Life Extension of the P-3 Aircraft by Robotic Applications of LPB

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OUTLINE

- Statement of Problem
- LPB Application to Floor Beam
- LPB Application to Propeller Bore
- Summary/Conclusions

STATEMENT OF PROBLEM

- Fatigue cracking and SCC cause:
  - reduced service life
  - increased O&M costs
  - reduced fleet readiness
- Floor Beam Fatigue
  - FSFT reveals fatigue failures in 7075-T6 Floor Beam
- Propeller Bore SCC/Fatigue
  - Heavy Shot peening and reaming done to mitigate SCC
  - Blades scrapped after 3 SP + re-machining cycles

Goals:

Use LPB to enhance floor beam fatigue life

Substitute LPB for SP in propeller bore

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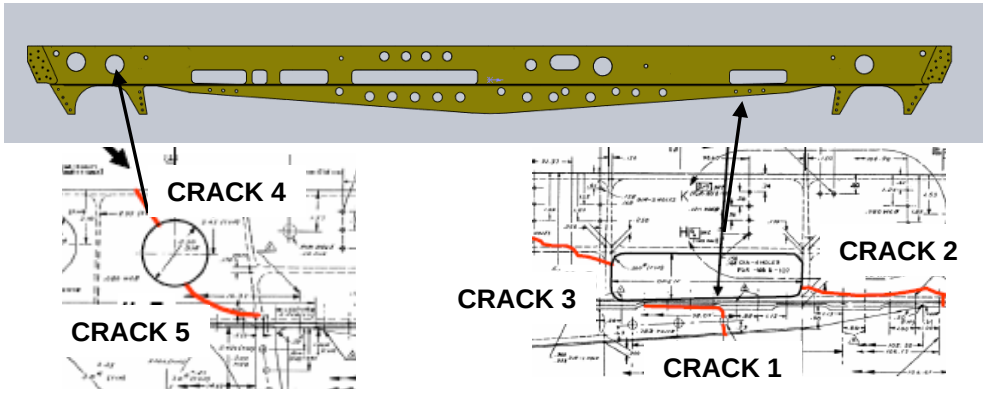
LPB Application to Floor Beam

Statement of Problem

* Images from LG04ER0112_VolII Report



- During FSFT, floor beams failed at combined 20,500 simulated flight hours and simulated fuselage pressure cycles
- Without proper repair fleet may not meet required service life
- Inspection can be proven costly
- In-flight failure could be catastrophic resulting in loss of aircraft and life

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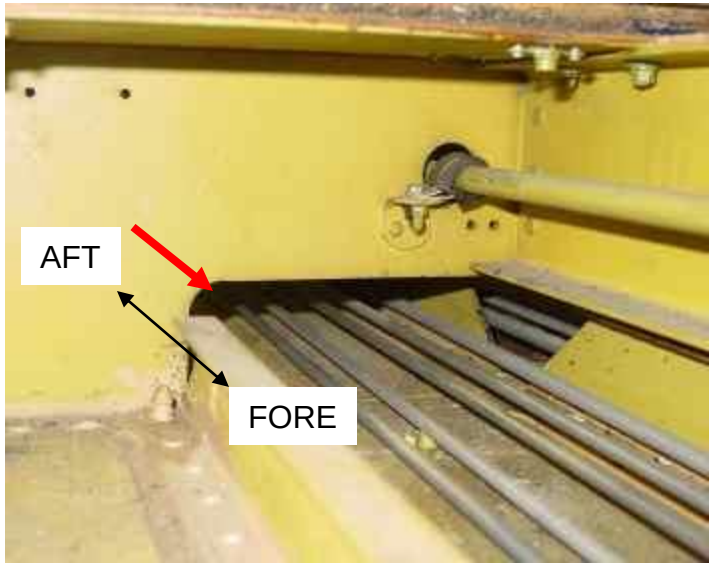
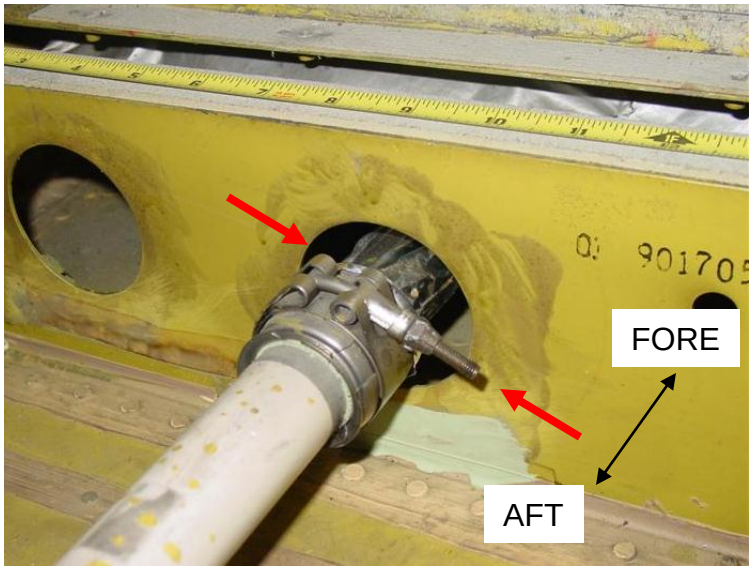
Fatigue Crack-Prone Floor Beams

