Raytheon

Customer Success Is Our Mission

Latest Reliability Growth Policies, Practices, and Theories for Improved Execution

Lou Gullo
Raytheon Missile Systems
Senior Principal Engineer
March 14, 2012

ENGINEERING, TECHNOLOGY & MISSION ASSURANCE

Purpose

- The purpose of this paper is to discuss a new approach to plan and assess reliability growth that benefits both the government and the defense contractor considering the latest Reliability Growth Policies, such as the Directive-Type Memorandum (DTM) 11-003, Reliability Analysis, Planning, Tracking, and Reporting.
- A new RG programmatic and test concept and theory for improved execution on a new system development based on leveraging existing RG practices, such as the AMSAA PM-2 process, and the Crow/AMSAA model, while ensuring mutual benefits are realized by the government and their industry partners.

DTM Amplifies the Need for Reliability

In accordance with the authority in DoD Directive 5134.01, "Under Secretary of Defense for Acquisition, Technology, and Logistics (USD(AT&L))," December 9, 2005, this DTM, consistent with the direction of the Under Secretary of Defense for Acquisition, Technology, and Logistics to immediately enhance reliability in the acquisition process and with recent Secretary of Defense direction to improve the efficiency of the Defense acquisition system:

- Amplifies procedures in DoD Instruction 5000.02, "Operation of the Defense Acquisition System," December 8, 2008 and is designed to improve reliability analysis, planning, tracking, and reporting.
- Institutionalizes reliability planning methods and reporting requirements timed to key acquisition activities to monitor reliability growth.

DTM 11-003 was signed by
Mr. Frank Kendall (OUSD AT&L) on March 21, 2011.

Copied from DTM 11-003

DTM Procedure

R&M program is an integral part of the systems engineering process

1. Program Managers (PMs) shall formulate a comprehensive reliability and maintainability (R&M) program using an appropriate reliability growth strategy to improve R&M performance until R&M requirements are satisfied. The program will co ring cri testing at the system and subsystem level; and a failure reporting and corrective action system maintained through design, development, production, and sustainment. The R&M program is an integral part of the systems engineering process.
2. The lead DoD Component and the PM, or equivalent, shall prepare a preliminary Reliability, Availability, Maintainability, and Cost Rationale Report in support of the Milestone (MS) A decision. This report provides a quantitative basis for reliability requirements and improves cost estimates and program planning. The report shall be attached to the Systems Engineering Plan (SEP) at MS A and updated in support of MS B and C.
3. The Technology Development Strategy preceding MS A and the Acquisition Strategy preceding MS B and C shall specify how the sustainment characteristics of the materiel solution resulting from the analysis of alternatives and the Capability Development Document sustainment key performance parameter thresholds have been translated into R&M design requirements and contract specifications. The strategies shall also include the tasks and processes to be stated in the request for proposal that the contractor will be required to employ to demonstrate the achievement of reliability design requirements. The Test and Evaluation Strategy and the Test and Evaluation Master Plan (TEMP) shall specify how reliability will be tested and evaluated during the associated acquisition phase.
4. Reliability Growth Curves (RGC) shall reflect the reliability growth strategy and be employed to plan, illustrate, and report reliability growth. A RGC shall be included in the SEP at MS A, and updated in the TEMP beginning at MS B. RGC will be stated in a series of intermediate goals and tracked through fully integrated, system-level test and evaluation events until the reliability threshold is achieved. If a single curve is not adequate to describe overall system reliability, curves will be provided for critical subsystems with rationale for their selection.
5. PMs and operational test agencies shall assess the reliability growth required for the system to achieve its reliability threshold during initial operational test and evaluation (IOT&E) and report the results of that assessment to the Milestone Decision Authority at MS C.
6. Reliability growth shall be monitored and reported throughout the acquisition process. PMs shall report the status of reliability objectives and/or thresholds as part of the formal design review process, during Program Support Reviews, and during systems engineering technical reviews. RGC shall be employed to report reliability growth status at Defense Acquisition Executive System reviews.

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Capability Development Document sustainment key performance parameter thresholds translated to R&M design requirements and contract specifications

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Reliability Growth Curves (RGC) shall be included in the SEP at MS A

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Preliminary Reliability, Availability, Maintainability, and Cost Rationale Report prior to the Milestone A (MS A) decision

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Assess the reliability growth required for the system to achieve its reliability threshold during IOT&E

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Reliability growth shall be monitored and reported throughout the acquisition process

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Reliability Growth Policies and Execution
RAMS 2012 Panel 04C

Raytheon

- Theme: High system reliability is essential in achieving continuous mission success and affordable ownership costs. As a consequence, the DoD and the Military Services have established reliability growth policies with the intent of improving the reliability of acquisition programs.
- Panelists:
  - Dr. James J. Streilein, Deputy Director, Net-Centric, Space and Missile Defense Systems, Director, Operational Test and Evaluation, OSD
  - Dr. Laura Freeman, Institute for Defense Analyses (IDA)
  - Mr. James Woodford, Director R&M Engineering, Department of the Navy
  - Mr. Bruce Baber, Reliability Lead, USAF AAC Munitions Directorate, Miniature Munitions Div
  - Mrs. Jane Krolewski, Technical Director, Reliability and Maintainability Engineering Directorate, Army Evaluation Center, U.S.Army Test and Evaluation Command (ATEC)
  - Mr. Martin Wayne, Team Leader, Center for Reliability Growth, U.S. Army Materiel Systems Analysis Activity (AMSAA)
  - Dr. Dmitry Tananko, Reliability Manager, General Dynamics Land Systems (GDLS)
  - Dr. Larry Crow, President, Crow Reliability Resources, Inc.
- Moderator: Ken Dalton, formerly Division Chief, Ground Combat and Fire Support Division, Reliability and Maintainability Directorate, Army Evaluation Center, U.S.Army Test and Evaluation Command (ATEC)

OSD Perspective
RAMS 2012 RG Panel

Raytheon

DoD Steps Taken to Improve Reliability

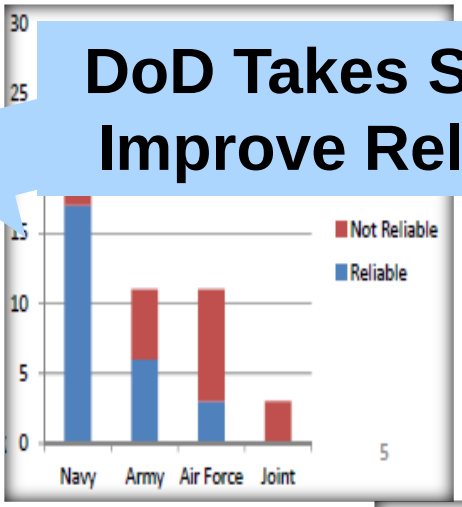
2007				2008				2009				2010				CY 2011			
1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th

