D-4387 non-std.

Design for Reliability using Robust Parameter Design

Laura J. Freeman

Joint Statistical Meetings 2011

IDA

Approved for public release; distribution unlimited.

IDA

Overview

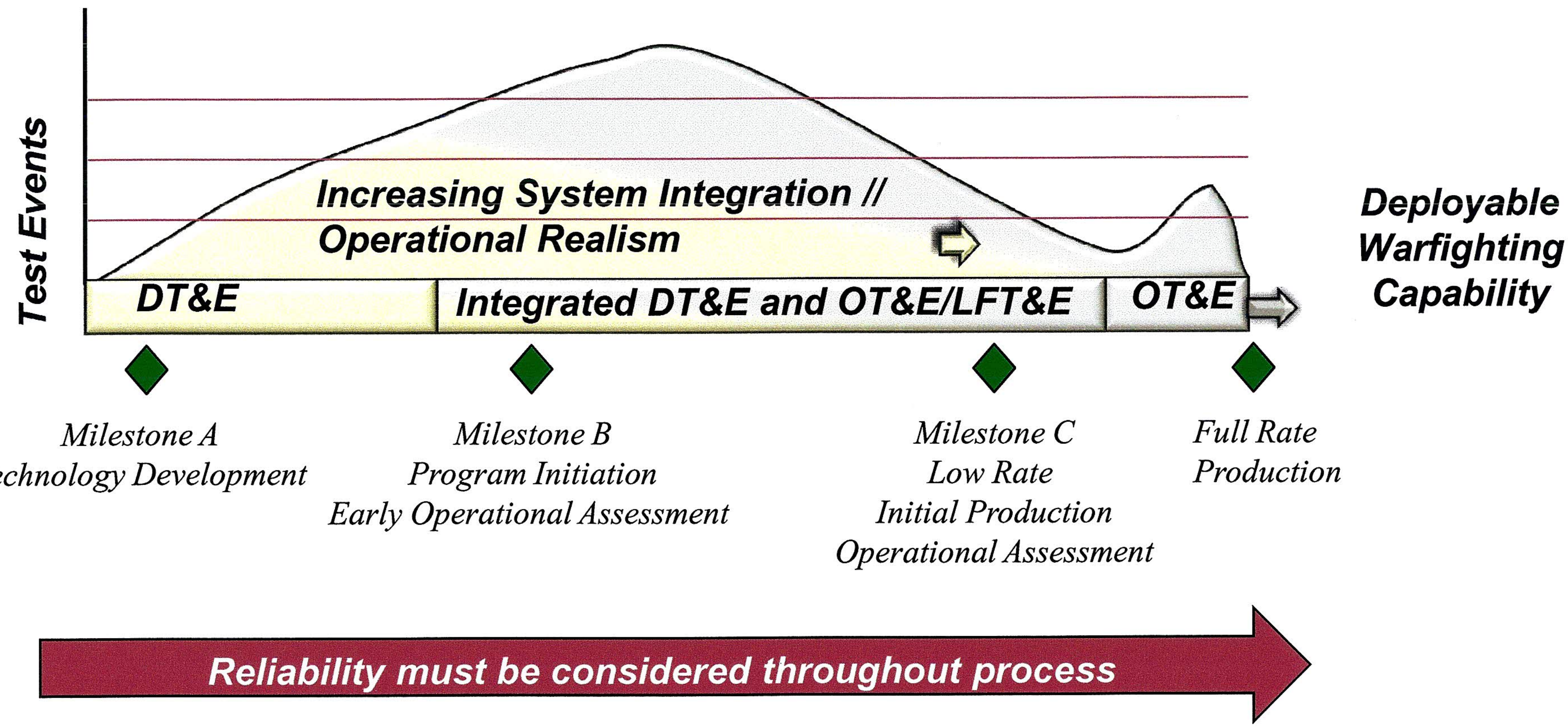
- **Motivation**
  - Department of Defense Acquisition Process
- **DOD Test and Evaluation Reliability Initiatives**
- **Overview of ANSI-0009**
  - Design for Reliability
- **Robust Parameter Design**
- **Case Study**

Approved for public release; distribution unlimited.

