An Approach to Lean Reliability Test and Evaluation Without Increasing Risk

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U.S. Army Test and Evaluation Command

Background

- Pre Milestone B, ACAT II Program with DOTE Oversight
- Four unique variants consisting of available Commercial Off-the Shelf (COTS), Government Off-the Shelf (GOTS), and Non-Developmental Items (NDI).
- Supports a variety of missions for the different Services
- Sustainment KPP plus reliability requirements for systems and sub-systems

“Traditional” T&E Strategy

- Test assumes reliability will NOT meet requirement
  - H_0: System reliability $\leq$ Requirement
  - H_1: System reliability is > Requirement
- Test design based on 20% Consumer Risk and 20% Producer Risk assuming a Discrimination Ratio of 2

Result is a test that is 8 times the length of the requirement.

What is the trade-off between risk and test size if we choose a different null hypothesis or consumer risk?

Planned Tests

- Component Level Test
  - Purpose
    - Verify assumed component reliabilities
      - Predict system/subsystem reliability in the absence of operational or integration related failure modes.
    - Determine sparing strategy since little opportunity to improve reliability through component-specific corrective actions
      - Goal is a system whose "true" reliability is twice the requirement.
- System Level Tests
  - Purpose:
    - Demonstrate the Requirements
    - Identify/Eliminate operational or integration related failure modes

Component Level Test

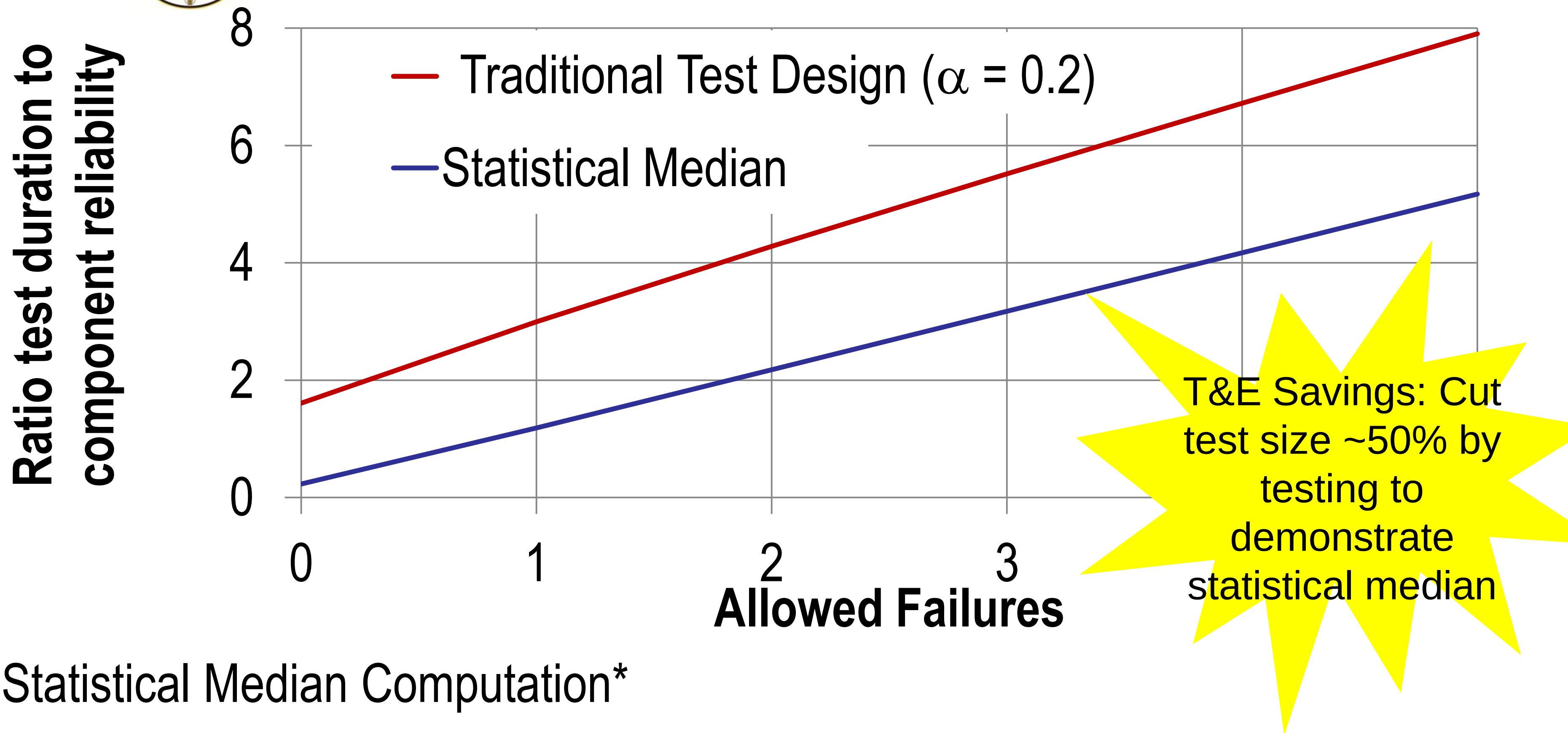
- Traditional consumer risk (α) accepted for a reliability requirement is 0.2
  - System/subsystems have a reliability requirement
  - No reliability requirement for component.
- What α should we accept in component level test?
  - Component α = 0.2 corresponds to a much lower system α
  - For n components $\alpha = 0.2^n$

