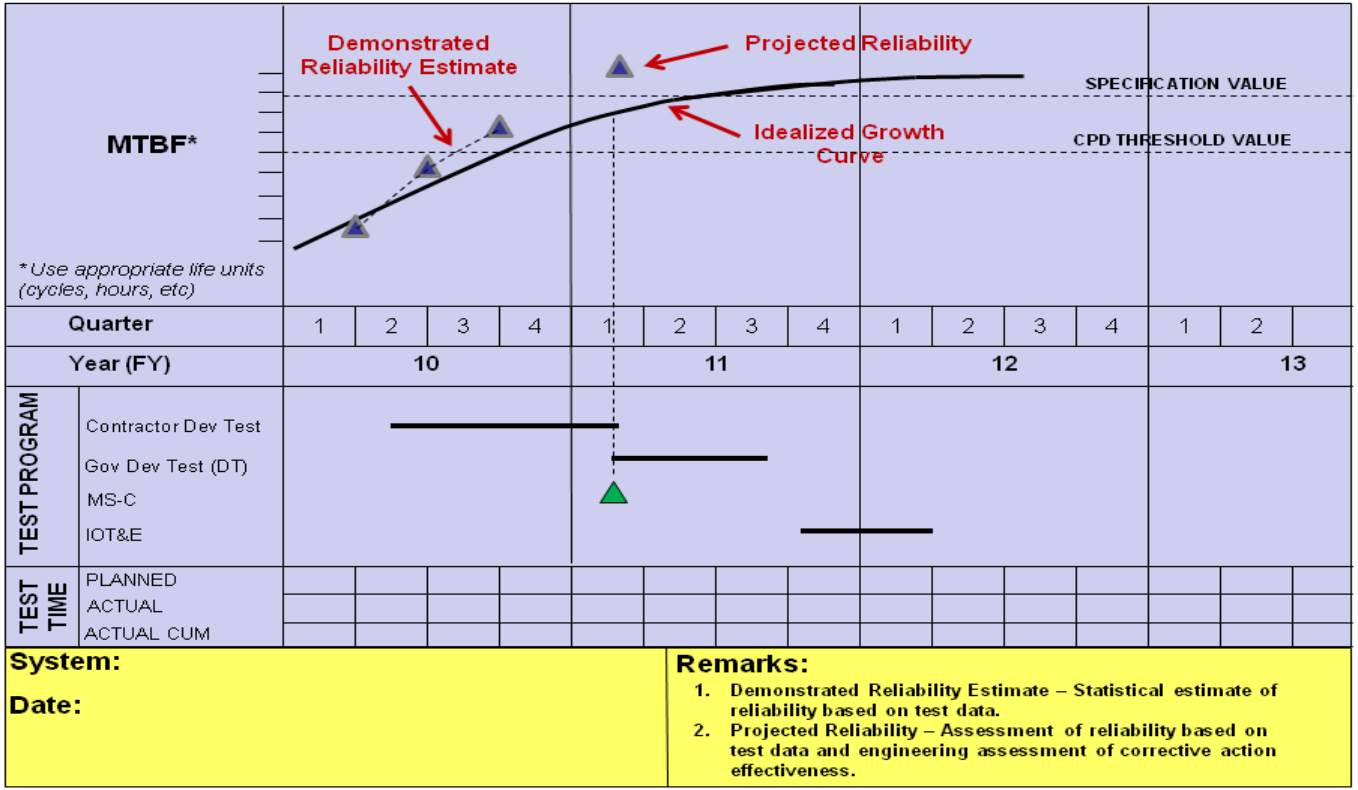


Figure 2-2 Defense Acquisition System RAM-C Report Submittal Events

Reliability growth curves (RGCs)

- RGCs reflect the reliability growth **strategy**
- Engineers use RGCs to **plan**, illustrate, and report reliability growth.
- Mandated for inclusion in the SEP
  - Milestone A SEP
  - Updated draft SEP at the Development RFP Release Decision Point
  - Final approved SEP
- Included in Test and Evaluation Master Plan submitted at Milestone B

