

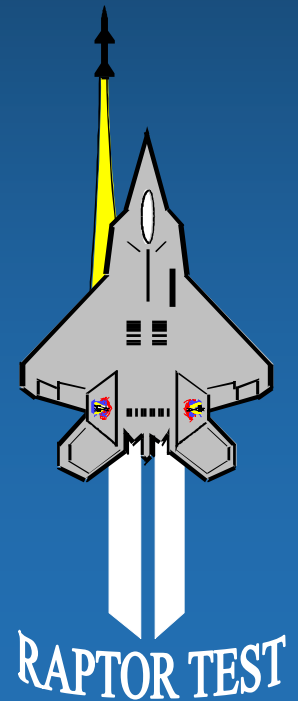
F-22 Full Scale Durability Test & Evaluation

*Pete Caruso, Tom Brussat, and Wendy Hynes
Lockheed Martin Aeronautics Company*

*2006 USAF ASIP Conference
San Antonio, Texas
28-30 November 2006*

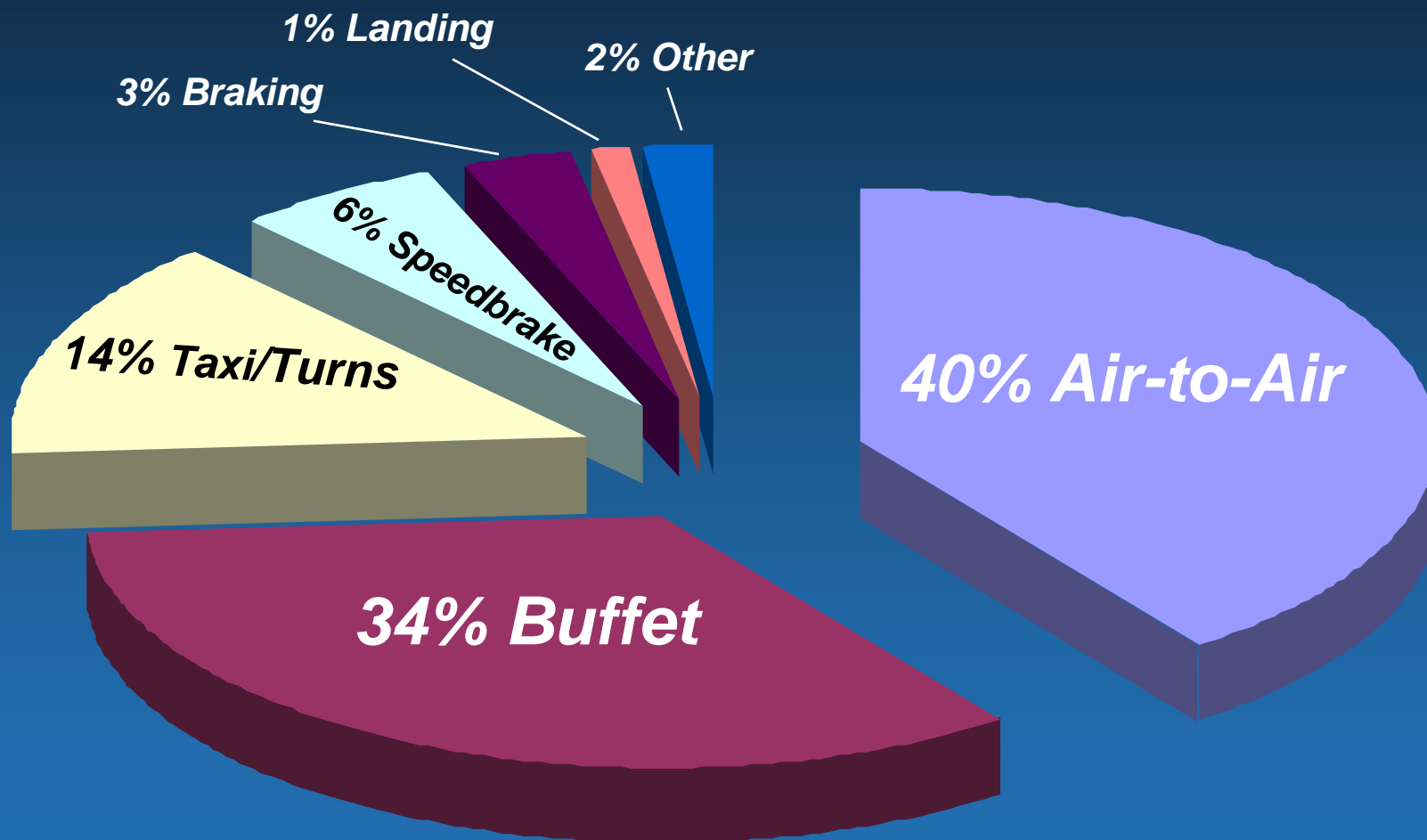


- **Applied Test Loads**
- **Full Scale Test Evaluation Challenges**
 - *Test Reaction Load Error*
 - *Test Spectrum Update*
 - *Coarse Grain Titanium*
- **Crack Growth Correlation**
- **Test Teardown Summary**
- **Summary/Conclusions**





➤ 2.67 Lifetimes of 2.78M Cycles

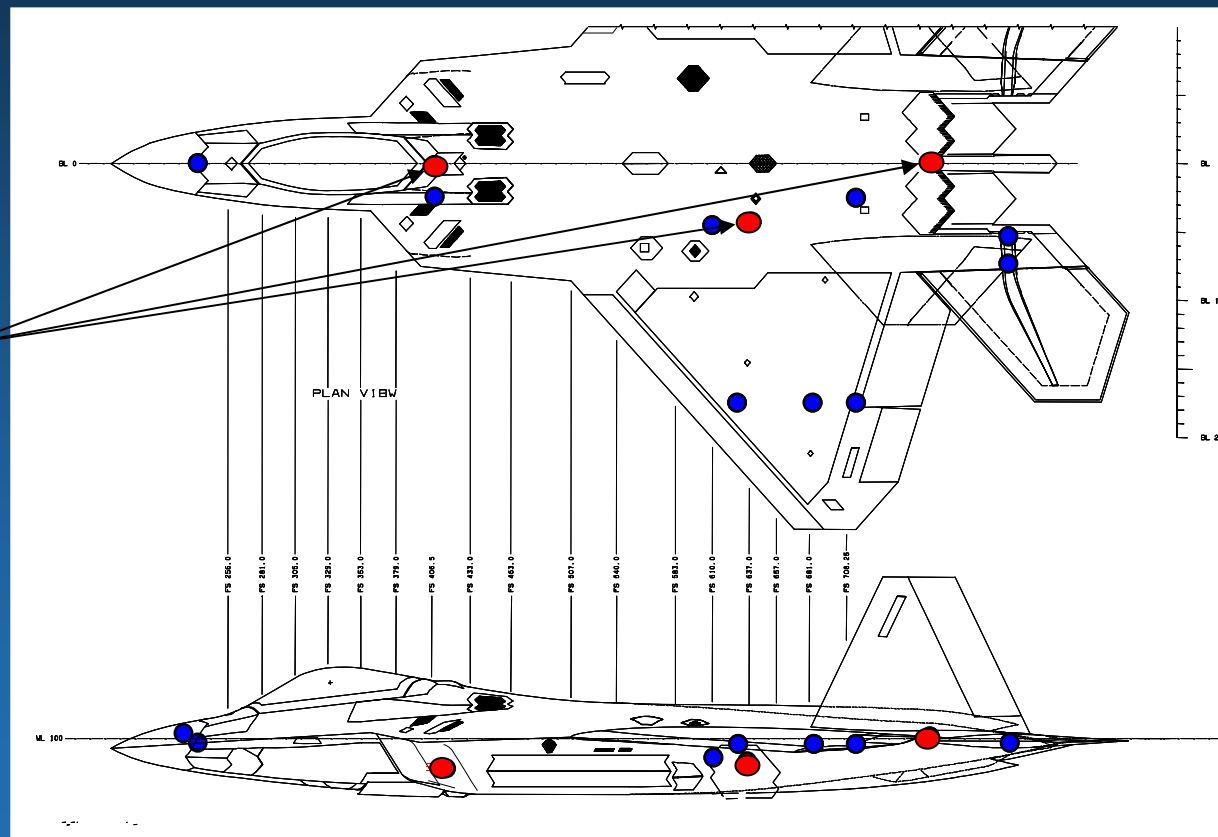


Flight Maneuvers and Buffet Loads Dominate the Test Spectrum



- 196 RAMS Balanced at 7 Reaction Points
- Imbalance Loads Detected
 - *Wear or Friction*
 - *RAM Load Errors*