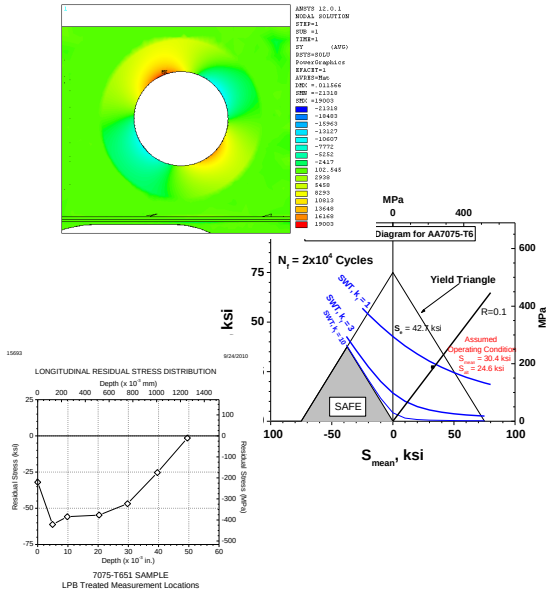




Cut outs in the FS 515 floor beam prone to fatigue cracking

Proposed LPB Solution

- **Turnkey robotic system for in-situ maintenance**
- **Treat the fatigue critical areas**



PHASE 1 - RESIDUAL STRESS DESIGN/ DEMONSTRATION ON SPECIMEN

PHASE 2 - ROBOTIC LPB SYSTEM

PHASE 3 - INSTALLATION AT DEPOT

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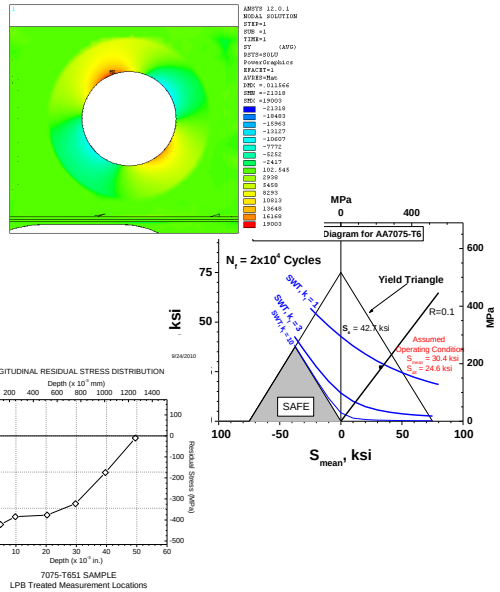
Proposed LPB Solution

- **Turnkey robotic system for in-situ maintenance**
- **Treat the fatigue critical areas**