IDA

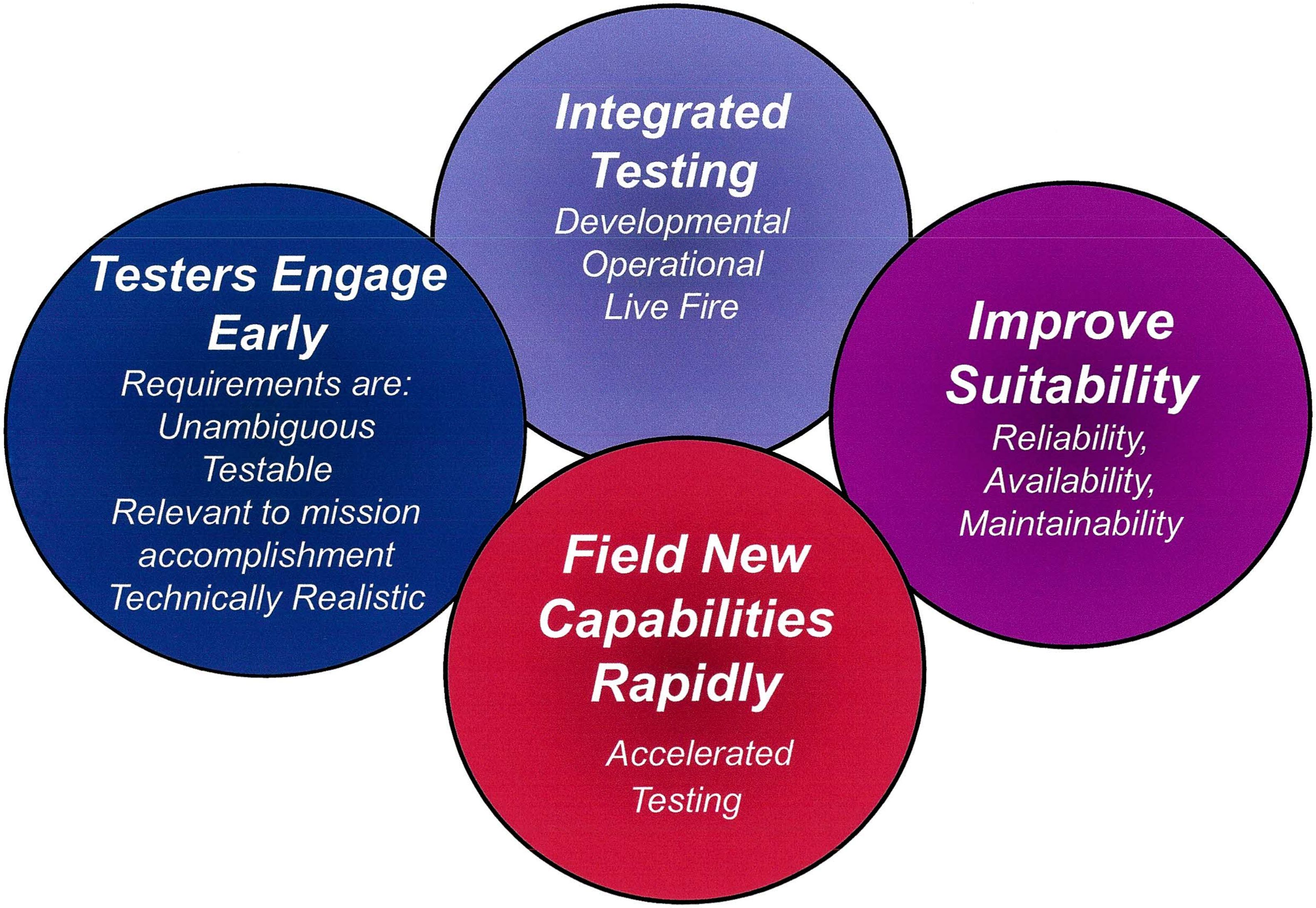
The DoD Acquisition Process

Notional Test Program



- **Operational Testing supports full rate production decision**
- **Report on programs, before full-rate production decision:**
  - Test adequacy, Operational Effectiveness, Suitability, Survivability and Lethality