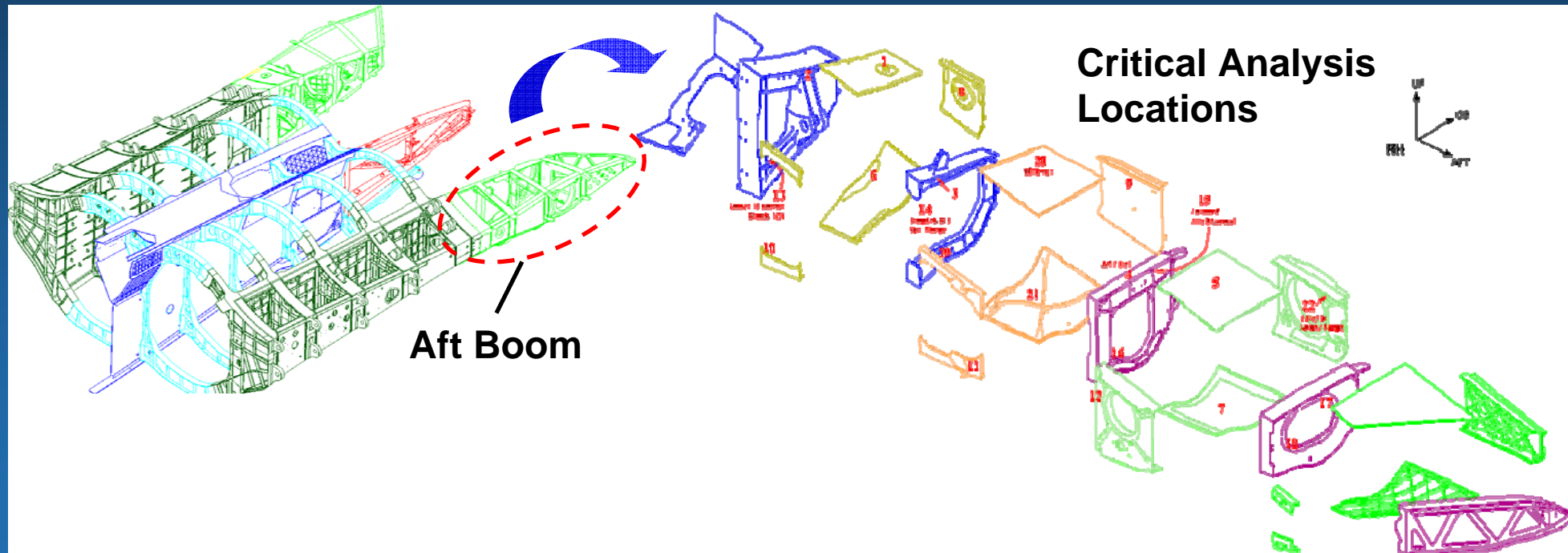
- *Reaction Point*
- *Balance Point*



New Method Required for Load Error Evaluation



- Pre-test Start Spectrum Adjustments
- Post-Start Spectrum Update
 - *Pre-Production AFT Boom Experienced Early Cracking*



New Method Required for Spectrum Updates



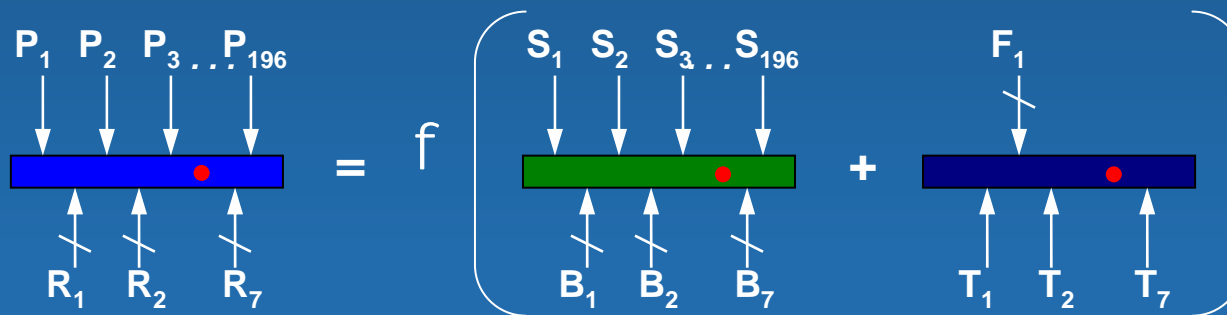
➤ Unit Load Cases Applied to Test Article FEM

➤ 1050 Unit Cases for 11 A/V Configurations, Pressures, and Reaction Loads

➤ Internal Loads Spectra With Actual Test Loads

$$\text{Reaction Error, } \Delta R_n = (R_n - B_{th,n})$$

$$\text{Internal Load} = \sigma_{th} + \sigma_{n,T} * \Delta R_n / T_n = \sigma_{th} + \sigma_{n,T} * (R_n - B_{th,n}) / T_n$$



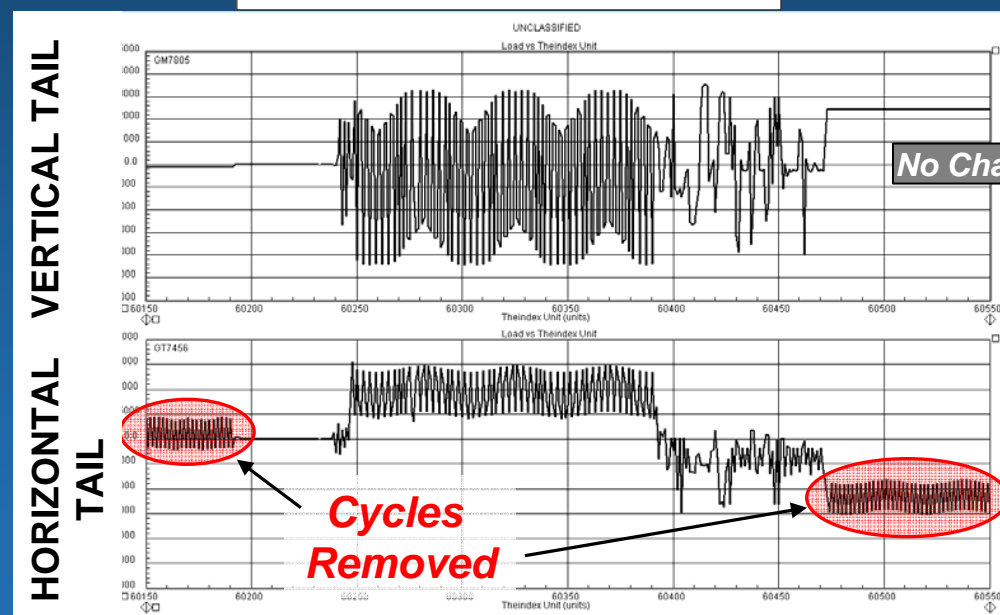
Stress Spectra Includes Sources of Error Loads



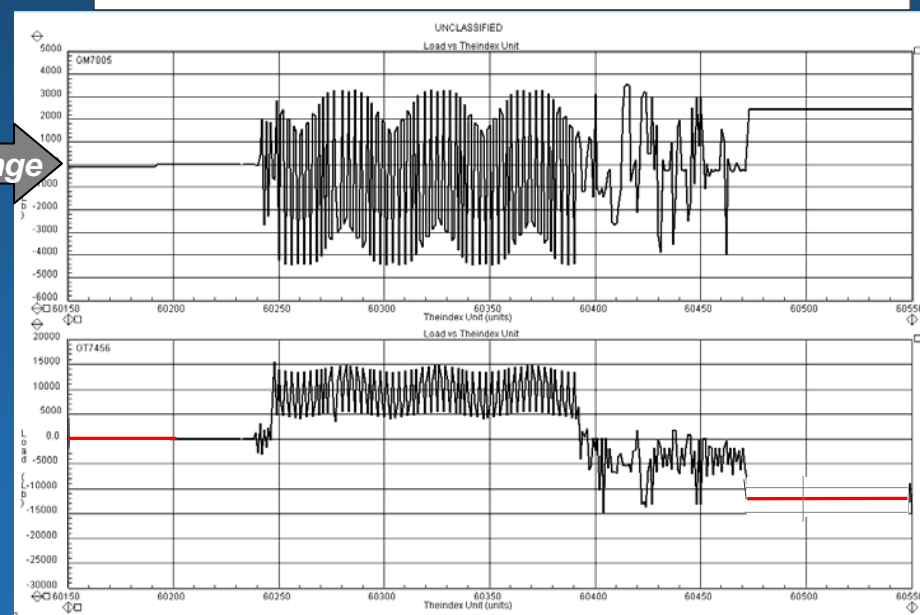
- 2nd and 3^d Lifetime Test Spectrum Updated
 - Horizontal Tail Buffet Cycles Removed (25% of End-Points)
 - Events Containing Both Vertical and Horizontal Buffet is Unchanged