PHASE 1 - RESIDUAL STRESS DESIGN / DEMO ON SPECIMEN

PHASE 2 - ROBOTIC LPB SYSTEM

PHASE 3 - INSTALLATION AT DEPOT

At present, RS design and proof of concept on feature specimen

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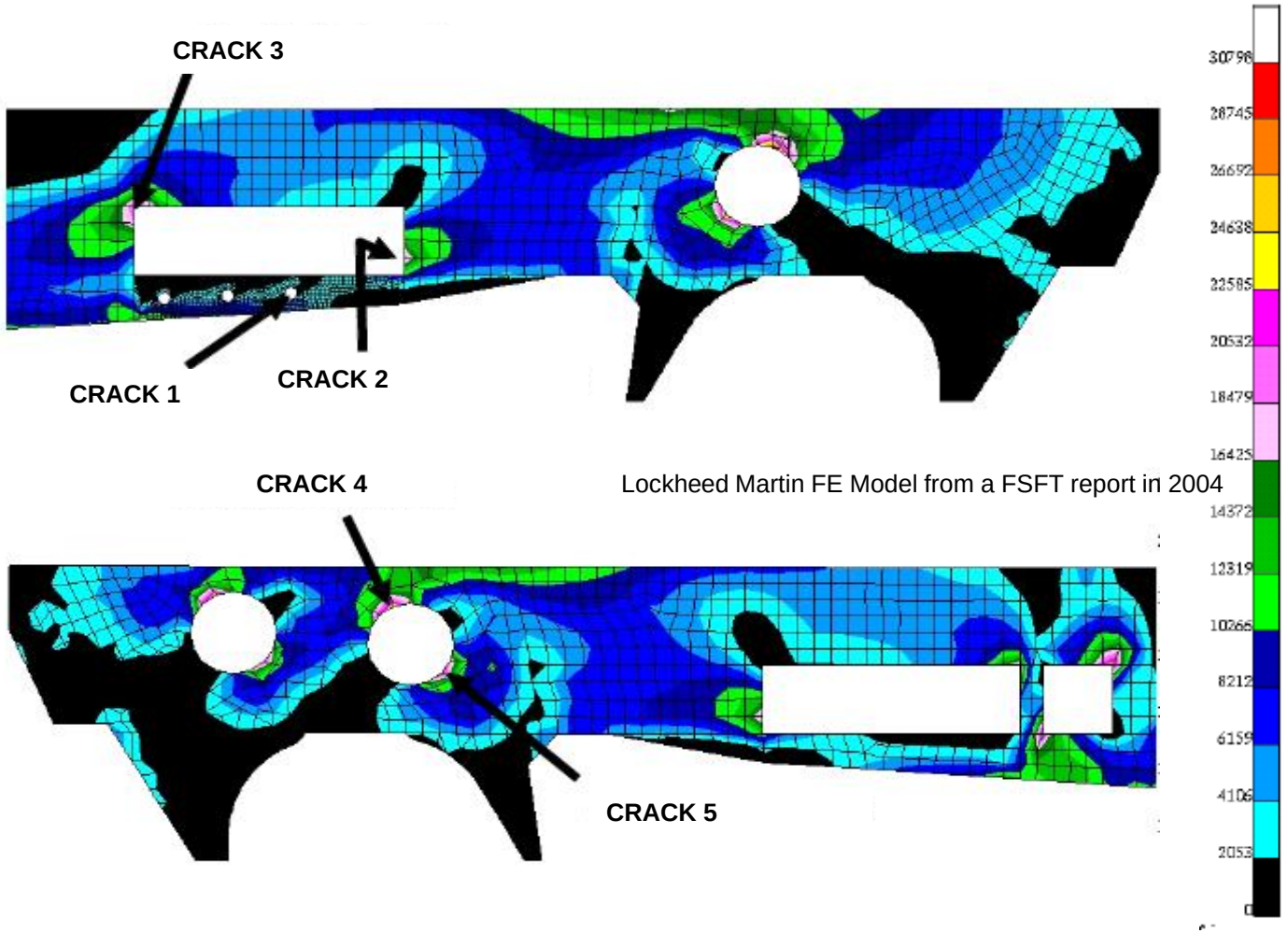
Applied Stresses



Lockheed Martin FE Model from a FSFT report in 2004

Analysis based on maximum pressure of 6.55psi.