McQueary DOT&E Priorities; CJCS 3170.01C JCIDS; Army Acquisition Policy (Bolton memo); Reliability Improvement Working Group; USD(AT&L) RAM (Young) Memo (in response to DSB); DODI 5000.02; WSARA; Gilmore DOT&E Initiatives; DOT&E State of Reliability Memo; USD (AT&L) DTM 11-003

- Reliability (MTBF) is a key factor in O&S costs of systems
  - Additional burden to user in unscheduled maintenance and down time
- DOT&E top priority since 2006 has been to improve suitability of fielded systems, in addition:
  - Army Acquisition Policy
  - Joint Staff Directive
  - Defense Science Board Study
  - Congressional Language
  - USD (AT&L) policy updates

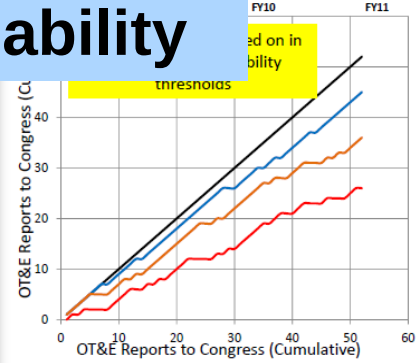
DoD needs systems that are effective when needed, not just effective when available

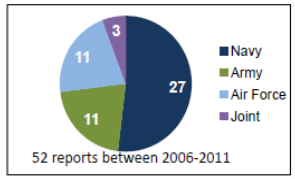
1



DoD Takes Steps to Improve Reliability

Trends in Reliability





IDEAL
EFFECTIVE
SUITABLE
RELIABLE

Overall since 1985:
30% of 170 Systems Reported Not Suitable

2

Reliability Program Standard

- In 1998, DoD canceled Mil-Std-785B: *Reliability Program for Systems and Equipment Development and Production*
  - Originally written in 1969, last updated 1980
  - Industry continues to follow -*785* tasks (reactive vice proactive)
    - Approx 30% reliability from design
    - Approx 70% reliability from growth tests (after design is completed)
- In 2008, OSD/DDR&E(SE) adopted the ANSI/GEIA-STD-0009, which promotes four objectives:
  - Understand customer/user requirements and constraints
  - Design for Reliability (DfR) and re-design for reliability
  - Produce reliable systems
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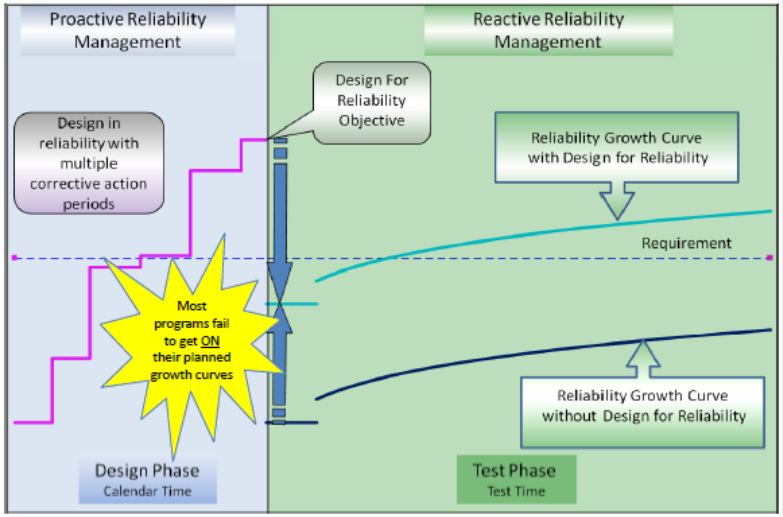
Reliability Management



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OSD Perspective
RAMS 2012 RG Panel

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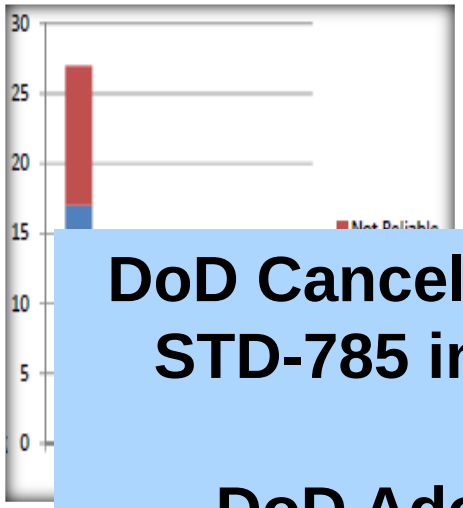
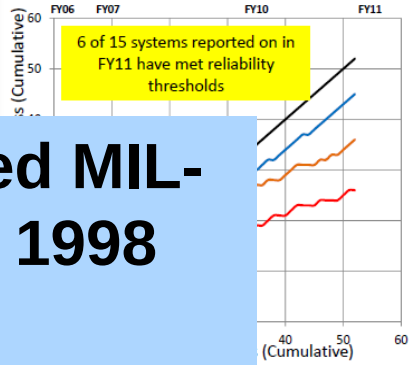
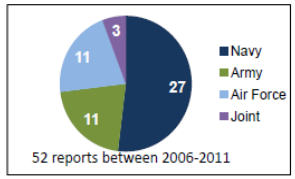
DoD needs systems that are effective when needed, not just effective when available



Trends in Reliability



6 of 15 systems reported on in FY11 have met reliability thresholds



52 reports between 2006-2011

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DoD Canceled MIL-STD-785 in 1998

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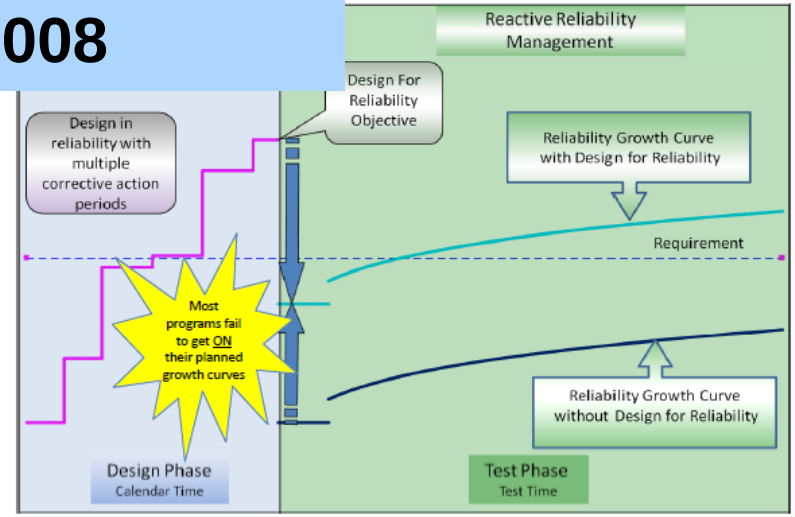