Sample Reliability Growth Curve



Not just one step

- “Growth” implies intermediate stages
- “System” reliability means system-level test and evaluation
- Include curves for critical subsystems if a single curve doesn’t really tell the story

Reliability Growth Planning Overview

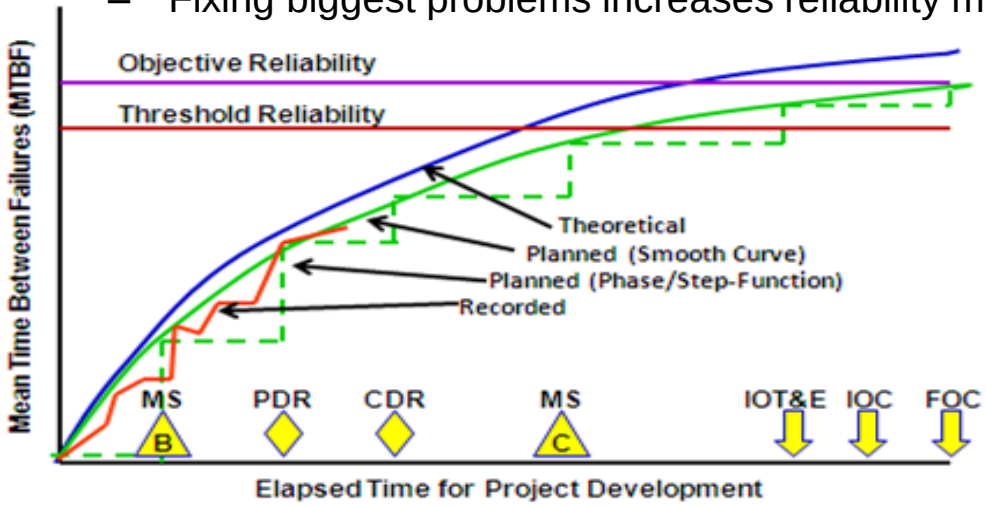
Characteristics of a Well-Run Reliability Growth Program

	Element	Details
✓	Adequate requirements	• System-level values achieved before fielding • Interim thresholds and/or Entrance/Exit criteria • Appropriate DT metrics (e.g., MTBEMA)
✓	Dedicated Test Events for Reliability	• Component HALT, BIT Demo, Integration testing, Component DfR
✓	RAM Analysis	• FMECA, Level of repair, reliability predictions
✓	Data collection, reporting, and tracking	• Independent data collector during DT and OT, FRACAS, RAM WG, scoring/assessment …data, etc.
✓	Corrective Actions	• Funding and time allotted with commitment from the management
✓	Realistic Growth Curve	• Based on funding • Realistic assumptions