1st Lifetime Spectrum

2nd and 3^d Lifetime – After Update



No Change



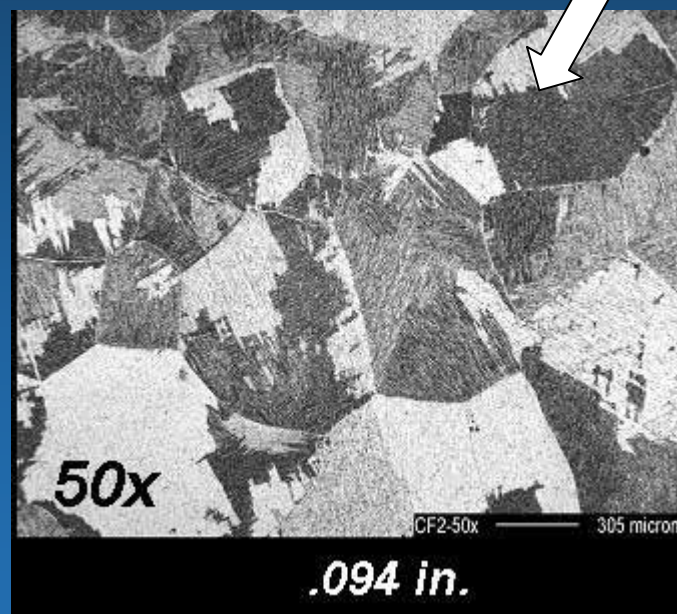
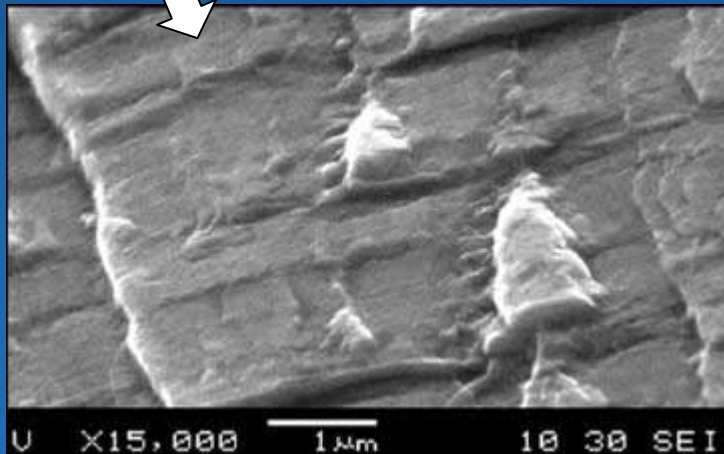
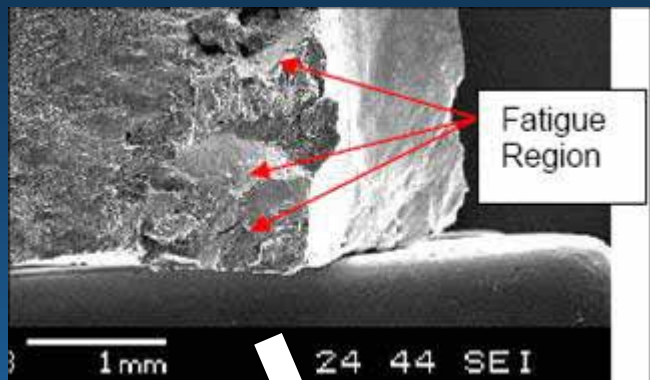
Test Life of Pre-Production AFT Boom Improved 7%-291%



3.175 mm
(.125 in)

➤ Ti 6Al-4V BA

➤ Poor fracture surface marking



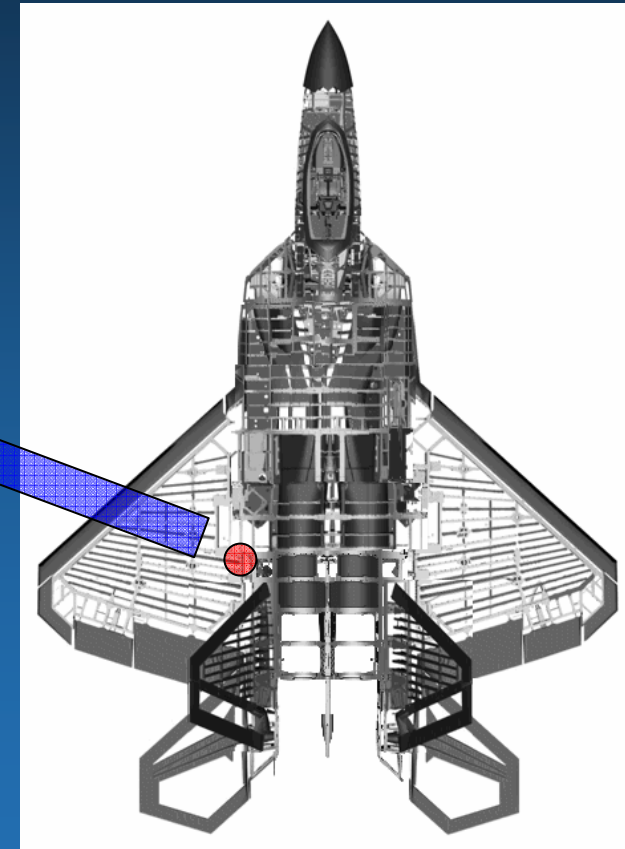
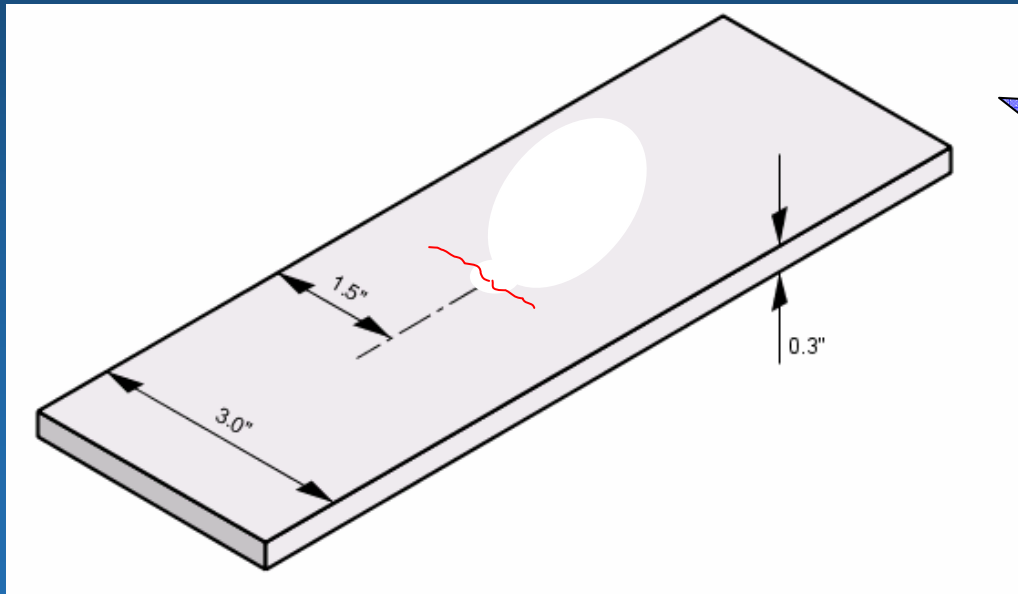
Limited Observations of Crack Growth Rate

Coarse Grain Titanium - Recovery Plan



- Additional Strain Gages During Cycling
- Quantitative Fractography (as feasible)
 - 75 Crack Indications Examined
- Spectrum Crack Growth Tests