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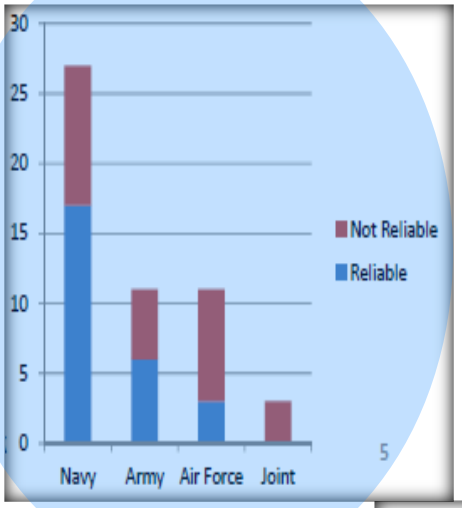
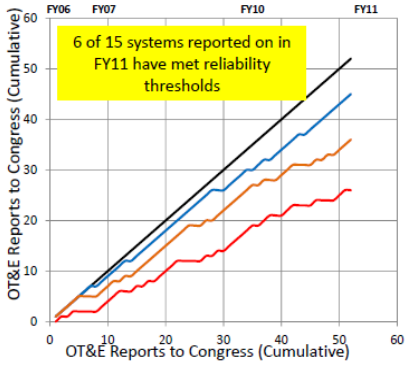
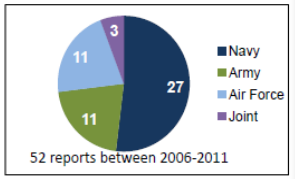


Trends in Reliability





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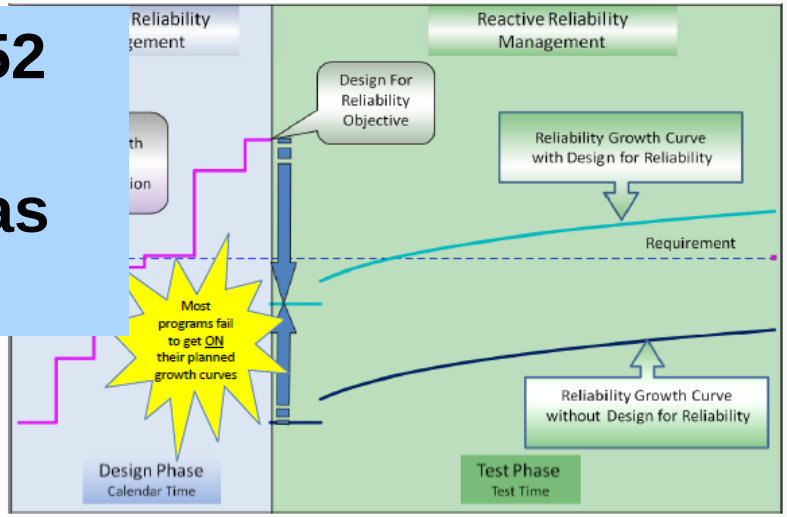
Distribution of 52 Programs
50% Assessed as Not Reliable

Reliability Management



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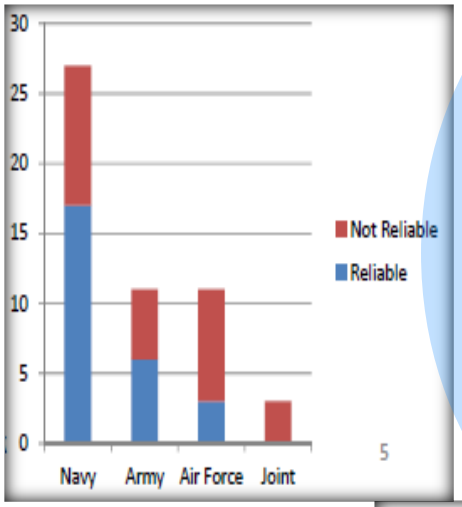

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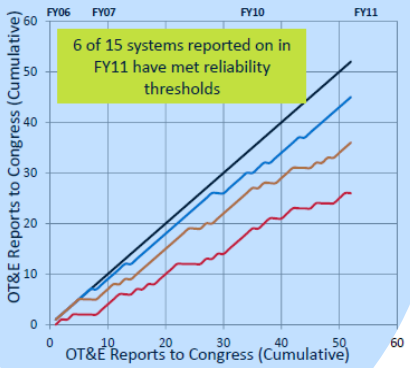

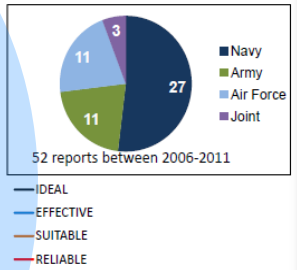

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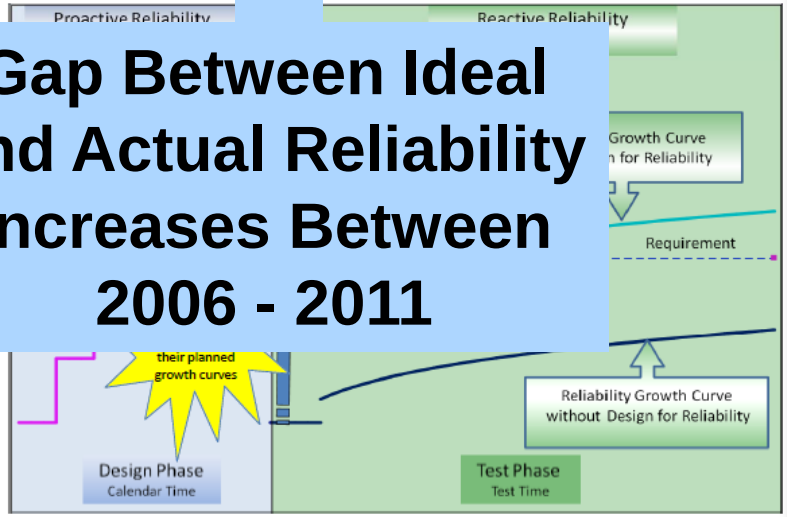
  - Industry continues to follow -*785* tasks (reactive vice proactive)
    - Approx 30% reliability from design
    - Approx 70% reliability from growth tests (after design is completed)
- In 2008, OSD/DDR&E(SE) adopted the ANSI/GEIA-STD-0009, which promotes four objectives:
  - Understand customer/user requirements and constraints
  - Design for Reliability (DfR) and re-design for reliability
  - Produce reliable systems
  - Monitor and assess user's experienced reliability