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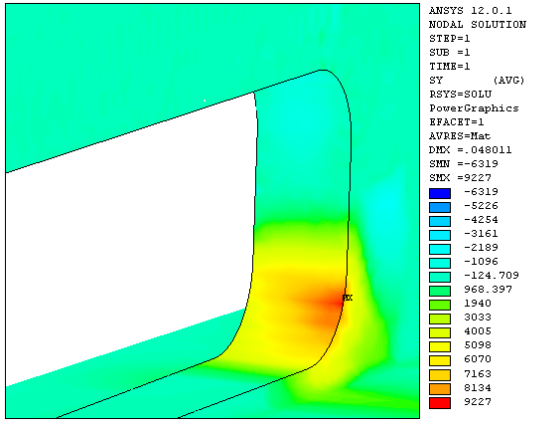
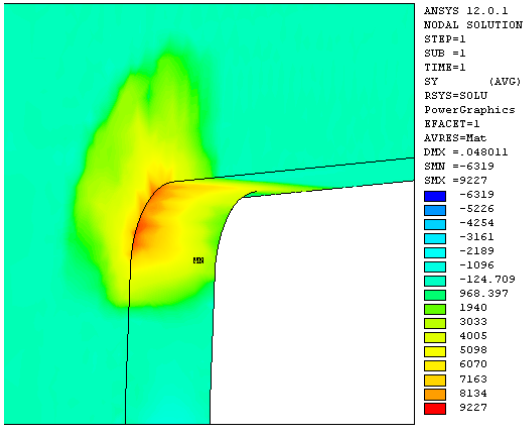
Applied Stresses