IDA Director, Operational Test & Evaluation Initiatives

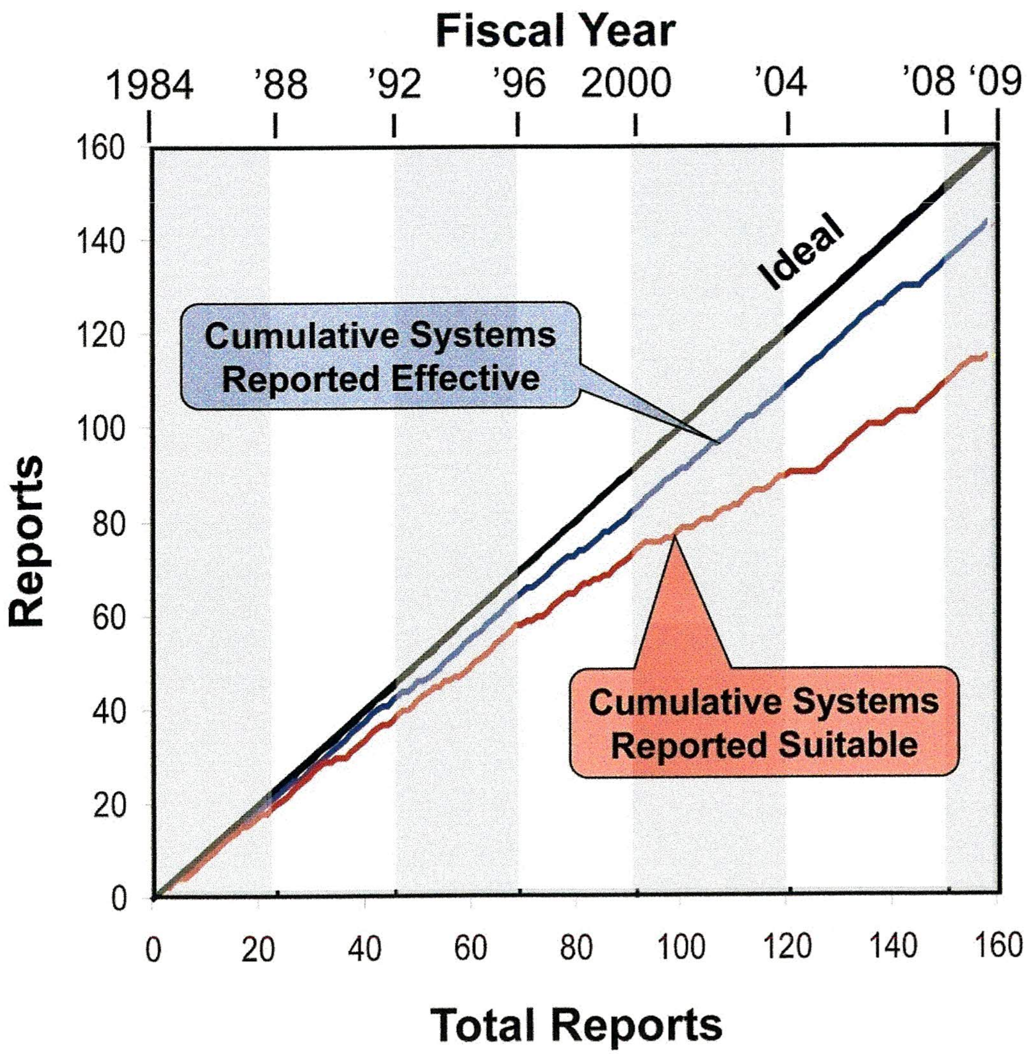


Approved for public release; distribution unlimited.