Reliability Management



Gap Between Ideal and Actual Reliability Increases Between 2006 - 2011

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OSD Perspective
RAMS 2012 RG Panel

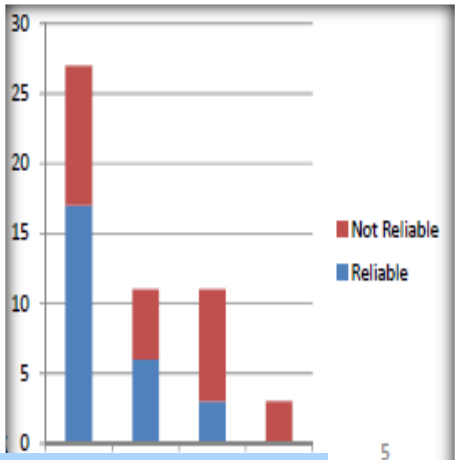
Raytheon

DoD Steps Taken to Improve Reliability

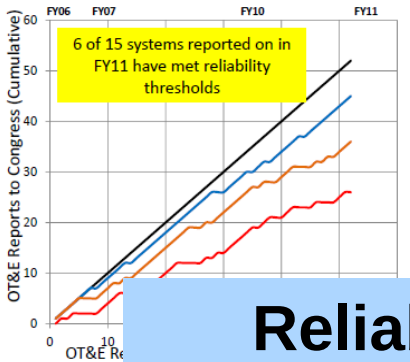
2007				2008				2009				2010				CY 2011			
1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th

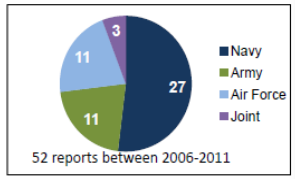
- McQueary DOT&E Priorities
- CJCS 3170.01C JCIDS
- Army Acquisition Policy (Bolton memo)
- Reliability Improvement Working Group
- USD(AT&L) RAM (Young) Memo (in response to DSB)
- DODI 5000.02
- WSARA
- Gilmore DOT&E Initiatives
- DOT&E State of Reliability Memo
- USD (AT&L) DTM 11-003

- Reliability (MTBF) is a key factor in O&S costs of systems
  - Additional burden to user in unscheduled maintenance and down time
- DOT&E top priority since 2006 has been to improve suitability of fielded systems, in addition:
  - Army Acquisition Policy
  - Joint Staff Directive
  - Defense Science Board Study
  - Congressional Language
  - USD (AT&L) policy updates



Trends in Reliability





IDEAL
EFFECTIVE
SUITABLE
RELIABLE

Overall since 1985:

Without DfR, most programs will fail to get on the planned growth curve

Reliability Growth Curve With DfR

Systems and Equipment Development and Production

- Originally written in 1969, last updated 1980
- Industry continues to follow -*785* tasks (reactive vice proactive)
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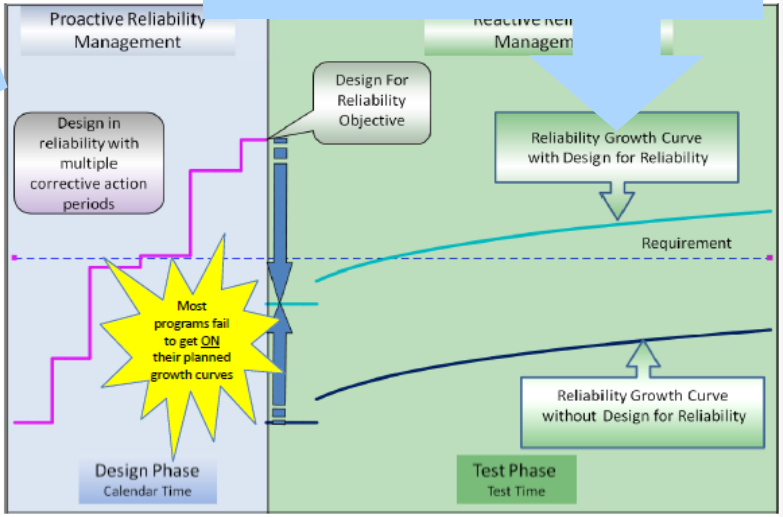

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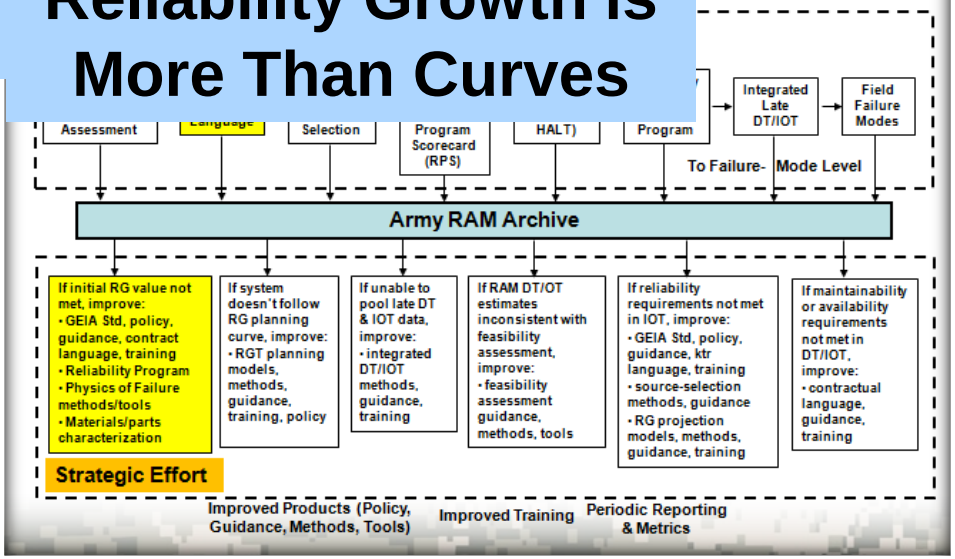
Reliability Growth is More Than Curves

RELIABILITY GROWTH IS MORE THAN CURVES

GROWTH is the result of:

- Properly stated REQUIREMENTS
  - Stated in design appropriate terms (translated) and verified
  - User (war fighter) requirements are nearly always stated in USER terms.
- Properly selected and applied R&M ENGINEERING ACTIVITIES
  - R&M allocations, block diagrams, and predictions
  - Documented failure definitions and scoring criteria (FD/SC)
  - Failure Mode, Effects, and Criticality Analysis (FMECA)
  - Built in test (BIT) demonstrations (aid fault detection and failure analysis)
  - Reliability Growth Planning and Tracking at the system and subsystem level
    - Combined with block diagrams when done separately
    - The curve is a management tool that can focus their attention (Time and Resources)
  - Failure Reporting, Analysis and Corrective Action System (FRACAS)
    - Analysis all the way to the ROOT CAUSE;
    - A review board that makes the right corrective action recommendations.
    - Management that makes the right corrective action decisions. (Time and Resources)
- Partnership with TEST & EVALUATION
  - With clear lines of authority and
  - Clearly understood (and practiced) divisions of labor.