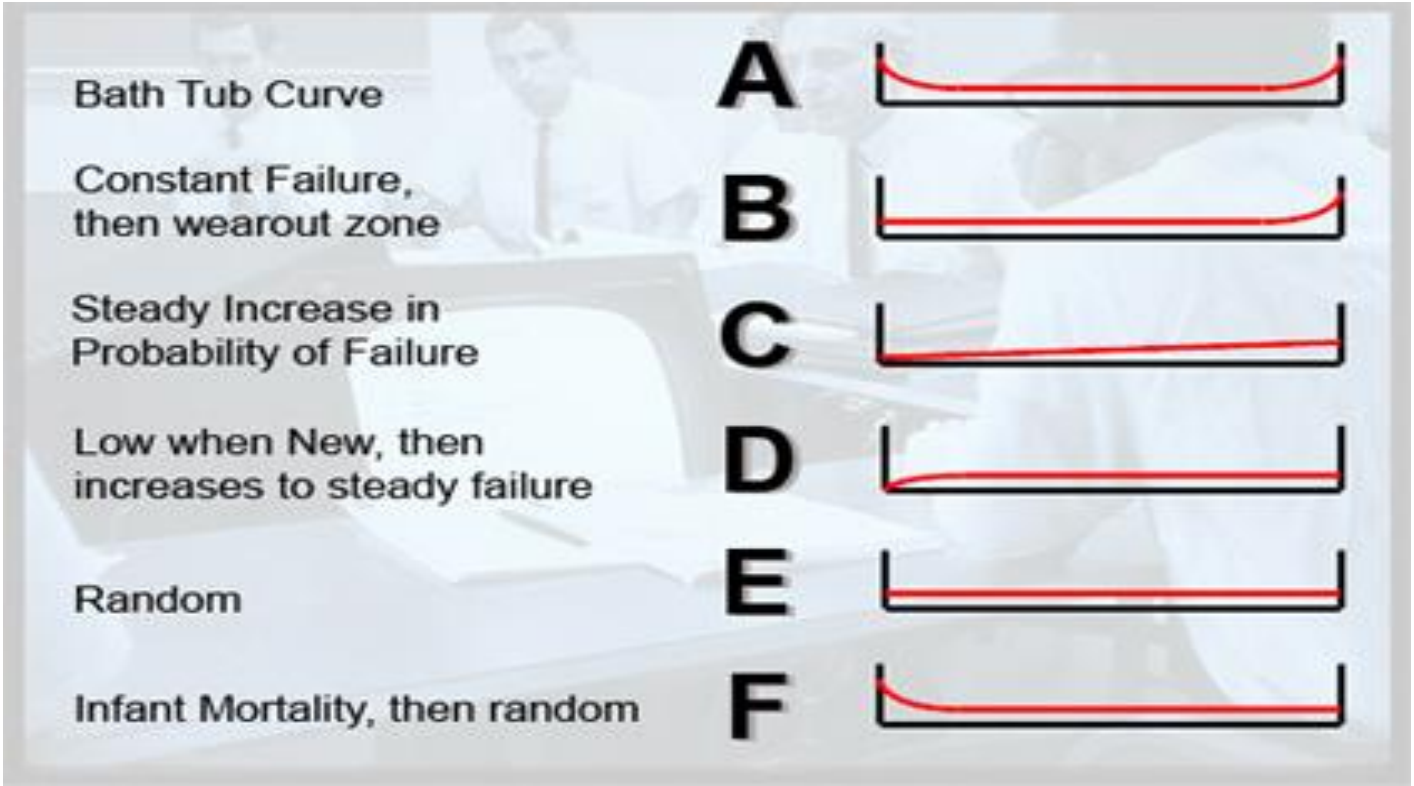
"Reliability cannot be tested-in….it must be designed-in, from the beginning."

The Reliability Growth Curve

- Non-homogeneous Poisson Process
  - Failure rate is a power function of time
- Assumptions:
  - Smooth curve assumes instantaneous fixes
  - Step-function based on number of corrective action periods
  - Fixing a problem increases reliability
  - Testing will usually reveal biggest (most frequent) problems first
  - Fixing biggest problems increases reliability most