Accept higher α in component reliability.

We accepted α = 0.5 for component tests

Design test to demonstrate statistical median

Component Level Test



Statistical Median Computation*

- α = 0.5
- Degrees of freedom = 2 * (Number_of_Failures) + 1

* Martz and Waller, Bayesian Reliability Analysis, pg 286-7

Component Level Test

- Limited test data indicates that component reliabilities vary widely
- Planned usage of components varies widely.
- **System/Subsystem reliability dominated by high-use, low reliability components.**

How do we determine the number of allowed failures in a component test that takes into account the impact on predicted system reliability?

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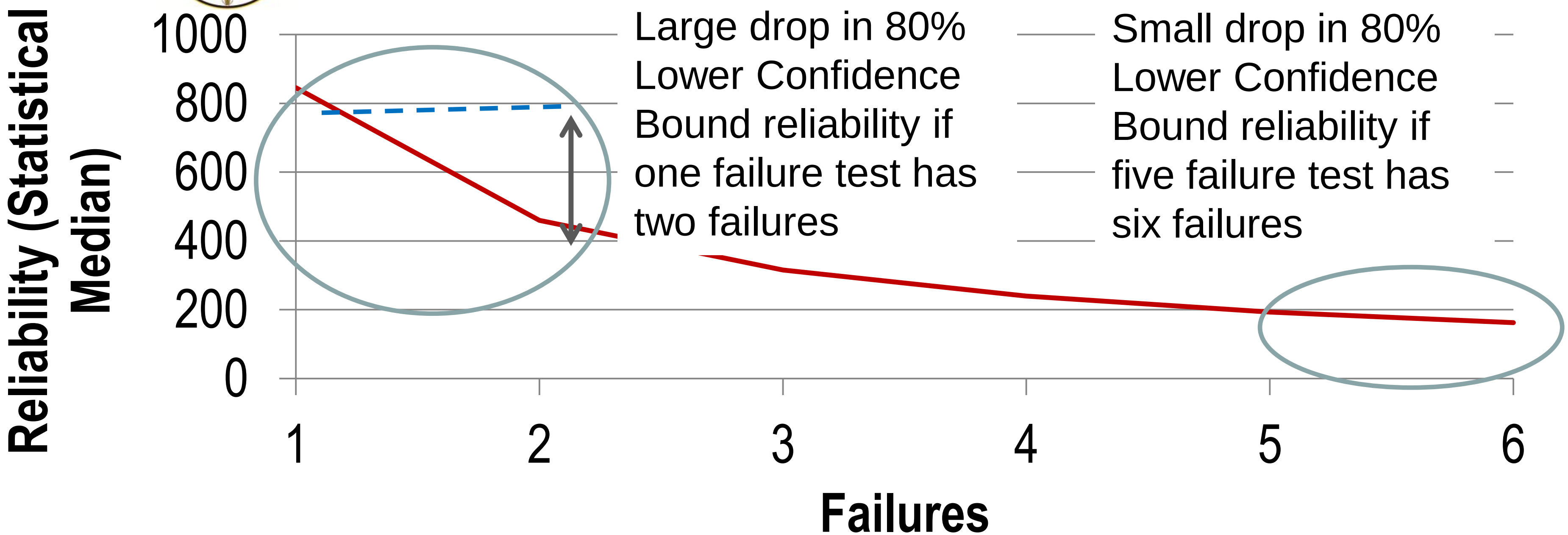
Component Level Test



- Compute the difference in system reliability if component test has one more failure than planned for a one failure test.
    - Components with little system reliability difference have a 1 failure test.
    - Low Impact Components
- Repeat process for 3 failure (moderate impact) and 5 failure test (high impact)