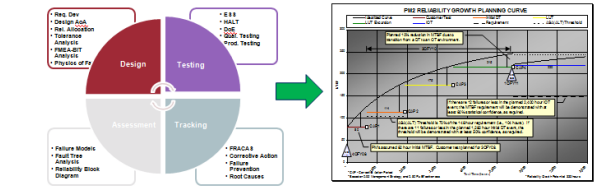
Army Center for Reliability Growth



Key Program Evolution

U.S. AIR FORCE

- Clearly Identifying and Characterizing the Transition from Design for Reliability (DFR) to System Level Reliability Growth Testing (RGT) is a Critical Point in the Reliability Growth Program (RGP) Towards a Mature System



Evolution from Design Stage to a Mature System

Integrity - Service - Excellence

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IDA Reliability Growth: Content in TEMPs

New Programs

- **MS B TEMP Content**
  - Basic description of the overall reliability growth program
    - Should be consistent with the SEP and/or Reliability Growth Plan
    - Definition of program reliability performance metrics
    - Summary of contractual reliability requirements and reliability improvement responsibilities and processes
  - Identify contractor and govt T&E evaluation targets for each test phase
    - Primary contractual reliability growth curve (MTBF, MBTCF, etc.)
    - System-level operational reliability growth curve (MTBSA, MTBOMF, etc.)
  - Reliability data collection, scoring, and evaluation methodology
  - Reliability maturity entrance criteria--major program milestones and OT events
  - RAM evaluation hours to be collected for each phase of test with rationale

Military Services and IDA Perspective
RAMS 2012 RG Panel

Raytheon

Reliability Growth involves Program-Specific Efforts and Strategic Efforts

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GROWTH is the result of:

- Prope
  - S
  - U
- Prope
  - F
  - D
  - F
  - E
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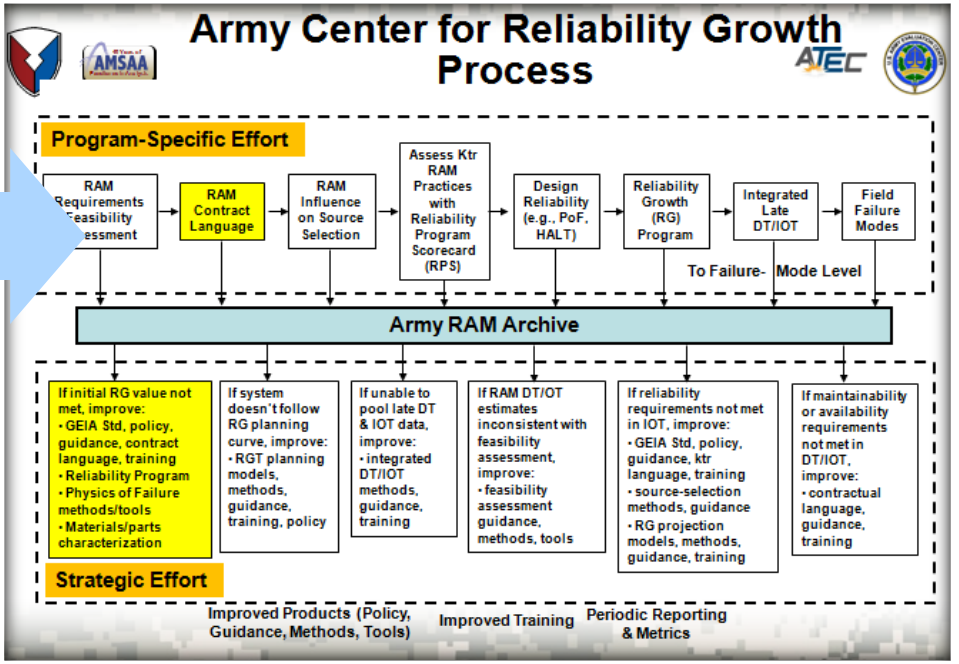
Army Center for Reliability Growth Process



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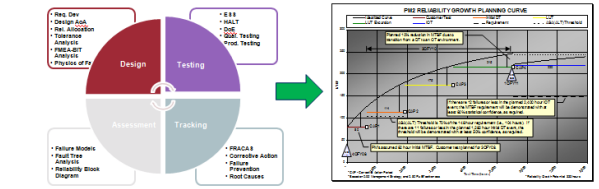

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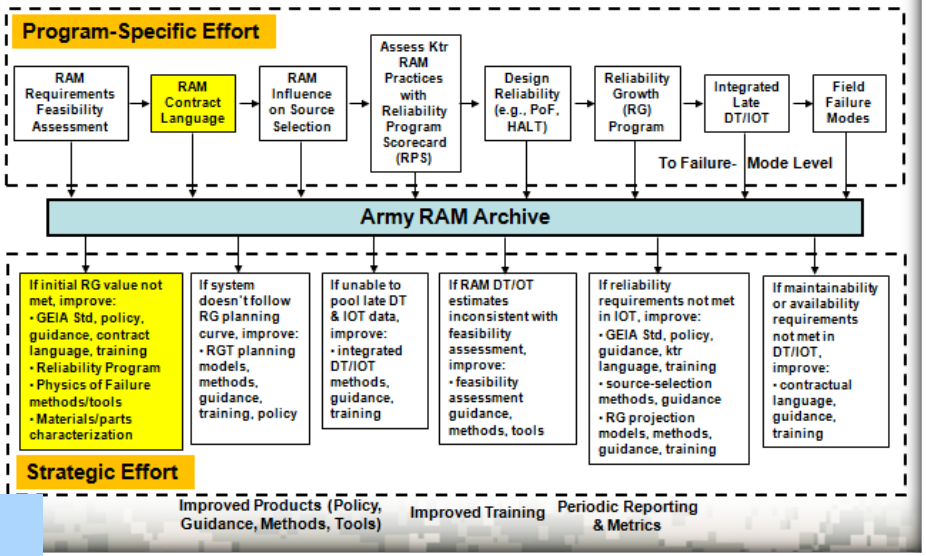

Reliability Growth Content in TEMPs for MS B Decision

U.S. AIR FORCE

- Clearly Identifying and
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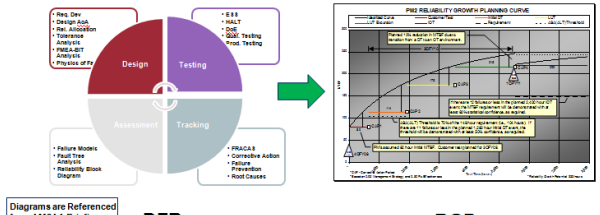