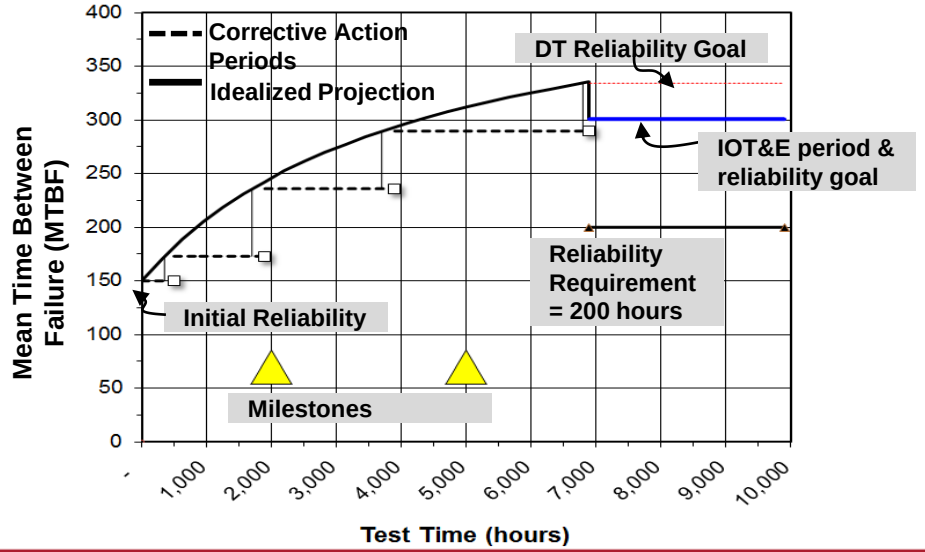
Six Failure Rate Patterns



Causing Reliability Growth

- Growth “occurs” when programs **identify failure modes** and **improve design** and quality
- Growth depends on:
  - Rate at which failure modes are surfaced
  - Turnaround time for analyzing and implementing corrective actions (fixes)
  - Management Strategy (MS) – fraction of initial failure rate addressed by fixes
  - Fix Effectiveness Factor (FEF) – fraction by which rate of occurrence of fixed modes is reduced

- Reliability Growth Curve is the tip of the iceberg!
  - Required in TEMPs
  - Accompanies description of the growth program/strategy



Reliability Growth Process

Design for Reliability (DfR)

- Component-level Testing
- Physics of Failure (PoF)
- Results in initial system design

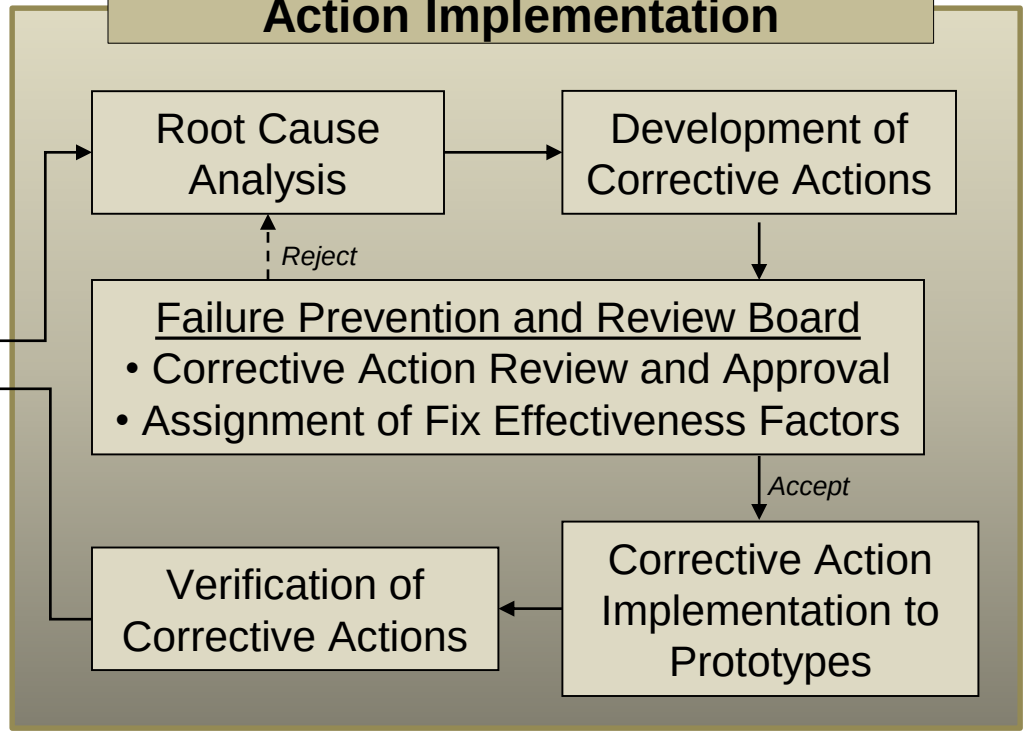
Developmental Testing (DT)