Component Level Savings

- Test design for components identified as High Impact
  - Test design allowed for five failures
  - Savings = 35% of "Traditional" test
- Test design for components identified as Moderate Impact
  - Test design allowed for three failures
  - Savings = 60% of "Traditional" test
- Test design for components identified as Low Impact
  - Test design allowed for one failure
  - Savings = 85% of "Traditional" test

Impact is the amount of change in system reliability associated with a small change in component reliability

T&E Strategy System Level Tests

- Developmental Test (DT)
  - Purpose: Primary demonstration meets reliability requirements (null hypothesis is that it DOES NOT meet requirement)
  - "Traditional" test design (H_0: Reliability $\leq$ Req't)
- Operational Test (OT)
  - Purpose: Confirm the level of operational reliability degradation is acceptable.
  - Leaned test design (H_0: Reliability $\geq$ Req't)

DT hours cheaper than OT hours!

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Design impact of Different Null (H_0: Reliability $\geq$ Req't)

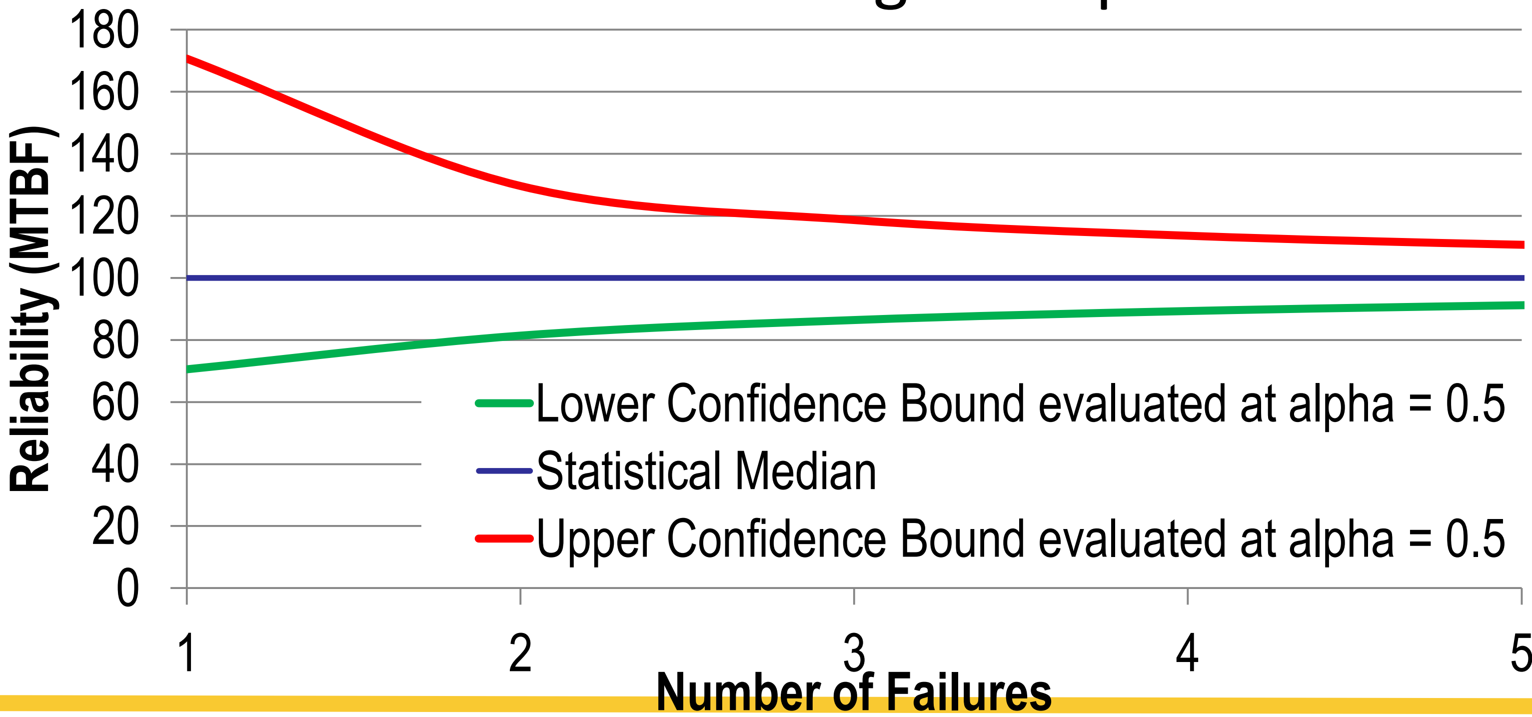
	Traditional Design	Leaned Design
Hypothesis	H_0: Reliability $\leq$ Req't H_1: Reliability > Req't	H_0: Reliability $\geq$ Req't H_1: Reliability < Req't
Accept System	LCB > Req't (reject H_0)	UCB $\geq$ Req't (fail to reject H_0)
2-failure test duration	4.3 x Req't	3 x Req't