IDA

DOT&E Initiative: Improve Suitability Before IOT&E

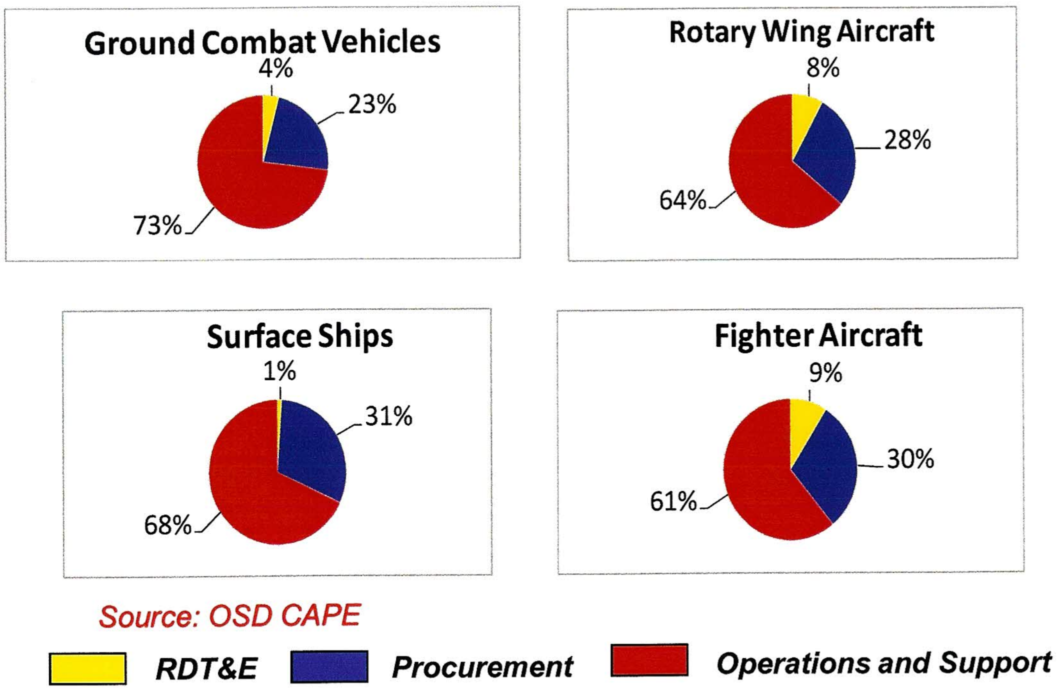
Cumulative Reports



- *Systems more frequently judged Not Suitable*
- *Reliability and Maintainability account for 80% of Not Suitable ratings (red line)*

IDA

Unreliable = Expensive



"We have a tendency to look at what it takes to get a program out the door. We don't think too much about what the life cycle [cost] is. It's 'Can I build it?' I would like us all to be mindful of what it costs to operate whatever we are building for whatever its life is going to be because I have to pay that bill every single year."

- CNO, ADM Michael G. Mullen in an interview with "Government Executive" magazine May 15, 2006
From "Improving System Reliability Through Better Systems Engineering," Dr. Charles E. McQueary, Director, OT&E
NDIA SE Conference, October 2007

Operations and Support (O&S) consumes about 2/3 of total program costs
- *About ½ of O&S costs are driven by system reliability*

Approved for public release; distribution unlimited.

IDA

The Process of Doing Reliability Right
Reliability Standard: ANSI-0009

1. **Understand user requirements and constraints**
   - Reliability requirements include the anticipated use environment
2. **Design for Reliability (DFR) and Re-design for Reliability**
   - This means that user needs will be allocated through system model to reliability specifications at lowest component levels.
   - Lowest level reliability specifications include internal stresses and impacts of use environment
   - Redesign as needed to meet allocated reliability requirements
   - During DT, all subassemblies, components, etc should demonstrate required reliability in anticipated use environments
3. **Produce reliable systems**
   - Meeting reliability requirements will often require reliability growth programs for components utilizing repeated DT experiments
4. **Monitor and assess user's experienced reliability**

Approved for public release; distribution unlimited.

Key Components of Design for Reliability (DfR)

- **Goal: develop the system so that it meets all design specifications, is producible and will meet user requirements throughout the life cycle**
- **Result: a robust product design that minimizes impact on cost and schedule**
- **Input Information**
  - Initial concept of reliability model
  - Rationale for reliability requirements
  - User and environmental life-cycle loads
  - Failure definitions
- **Developed information**
  - Identification of system design configuration & corresponding reliability data
  - Refined reliability model
  - Engineering analysis of failure modes under assumed loading