- Enter DT with Initial MTBF (M_I)
- Discover Failure Modes
- Grow to Goal MTBF in DT (M_G)

Demonstration Test (IOT)

- Fixed Configuration Test to Demonstrate Req't w/ Confidence
- Enter with Goal MTBF in IOT (M_R^+)

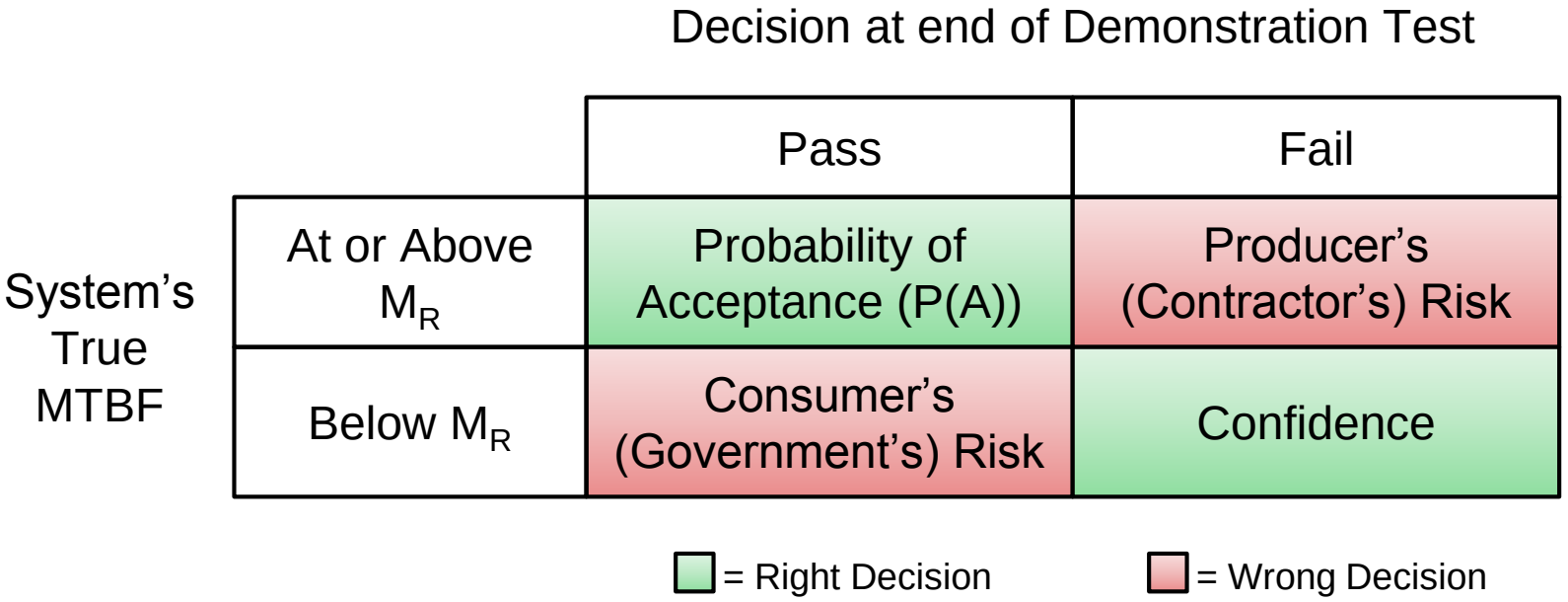
Failure Mode Analysis & Corrective Action Implementation



Modeling reliability growth

- M_R Reliability requirement (MTBF)
- How willing you are to accept a system that does not meet M_R
- How willing you are to reject a system that meets M_R