LCB is Lower Confidence Bound; UCB is Upper Confidence Bound

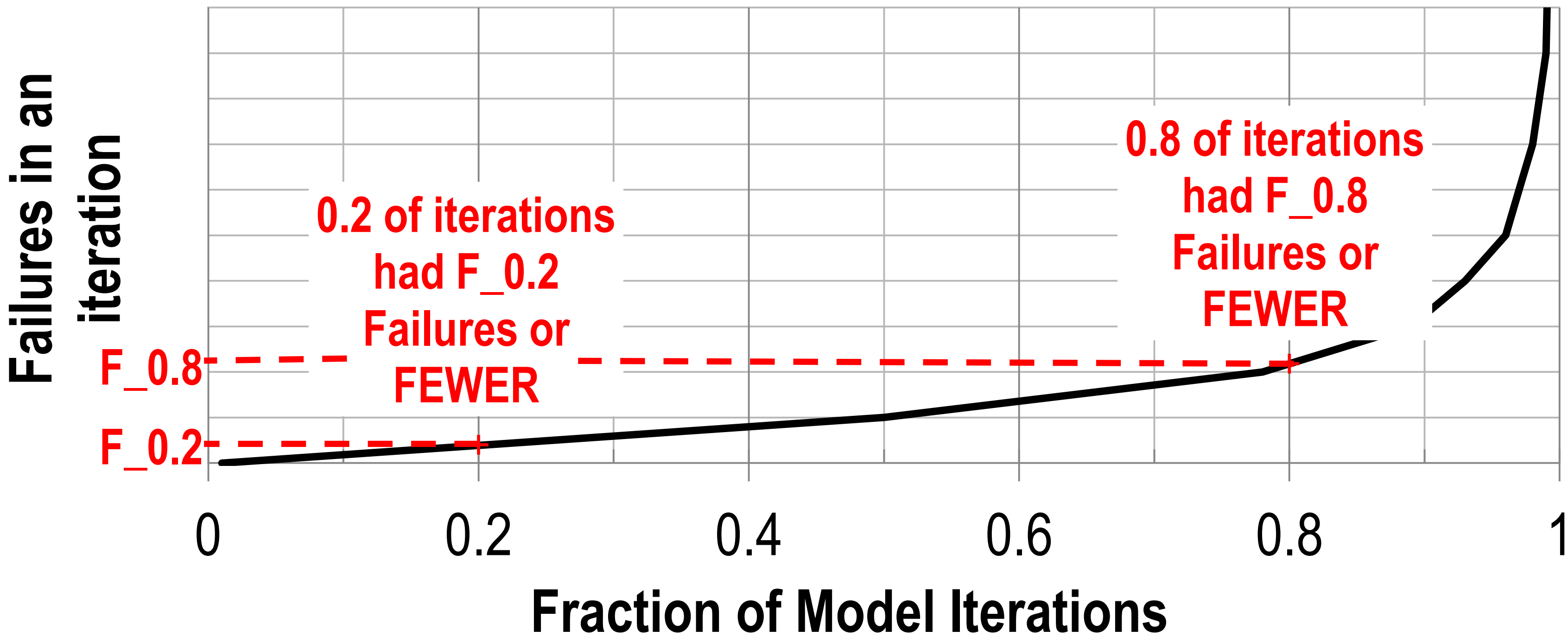
Applying Leaned Design for OT requires that reliability exiting DT is at least twice requirement (Best Reliability Growth Practice)

T&E Strategy

- Use Operational Availability Model (Monte Carlo) to evaluate confidence bounds and test power.
  - "True" Reliability from Reliability Block Diagrams
  - Eliminates bias from using Chi Squared-Distribution



Example of using Availability Model for Test Design



H_0: System reliability $\geq$ Reliability Block Diagram prediction (R_{RBD})

H_1: System reliability is $< R_{RBD}$

Reject H_0 at 0.8 confidence if failures > F_0.8

Test has a power of 0.8 for $R = R_{RBD}$* (F_0.2/F_0.8)

Conclusions

- Reducing System of System T&E cost and schedule means accepting not all knowledge has equal value
  - Match subsystem/component test size to its impact on system reliability requirement.
- Modeling and Simulation can optimize test risk/cost.
  - Eliminates Chi Squared-Distribution bias
- Null Hypothesis selection can reduce T&E cost by leveraging DT to reduce OT.
  - DT reliability must be greater than requirement.

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