Diagrams are Referenced from AMSAA Briefings

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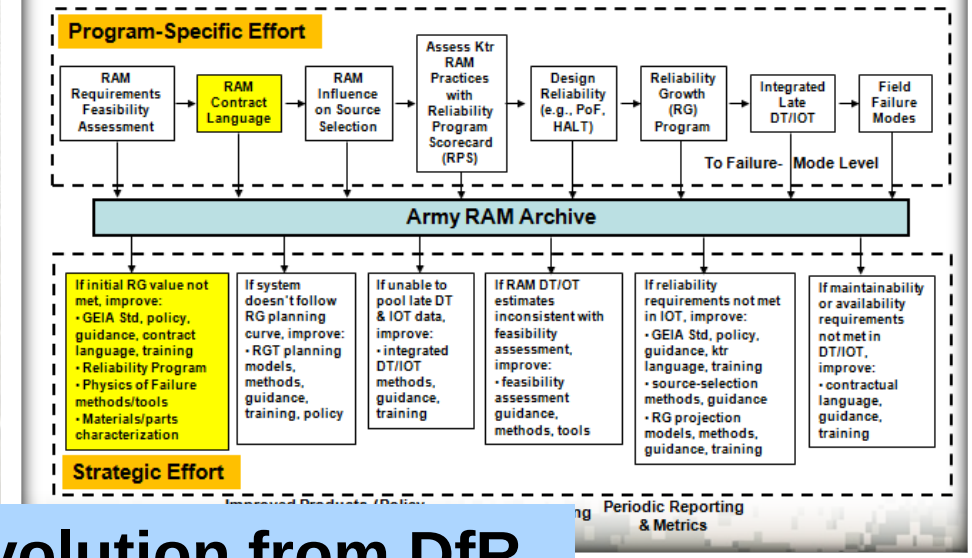

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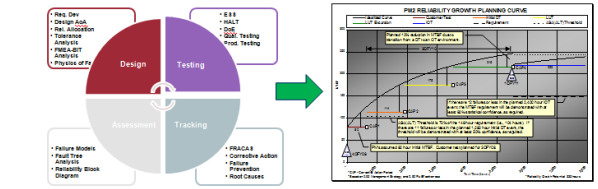

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DFR RGP

Evolution from Design Stage to a Mature System

Integrity - Service - Excellence

Evolution from DfR Efforts to Reliability Growth on a Program

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th: Content in TEMPs

grams

- bility growth program
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ANSI/GEIA-STD-0009-2008 Objectives

- ANSI/GEIA-STD-0009-2008 and the HB0009 Reliability Handbook (draft) directly support the DTM 11-003 and reliability growth policies.
  - The ANSI/GEIA-STD-0009-2008 standard was published in November 2008.
  - The draft HB0009 handbook is a companion guide to ANSI/GEIA-STD-0009-2008.
  - The draft HB0009 handbook began the government/industry peer review period in February 2012.

ANSI/GEIA-STD-0009-2008 is intended to align best practices of reliability management, design and testing with reliability methods that provide the most value and the least risk in terms of achieving reliable products.

Excerpt fromTechAmerica GEIA-0009 Slides

Example Program Using RG Plan

- Recent Raytheon Missile System Program employs a Reliability Growth (RG) Program in place today
- The Reliability Growth Plan is:
  - Part of the Reliability Program Plan (RPP)
  - Appendix A of the System Engineering Management Plan (SEMP).
  - A roadmap of the reliability tasks planned to ensure a reliable product is delivered to the U.S. Air Force (USAF) and the United States Navy (USN).

RPP is based on the ANSI/GEIA-STD-0009-2008

Example RPP Process Mapped to ANSI/GEIA-0009-2008

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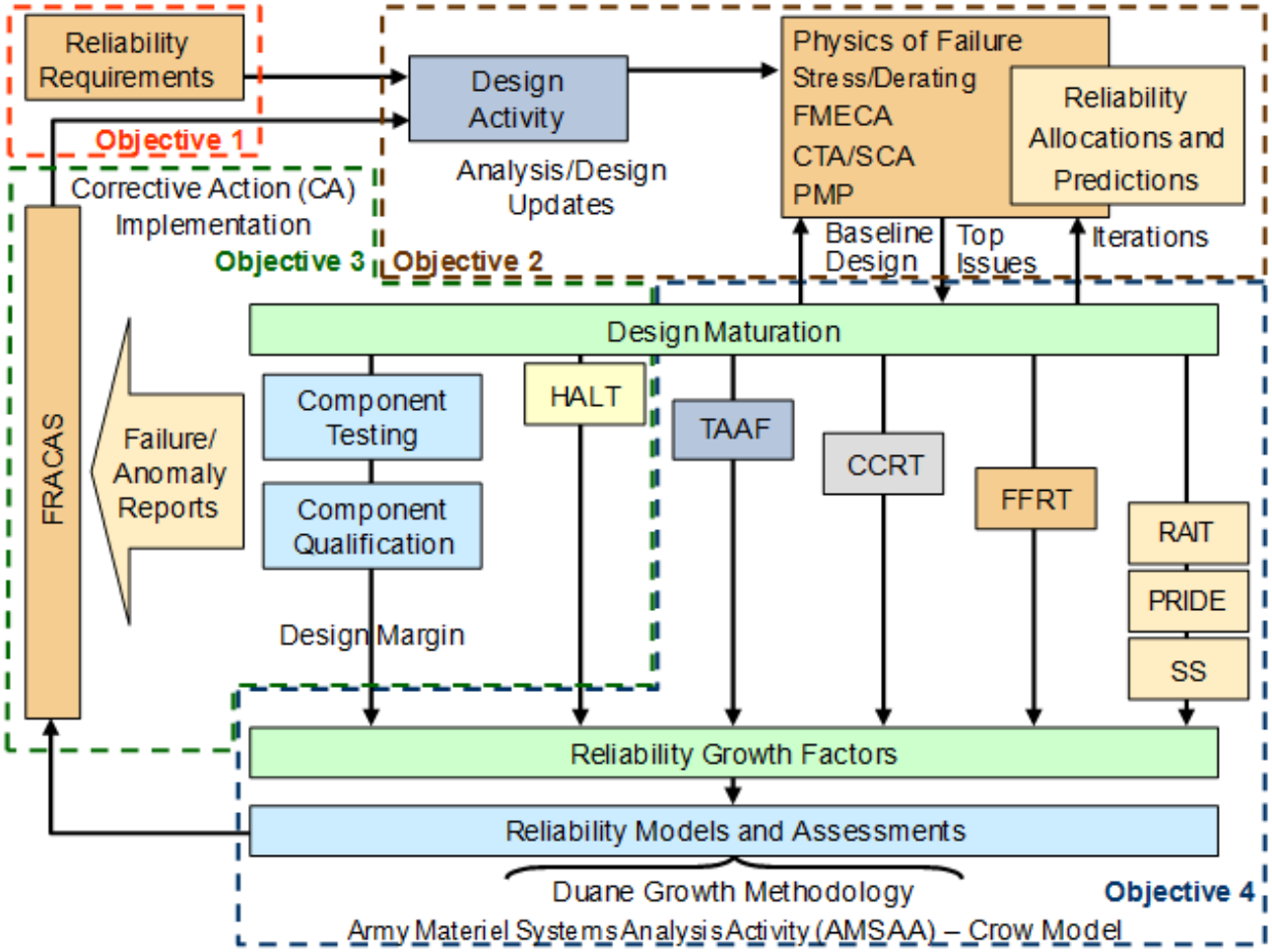