Risk



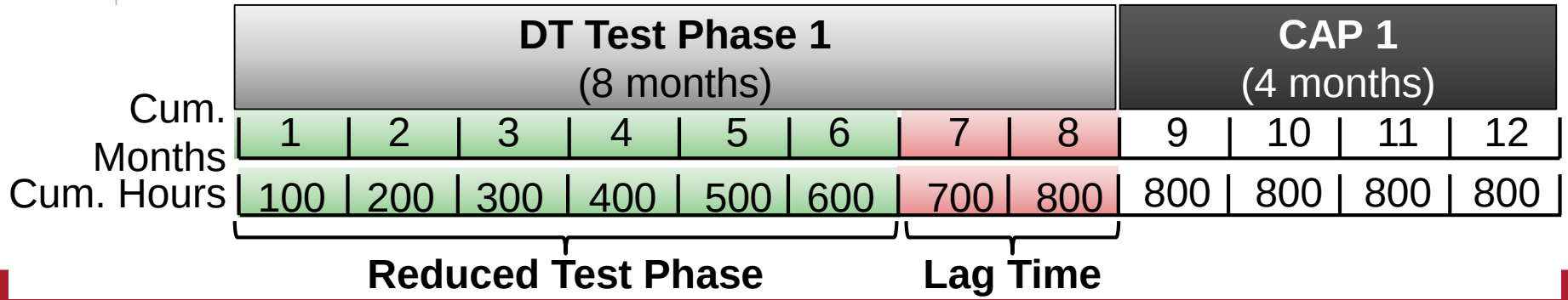
It takes time and money to shrink the "red"

Modeling reliability growth

- How much testing can we afford?
  - Contractor testing
  - Government DT testing
  - IOT&E
- (These need to be in your TEMP)

Corrective Action Periods

- Growth occurs from corrective actions
- CAPs are calendar periods where testing stops and CAs are implemented
- For example, assume the following 12 month test scenario:
  - 6 month delay for incorporating CAs into CAP 1
- Failure modes surfaced in the final 2 months of the test phase cannot be addressed until the following CAP.



Modeling reliability growth

- How many of the problems you find will you plan to fix?
- How often will your fixes work?

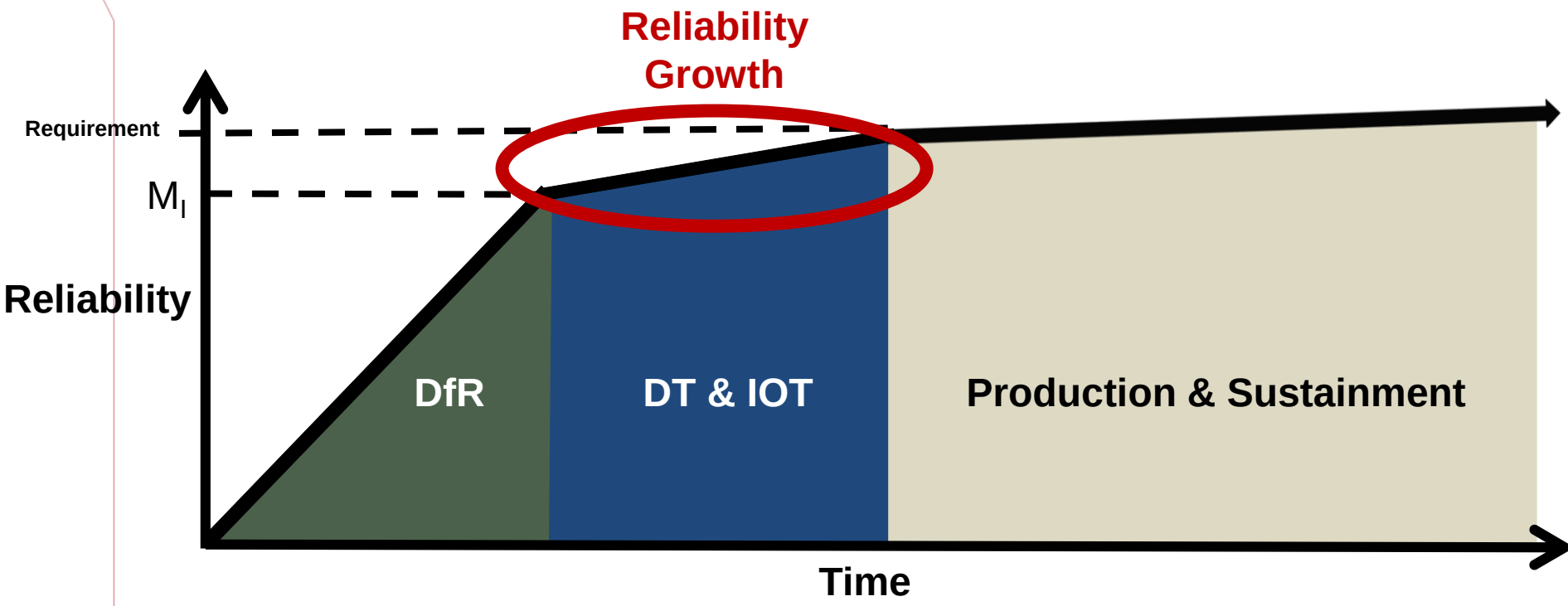
Management Strategy (MS) & Fix Effectiveness Factor (FEF)