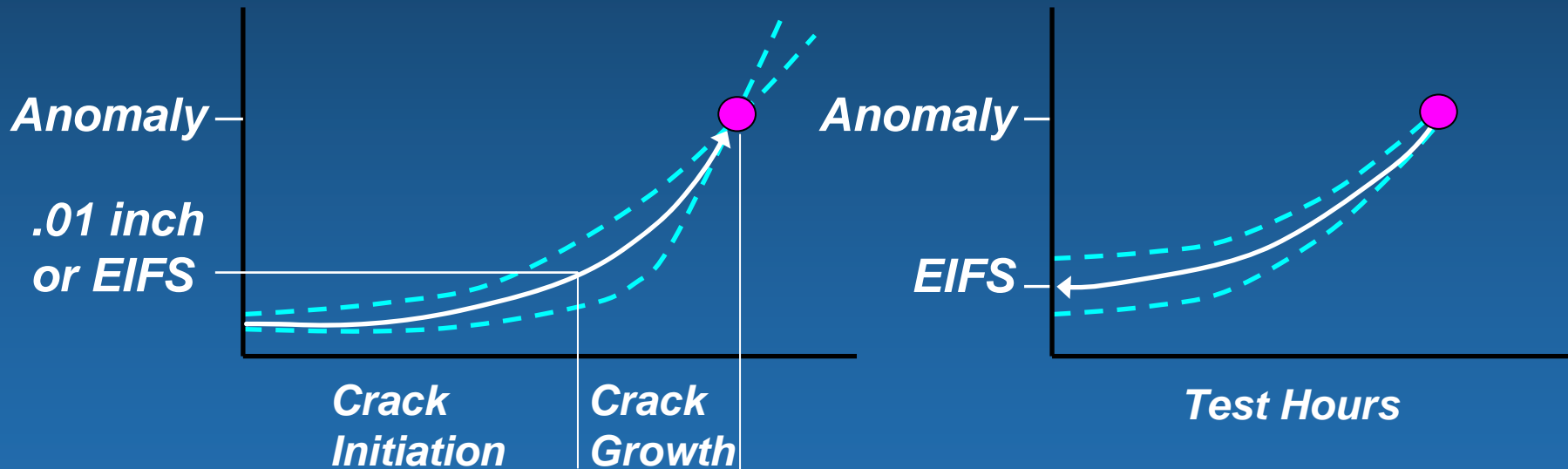
Center Crack Specimen



Crack Models have Improved



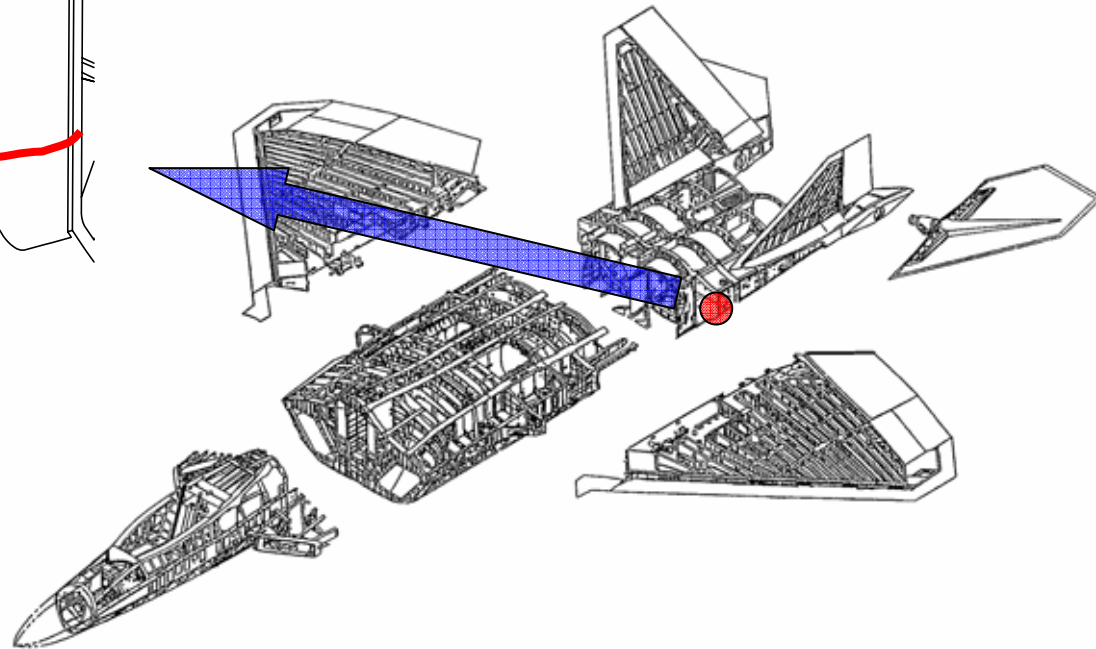
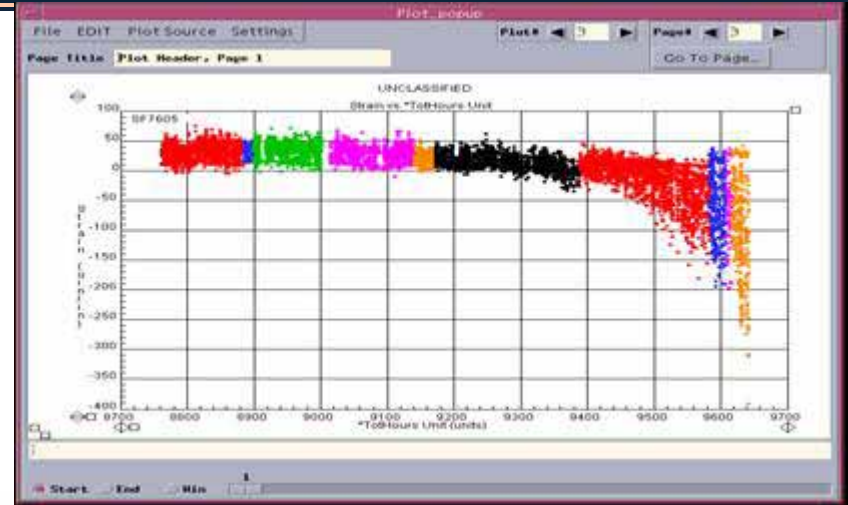
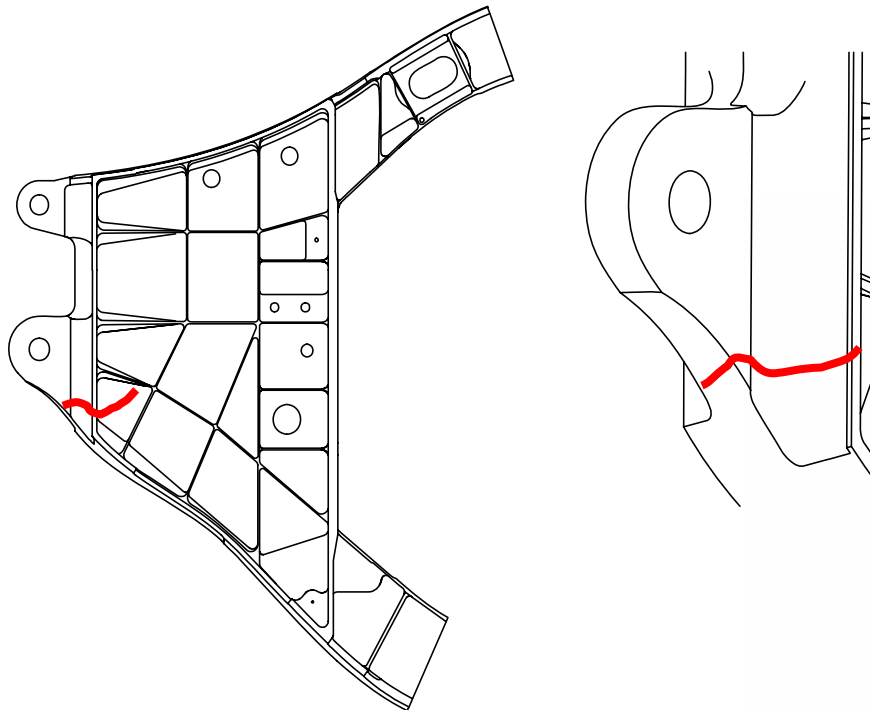
- Crack Correlation Procedure
 - Crack Initiation + Crack Growth
 - EIFS Developed

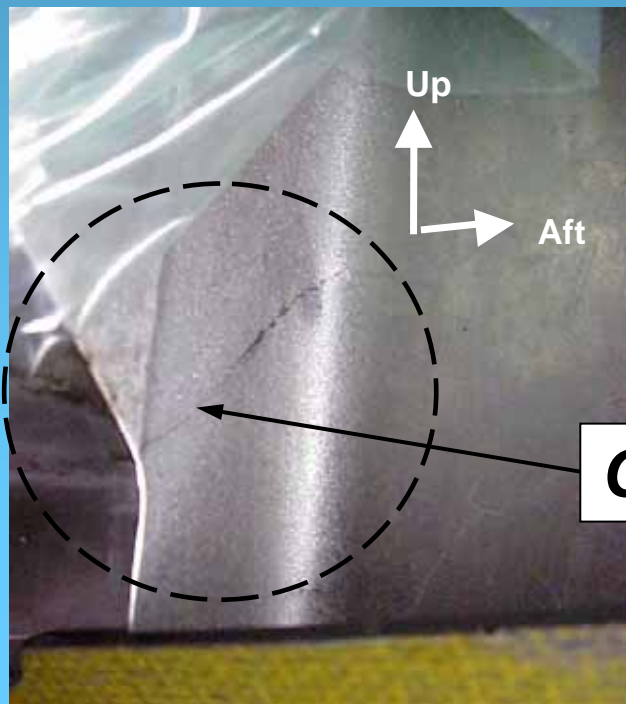
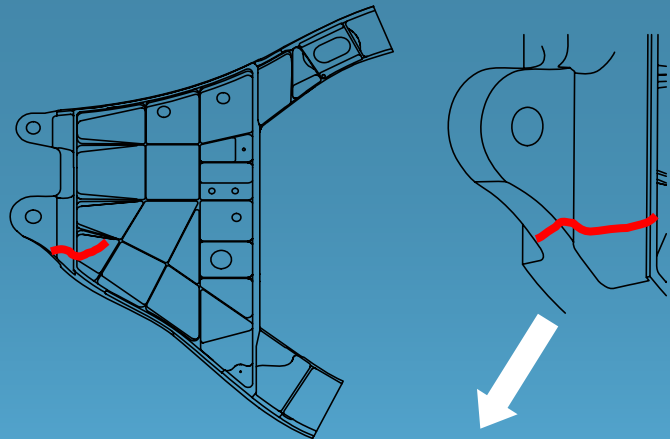