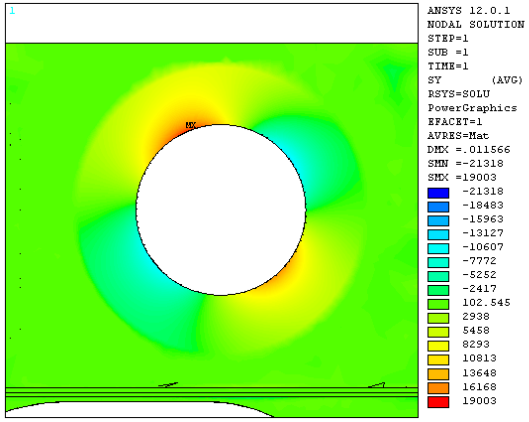
Crack 2

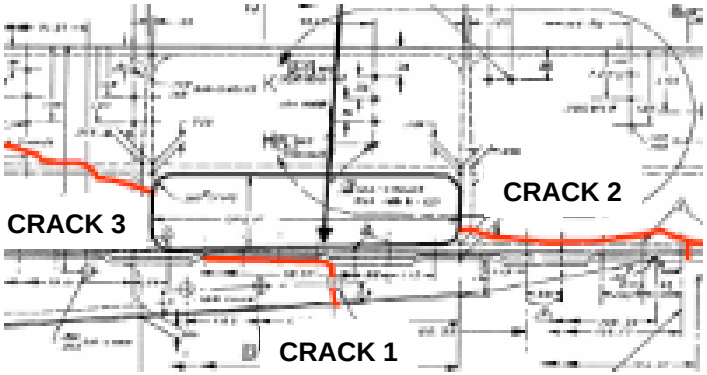


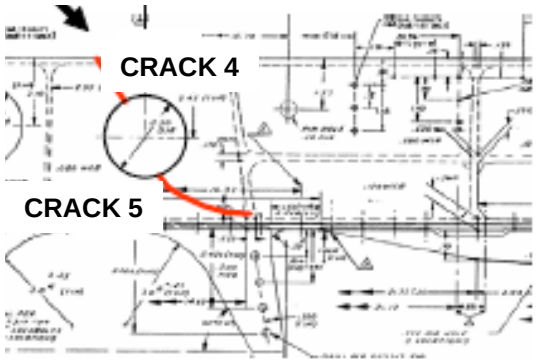
Crack 3



Cracks 4 and 5







- **Peak stress magnitude 45-55 ksi**
- **Model correlates well to the FSFT**

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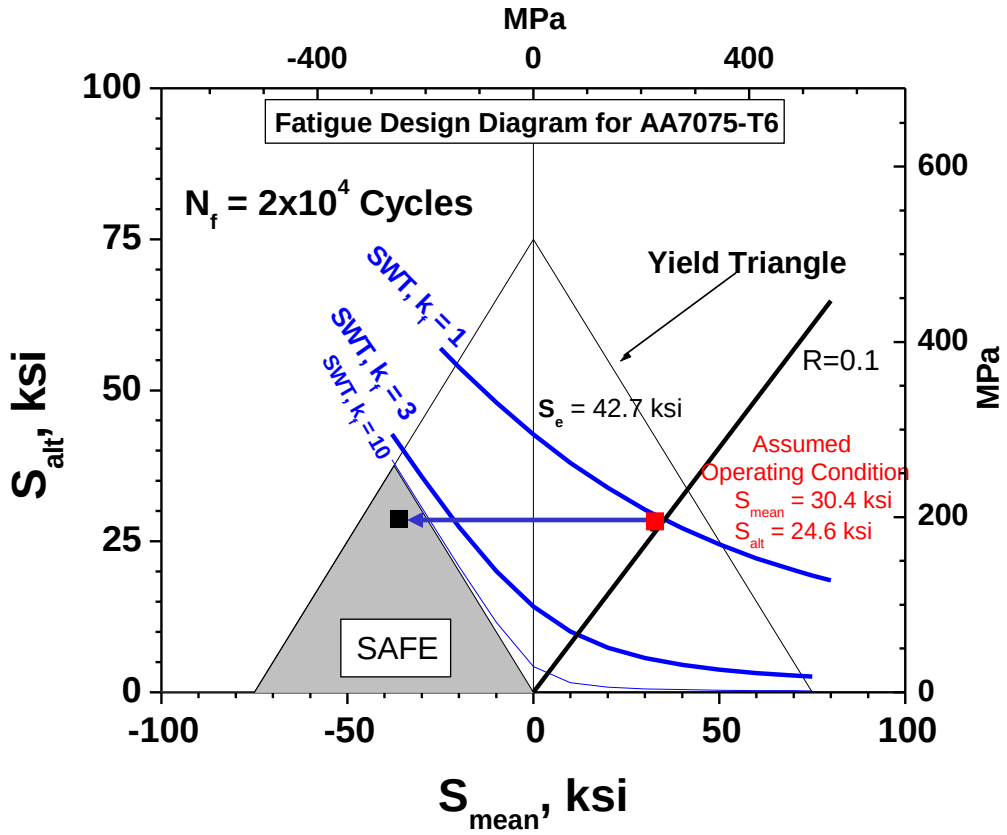
Fatigue Design Diagram



Residual stress of –60 ksi will lead to SAFE zone.
Fatigue life will be extended.

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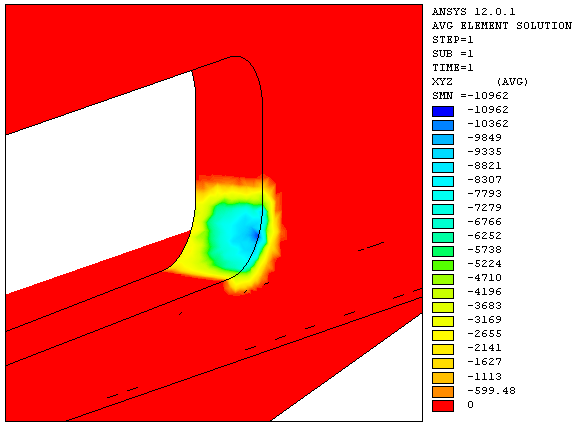
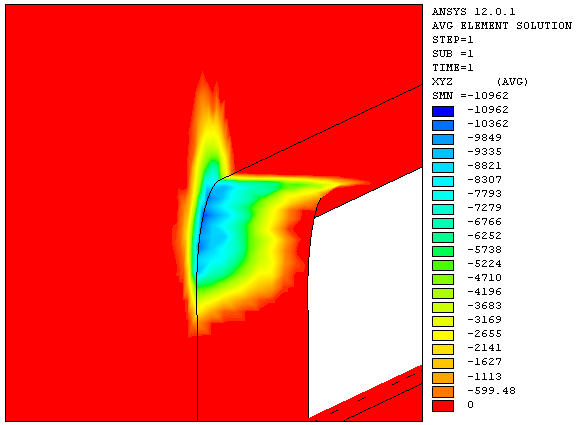
Residual Stress Goals