IDA

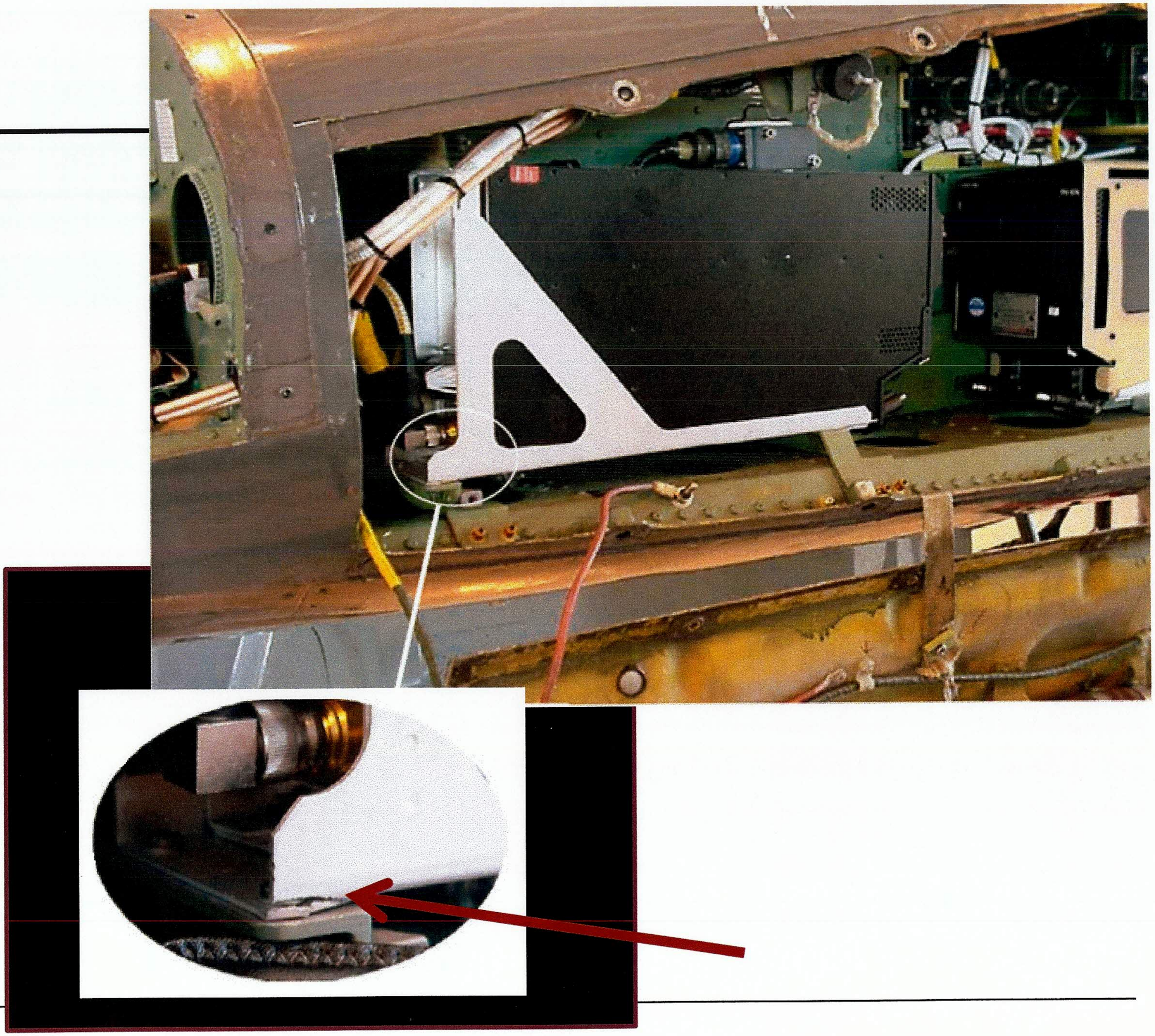
Robust Parameter Design

- **Industrial problem solving methodology proposed by Taguchi**
  - Cost effective approach for improving quality
  - Goal: reduce product variation by choosing levels of control factors that are insensitive to changes in noise factors
- **Methodologies**
  - Taguchi's signal to noise ratio
  - Response surface methodology, dual response problem
  - Multivariate response modeling
- **Noise variables**
  - Environmental conditions (humidity, temperature, etc.)
  - Consumer use of the product (workload factors, use and abuse)
  - Noise variables are controllable during product design stage, but not in the field
- **Noise variables closely relate to military use of acquisition systems!**

IDA

Partially Hypothetical Case Study: Mounting Bracket for Aircraft Transponder Tray

- **Problem Statement:**
  - The mounting bracket that holds the transponder tray in place on military aircraft is cracking. The brackets were designed to be used on commercial aircraft. To fix the problem the Air Force has proposed an updated mounting tray with additional stabilizer(s). However, there is concern that this additional stabilizer(s) may induce new failure mechanisms.
- **Goal:**
  - Develop a bracket that holds the transponder tray in place without failure
- **Historical Data:**
  - Time to failure for historical mounting bracket
  - Times are interval censored
- **Control Variables:**
  - Number of stabilizers (1, 2 or 3)
  - Thickness of bracket
- **Noise Variables:**
  - Vibration
  - Temperature
  - For operational realism, mounting bracket needs to be tested with actual aircraft and transponder tray