Single point data requires conservative correlation analysis

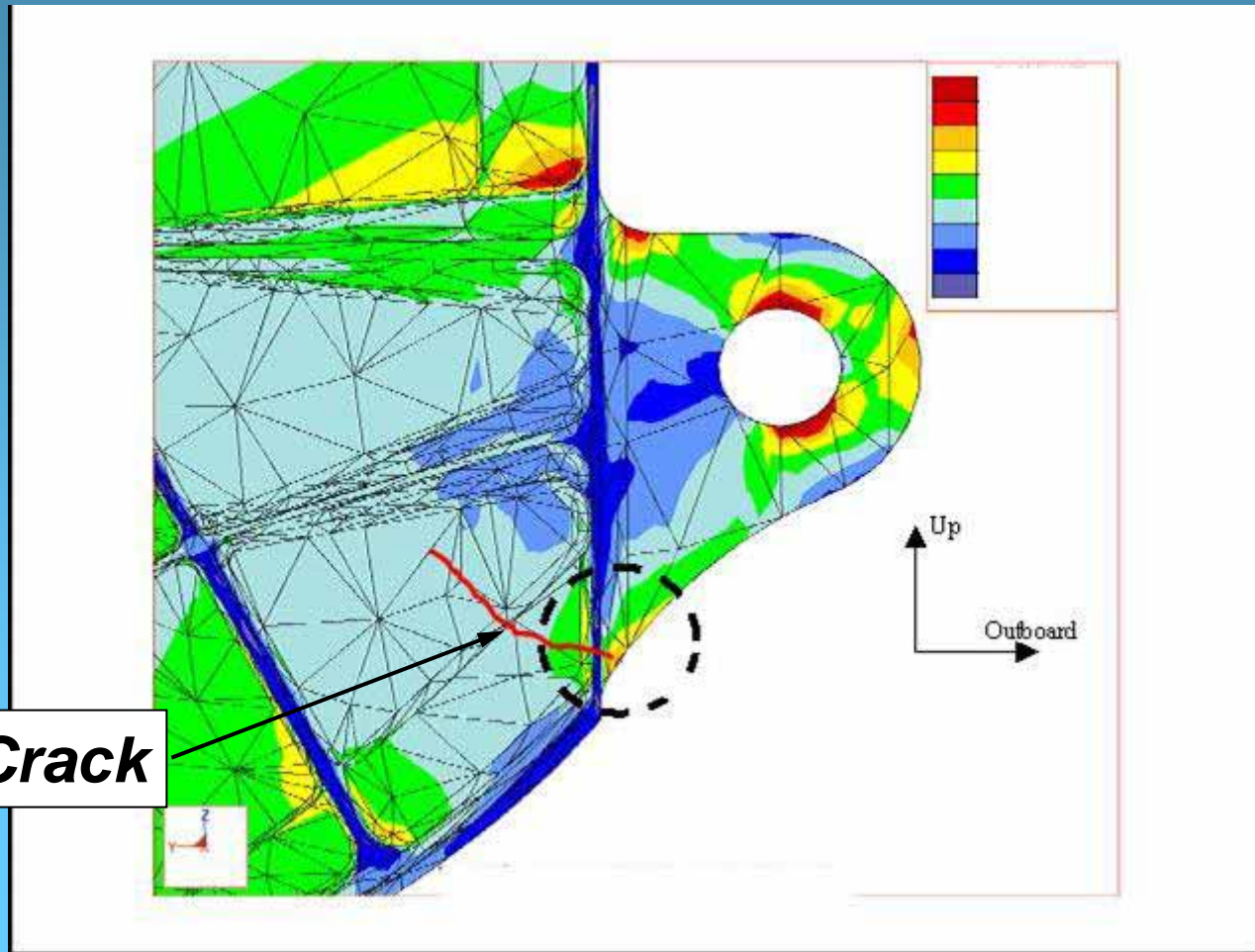


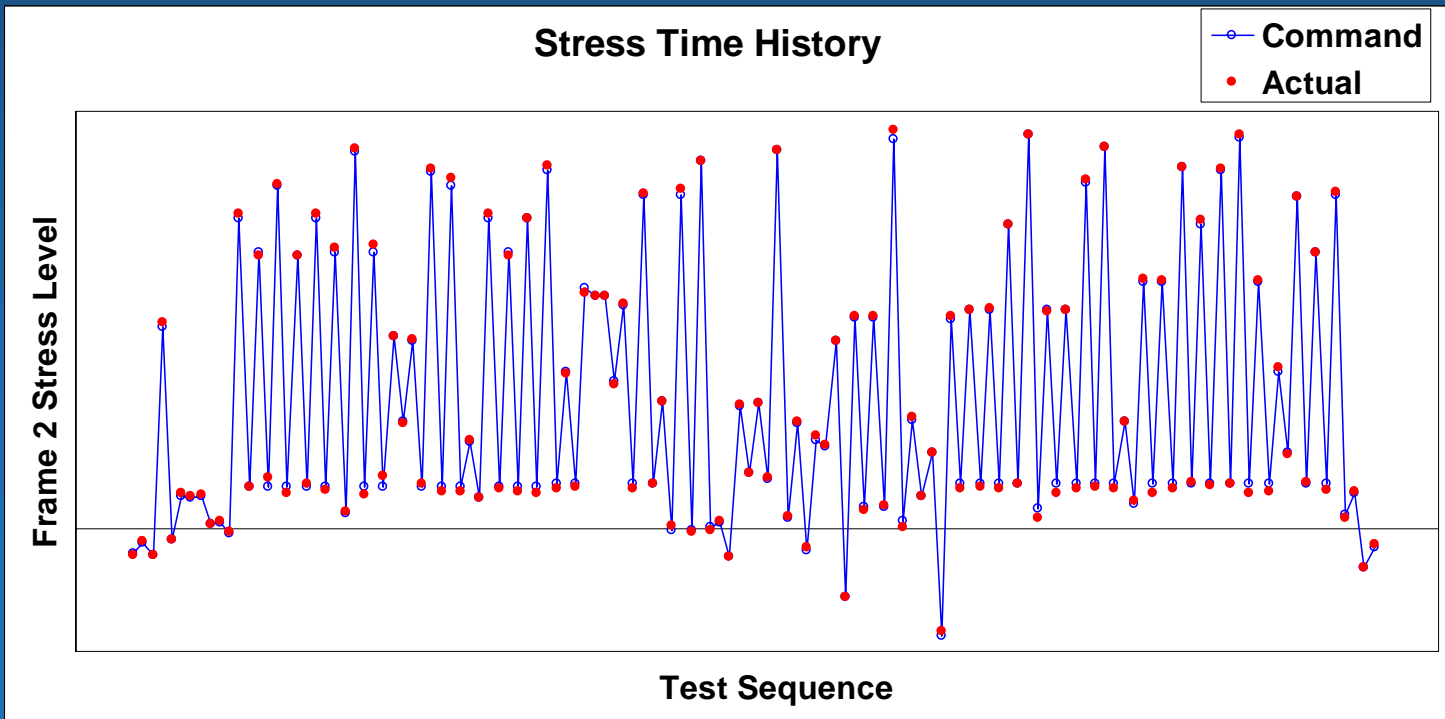
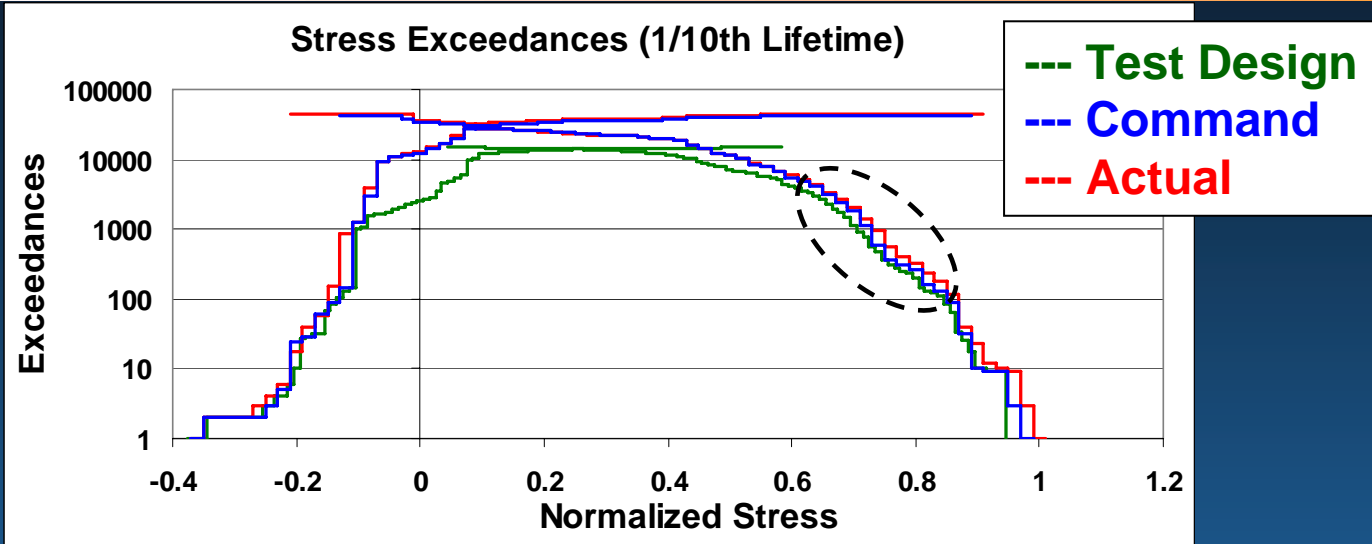
- **Strain Departure Detected**
- **Crack Located**