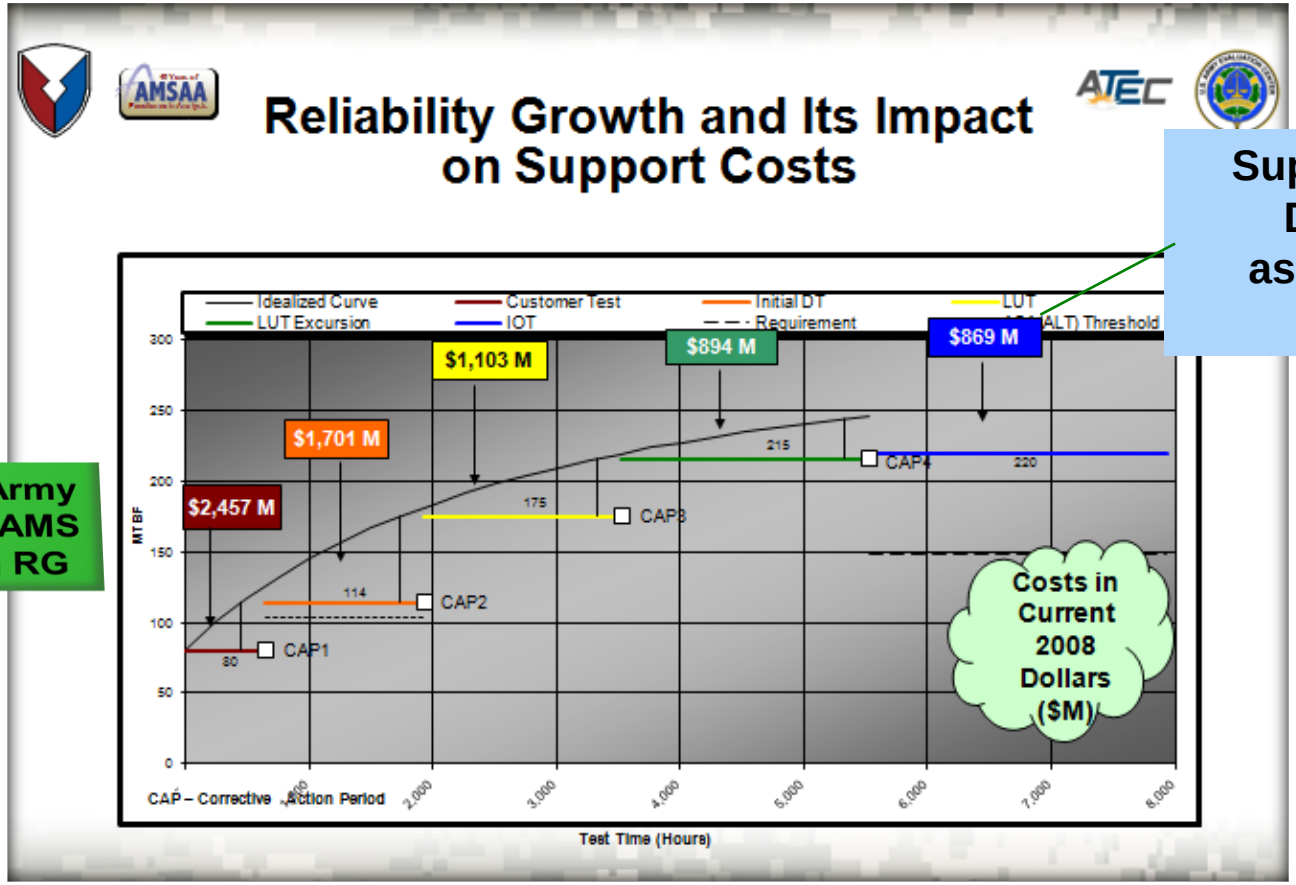
Strategy is to design the system to comply with all the reliability, availability, and maintainability requirements with adequate margins throughout the service use profile

Theory to Approach Design Reliability

- How do we know what the design reliability is expected to be? …Set goals through models and allocations
- How do we know what the design is capable of? ...assess the design, determine design margin, uncover gaps, and forecast growth performance using predictions
- How do we know we have accomplished our reliability goals? ...verify the growth model and achieve team acceptance
- How do we accomplish our goals if we do not verify our model meets the reliability requirements? …adjust the model and/or implement design improvements

Models and Allocations

- Allocate Reliability Metrics down to each LRU, subassembly, CCA, and components…Incorporate into each specification
- Reliability Models based on the allocations from top down
- Reliability Growth Model based on the phases of development