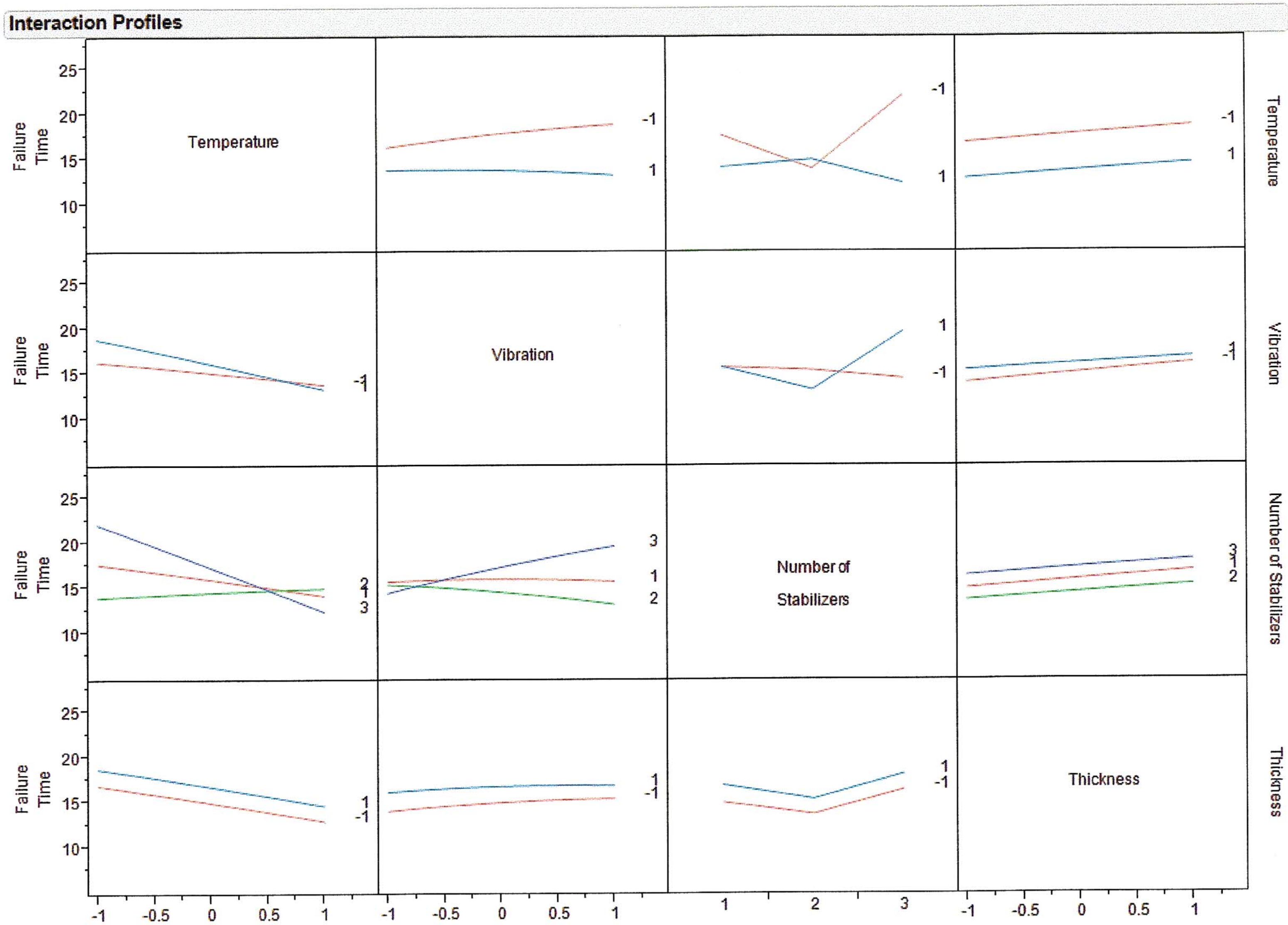
Approved for public release; distribution unlimited.

IDA

Experimental Design

- **Split-Plot Design**
  - Noise variables (Temperature & Vibration) are costly to change
- **Response Variables**
  - Time until failure
  - Length of crack (known existing failure mechanism)
  - New failure mechanisms and amplifying information
  - Assumptions: log of response variables are normally distributed
- **Response Surface Methodology**
  - Model supported quadratic, plus interactions
  - Face centered cube design
- **Sample Size**
  - 48 runs, 12 whole plots

Results – Interaction Plots



Approved for public release; distribution unlimited.