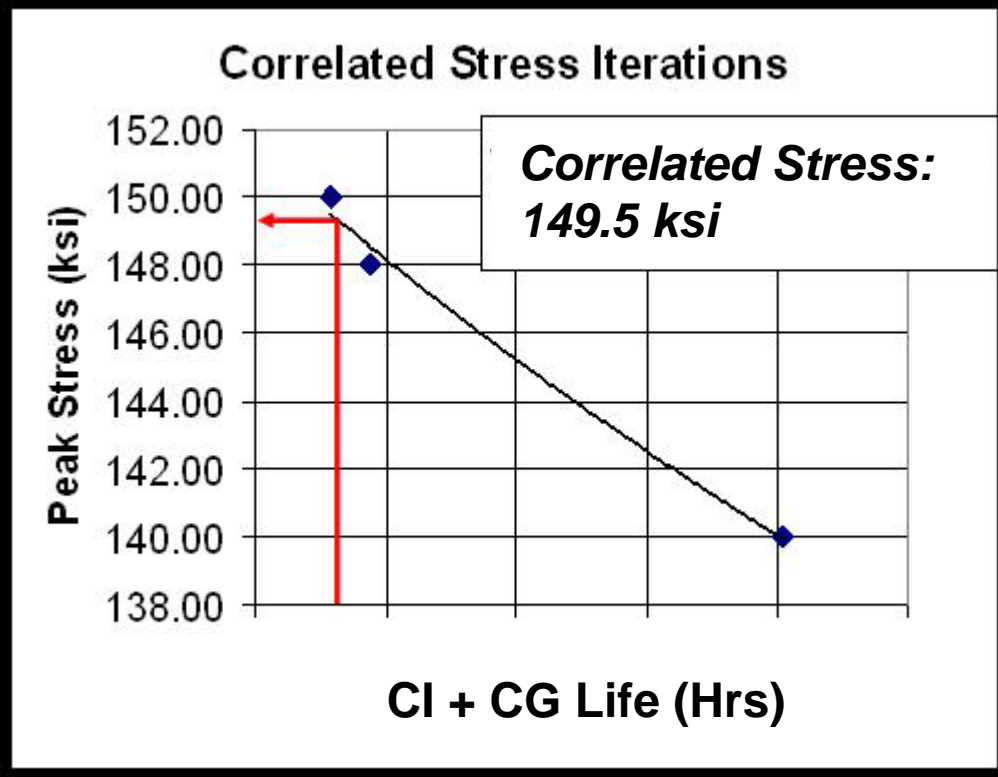
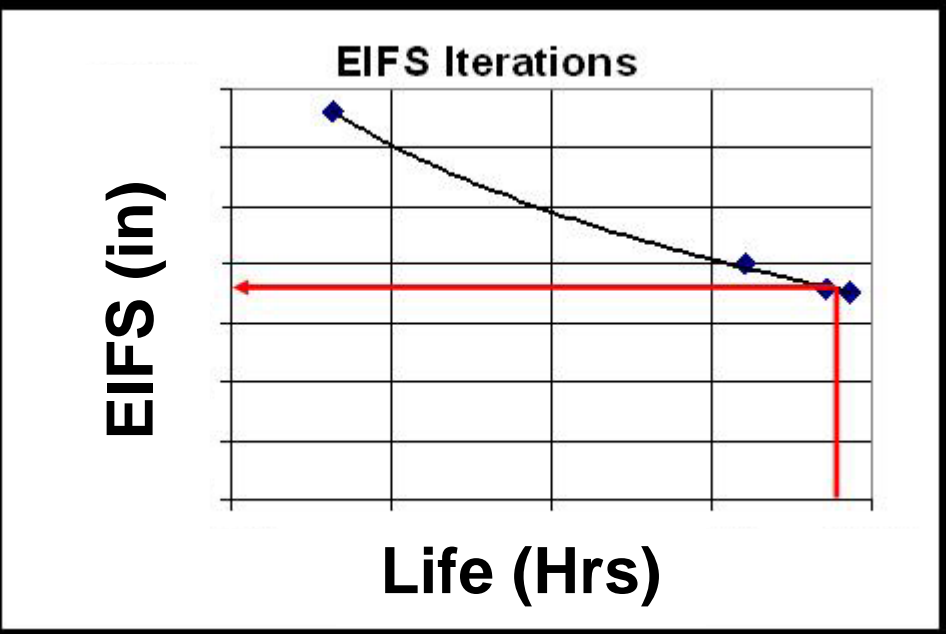




Crack







Redesign Eliminated this Shortfall in Production A/C

Durability Analysis Updated

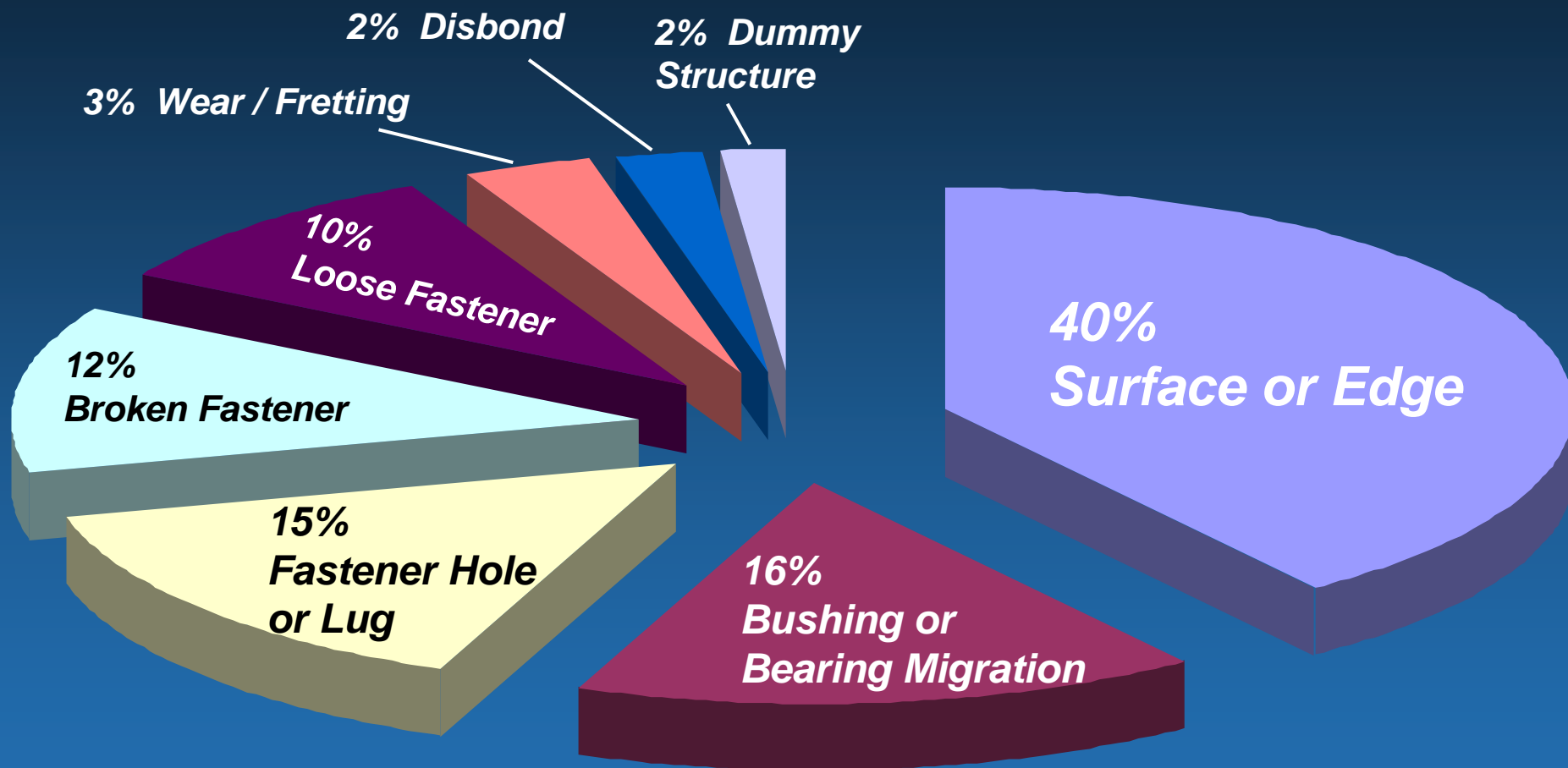


➤ NDI Scope

Bolt Hole Eddy Current	30,589 holes
Fluorescent Penetrant	14,626 sq. inches
Ultrasonic	9,470 sq. inches
Eddy Current Surface Scan	6,680 sq. inches