- Should be chosen based on what can realistically be achieved (Based on past performance, type of system, etc.)
- MS is the proportion of total failure intensity that is addressed with corrective actions
- FEF is the fraction reduction in the failure rate for a failure mode that has been addressed via corrective action

Initial MTBF

- M_I is the system's initial MTBF when entering DT
  - DfR activities should result in a high M_I
  - M_I should be chosen based on what can realistically be achieved
- M_I can be obtained 2 ways
  1) Estimate M_I based on insights from reliability models, previous test results, M_I for similar systems, etc.
  2) Establish a lower bound for M_I using the planning parameters (MS and μ_d) and the desired M_G/M_{GP} Ratio

Reliability must be designed in



References

- **DoDI 5000.02** Operation of the Defense Acquisition System (January 7, 2015)
- **MIL-HDBK-189C** Reliability Growth Management (14 June 2011)
- **DOD Guide for Achieving Reliability, Availability, and Maintainability** (August 3, 2005)

Courses

- DAWIA Courses
  - ENG 301: Leadership in Engineering Defense Systems
  - TST 303: Advanced Test and Evaluation
  - LOG 103: Reliability, Availability, and Maintainability (RAM)
- Continuous Learning Modules
  - CLE 301: Reliability and Maintainability
  - CLL 030: Reliability Centered Maintenance (RCM)
- Workshops
  - WSE 018: Reliability and Maintainability (R&M) For Engineers
  - WSL 003: Reliability and Maintainability (R&M) For Logisticians

Model Sources

- AMSAA www.amsaa.army.mil
  - Reliability tool “PM2” http://www.amsaa.army.mil/CRG_Tools.html
- ReliaSoft Corporation (www.reliasoft.com)
- Reliability Information Analysis Center (RIAC) (www.theriac.org)
- Relex (www.relex.com)

AMSAA

- The US Army Materiel Systems Analysis Activity, known as AMSAA, is an Army Materiel Command organization that conducts a variety of critical analyses to provide state-of-the-art analytical solutions to senior level Army and Department of Defense officials.
- AMSAA's responsive systems analysis supports the "Equipping" and "Sustaining" of weapons and materiel for our Soldiers in the field as well as our Future Army Force.

Summary

- A well-developed Reliability Growth Curve is evidence of a robust Reliability and Maintainability (R&M) Program
- (Not a substitute for one)