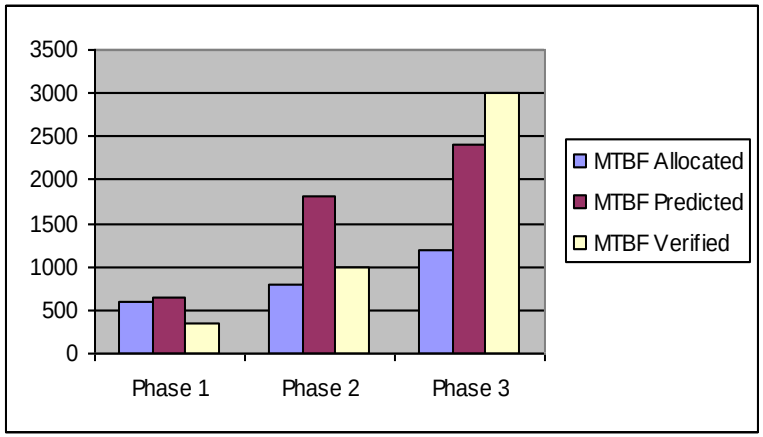


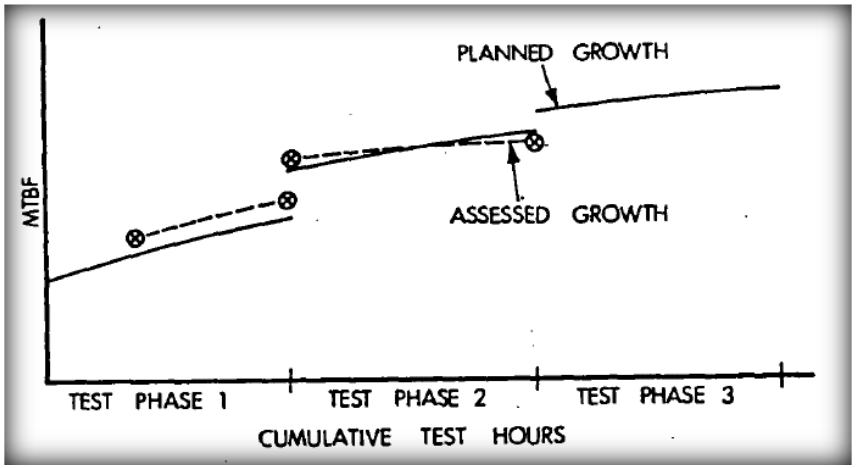
Support Costs Decrease as Reliability Grows

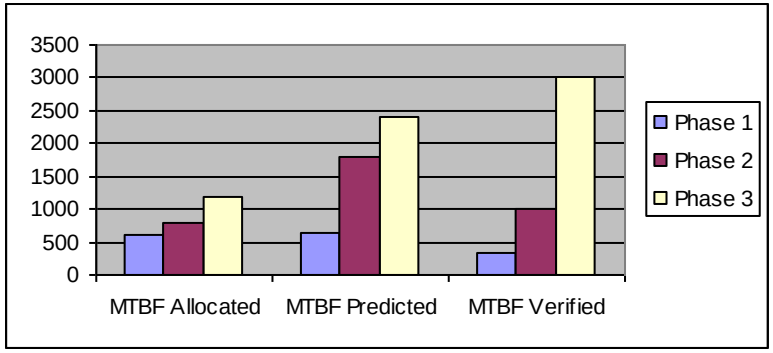
Excerpt from Army Slides at the RAMS 2012 Panel on RG

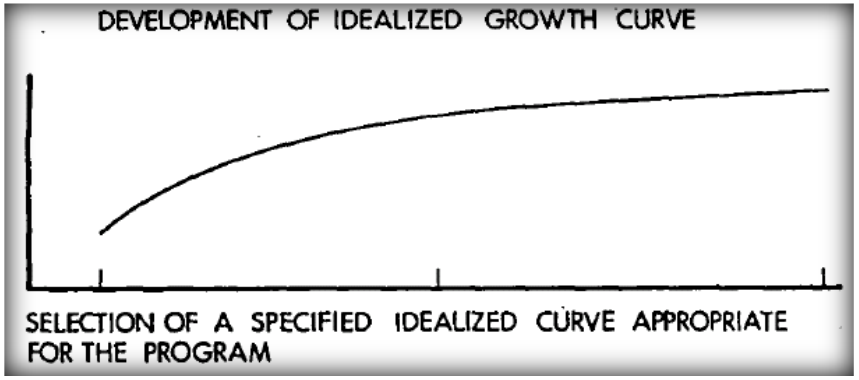
Reliability Growth Model Example

- MIL-HDBK-189
- IEEE papers
- Duane Growth >> Crow AMSAA Method









Notional Concept to Incentivize RG

- A concept and theory for improved methods for RG plans, analysis and test execution include a correlation factor between reliability expected and actual.
- The correlation factor equates empirical achievements of reliability growth analysis and test objectives as plotted on the reliability growth curves with monetary incentives or penalties to the industry partner.
- Correlation factor is a number between 0.1 and 10.0
  - The correlation factor equates to a multiplier to a nominal award target
  - Factor = 1 if the contractor demonstrates reliability that is equal to the specified reliability
  - Factor > 1 correlates to award paid to contractor above the target based on the reliability demonstrated above the reliability spec or RG curve
  - Factor < 1 is the amount paid by contractor to the government for reliability demonstrated below the reliability spec.

How Do We Go Forward?

- Consider Comprehensive Reliability Growth Program and Plan/Schedule with plans to achieve incentives in new contracts
- Recommend a Reliability Growth team composed of Customer/Contractor team members
  - Hold periodic meetings with SMEs after contract award
  - Verify test beds used to verify the reliability growth
- Solicit recommendations for quick fix solutions, and long term solutions
  - Catch the low hanging fruit first (high product acceptance rate) tied to achieving max incentive award
  - Incorporate reliability design improvements into the design evolution (cover incorporation of fault fixes over time)

Conclusions and recommendations

- Uncover Gaps in the Design
- Use new ways to assess the trade space of reliability versus affordability on military programs so that the government and defense contractor achieve a WIN-WIN strategy with continuous cost of ownership reductions over the system product life cycle.
- Conduct a thorough requirements analysis and develop a cost savings contractor incentive award
- Contractor makes Investments in the Design for Reliability and design process
  - Eliminate failure modes early in the design process
  - Understand the design margin between the design operating limits and the specifications
  - Grow confidence and the probability of success during the refurbishment cycle and design upgrade cycle
  - Reliability Model verification and validation with empirical evidence

QUESTIONS

References

- This paper leverages material presented at the National Academy of Sciences (NAS) Workshop on Reliability Growth in September 2011, and material presented at the Reliability and Maintainability Symposium (RAMS) in January 2012 at the Reliability Growth (RG) Panel.
- ANSI/GEIA-STD-0009-2008 (*Reliability Program Standard for Systems Design, Development, and Manufacturing)*
- HB0009 Reliability Handbook (draft), a companion guide to the ANSI/GEIA-STD-0009-2008

Acronyms

- DTM - Directive-Type Memorandum
- HB - Handbook
- NAS - National Academy of Sciences
- RAMS - Reliability and Maintainability Symposium
- RG – Reliability Growth
- RPP - Reliability Program Plan
- SEMP - System Engineering Management Plan
- SEP - System Engineering Plan
- USD (AT&L) - Under Secretary of Defense for Acquisition, Technology, and Logistics

Biography

– **Lou Gullo,** Raytheon Missile Systems, Engineering Product Support Directorate (EPSD), Reliability Engineering Department located in Tucson, AZ. Leader of several Enterprise-wide Engineering Council-sponsored special projects including IEEE reliability standards development, software reliability methods and the automation of electrical stress analysis methods. 30 years experience in military, space and commercial programs. Retired US Army Lieutenant Colonel. Senior Member of the IEEE. IEEE Reliability Society Standards Committee Chair. Member of the Reliability and Maintainability Symposium (RAMS) Management Committee.

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