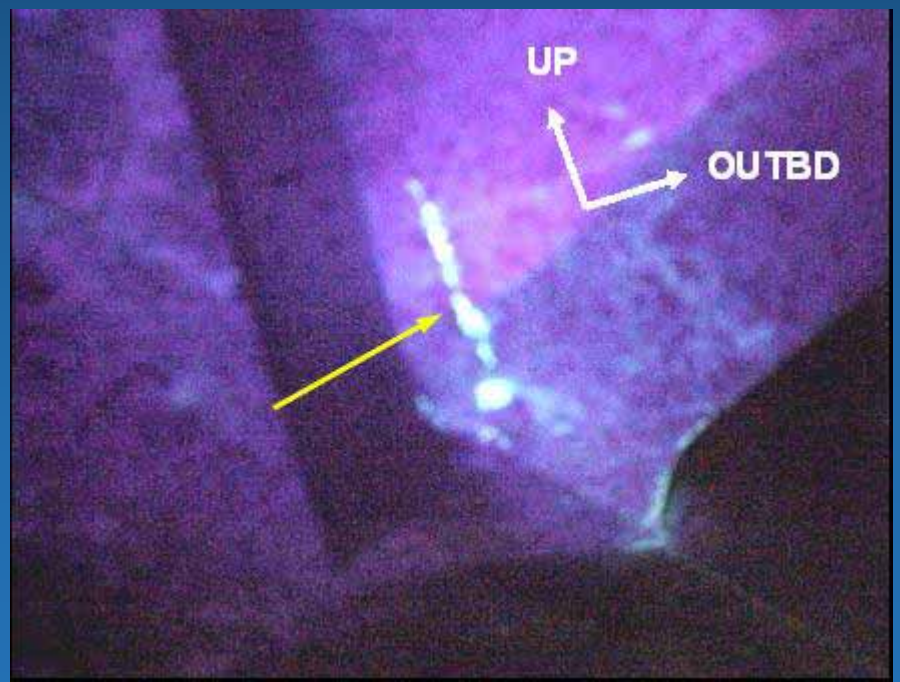
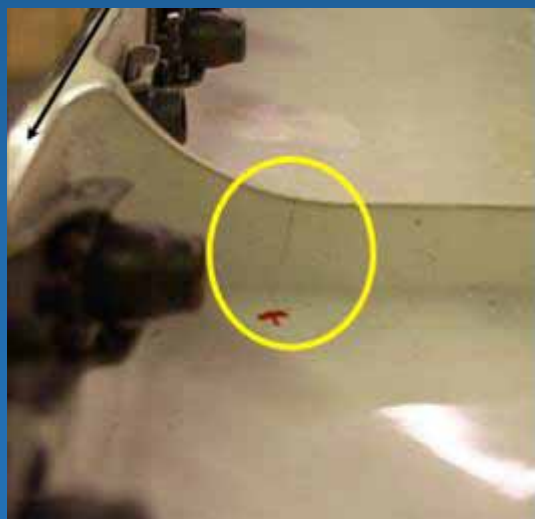
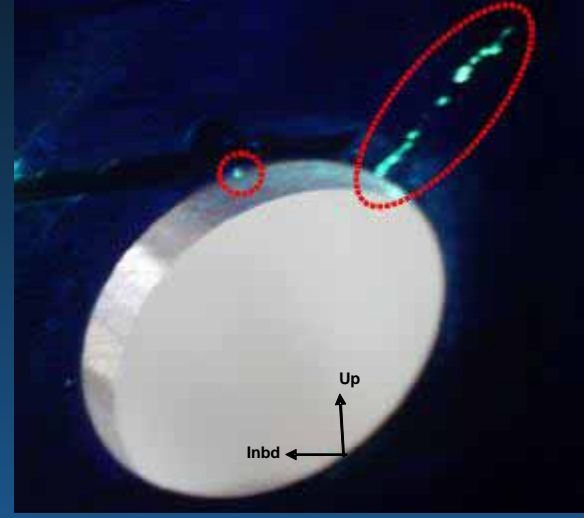
➤ 37 New Discrepancies Documented

<p>Location Illustration</p>	<p>Blacklight photo of RHS hinge 5 otbd/upr crack</p>
<p>From 5H0002107, Sheet 2</p>	<p>Measured dimensions</p> <p>Section A-A</p>

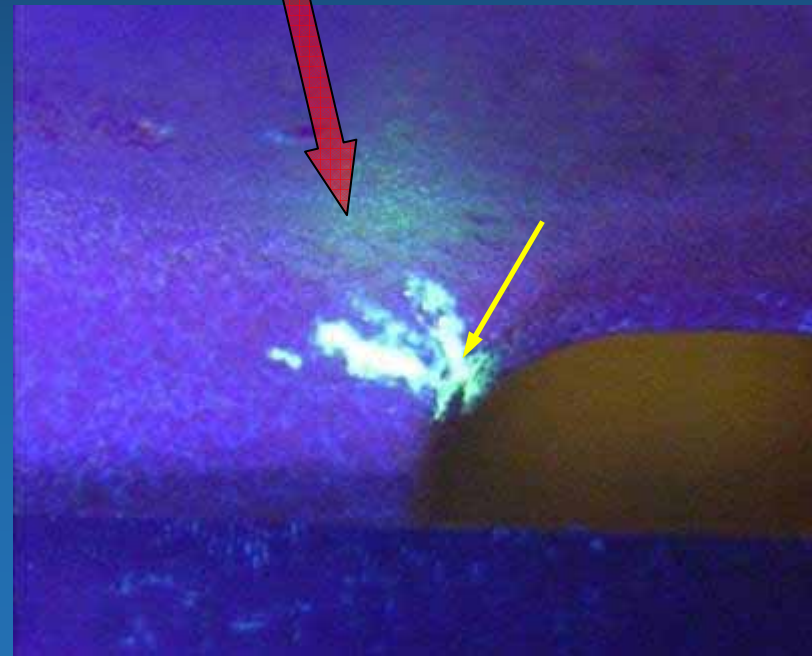
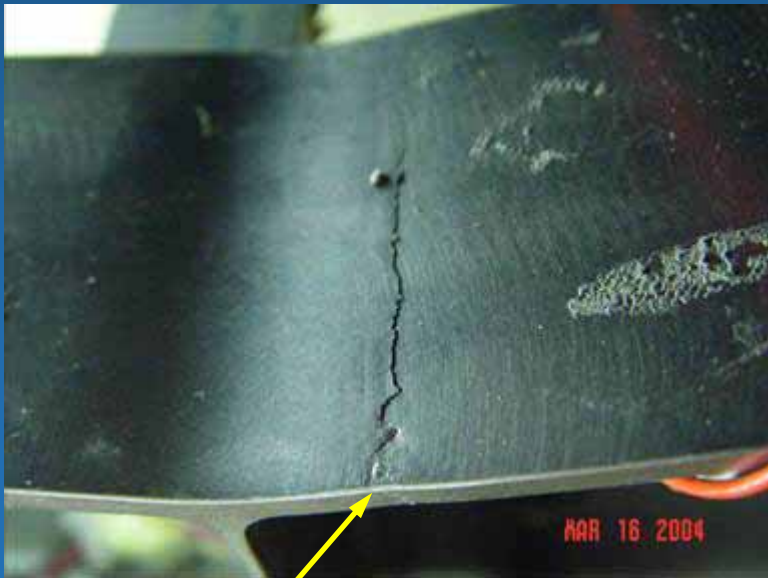
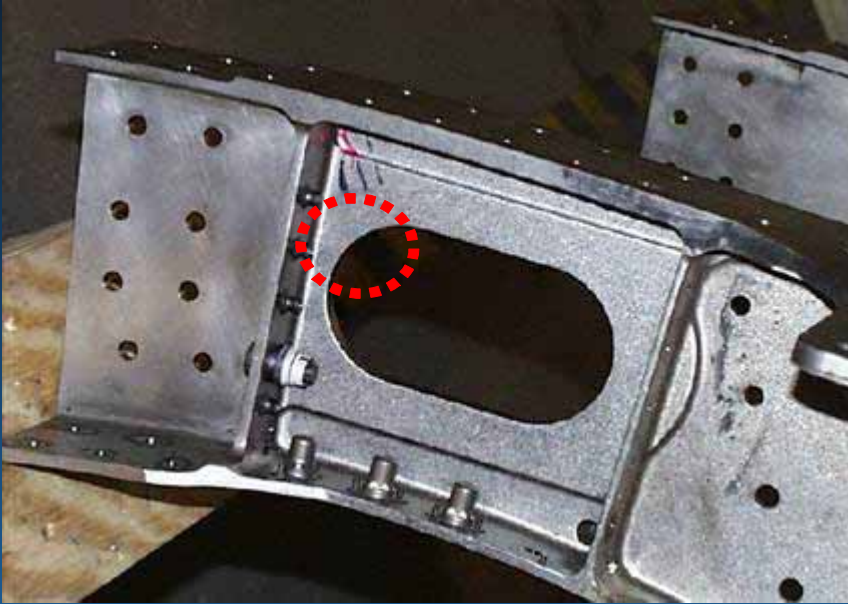


Majority of Test Anomalies Were Surface Cracks or Bushing Migration

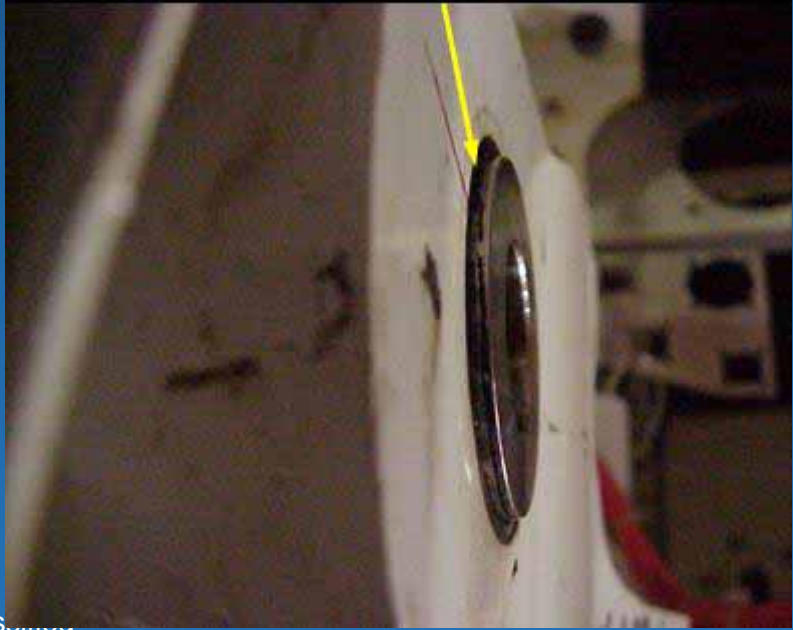
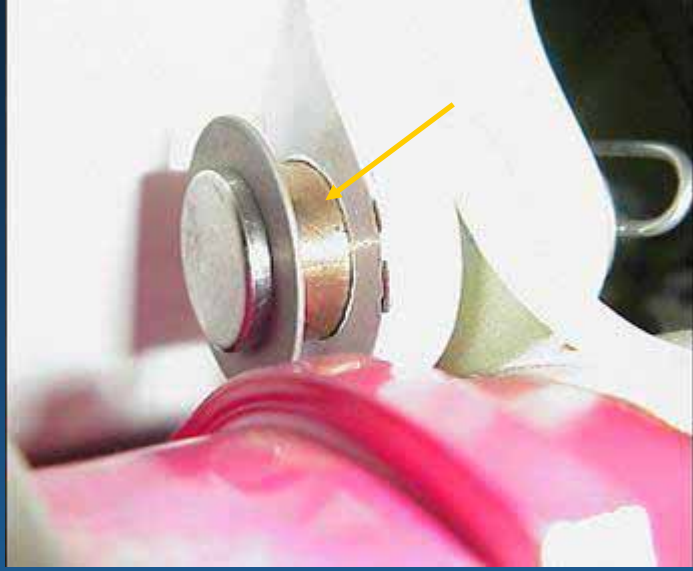
Surface or Edge Discrepancies



Surface or Edge Discrepancies

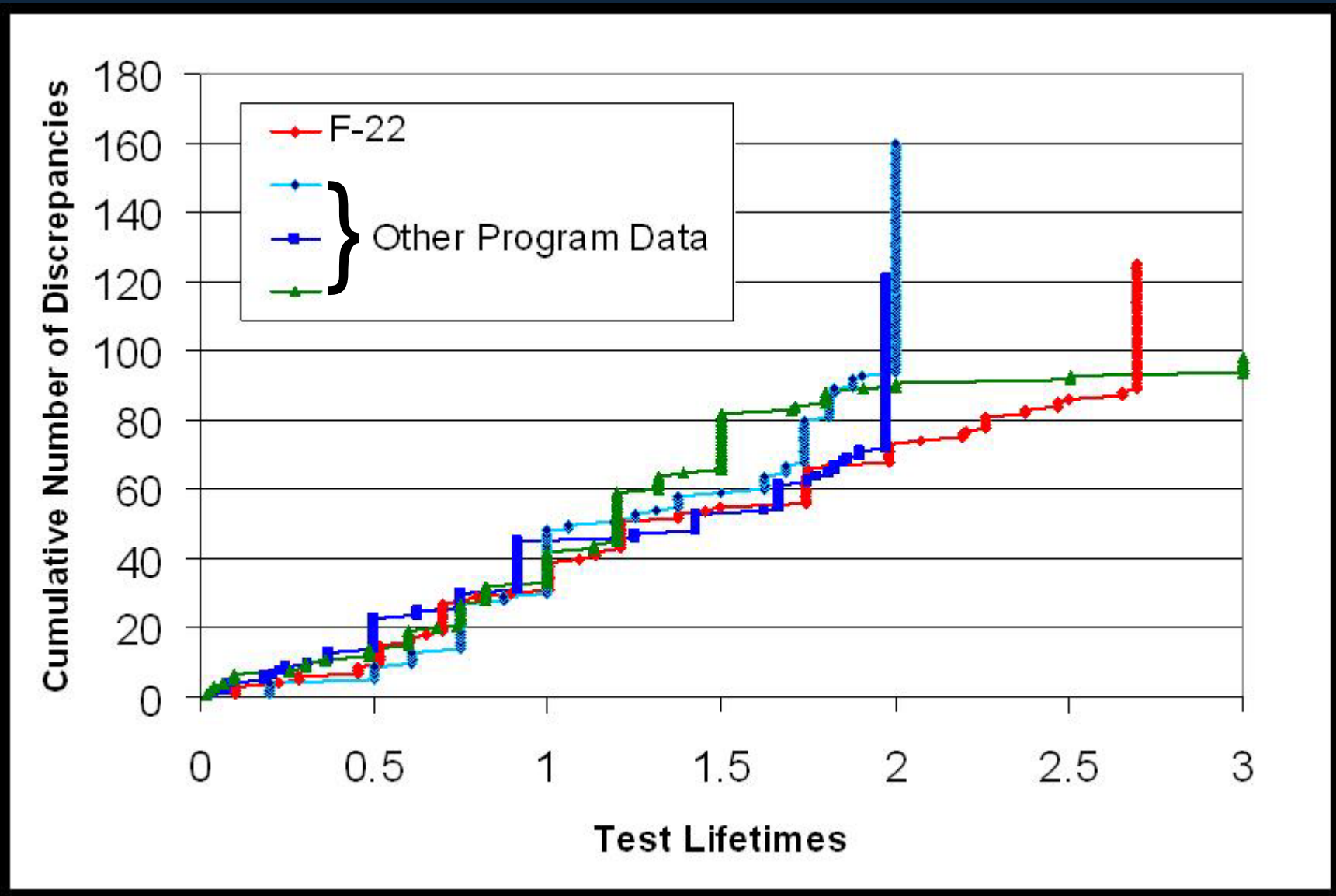


Bushing or Bearing Migration





Test Discrepancy Summary





Summary/Conclusions



- **F-22 Successfully Completed the Full Scale Durability Test Program**
 - ***Test Unit Loads Method Applied***
 - Reaction Error Loads, Test Spectrum Update, and Crack Correlation
- **Corrective Action Policies**
 - **Conservative Crack Correlation Analysis**
 - **Proactively Implemented Repairs and Redesigns for Test Demonstrated Lives < 2 LT**
 - **In-service Inspections for Correlated Crack Growth Lives < 2 LT**
 - **Continuing Development Testing to Relieve Inspection Burden**
 - **Developing an Air Vehicle Crack & Anomaly Database**



QUESTIONS?



The Alamo