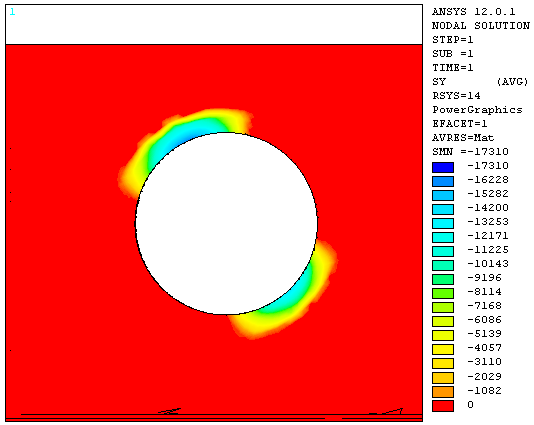
Crack 2



Crack 3



Cracks 4 and 5



Cracks 2 and 3

- **Process inside face rectangular cutout radius**
- **Achieve -60 ksi residual stress in LPB zone**

Cracks 4 and 5

- **Process front and back face of the 2.5”**
- **Achieve -60 ksi residual stress in LPB zone**
- **Achieve through-thickness compression**

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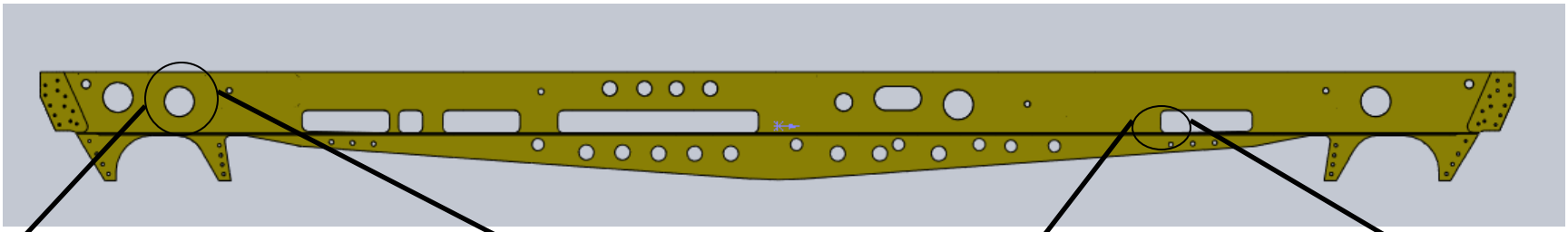
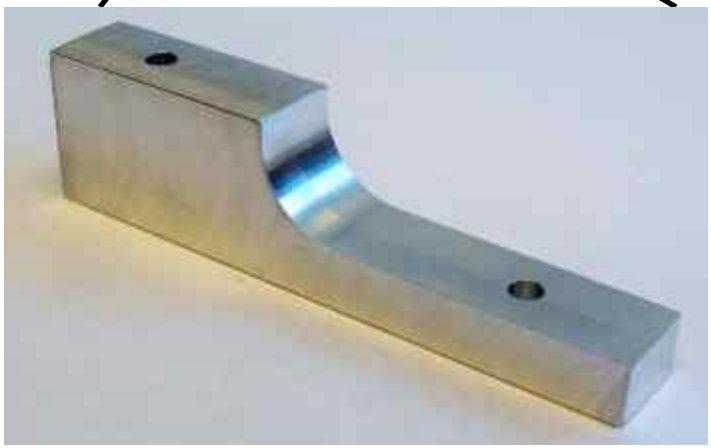
Feature Specimen Design



Cracks 4 and 5



Cracks 2 and 3

Simulate geometry of the fatigue critical areas

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Application of LPB Process

Process design completed

- **Tool design**
- **Process parameters**
- **Processing codes**

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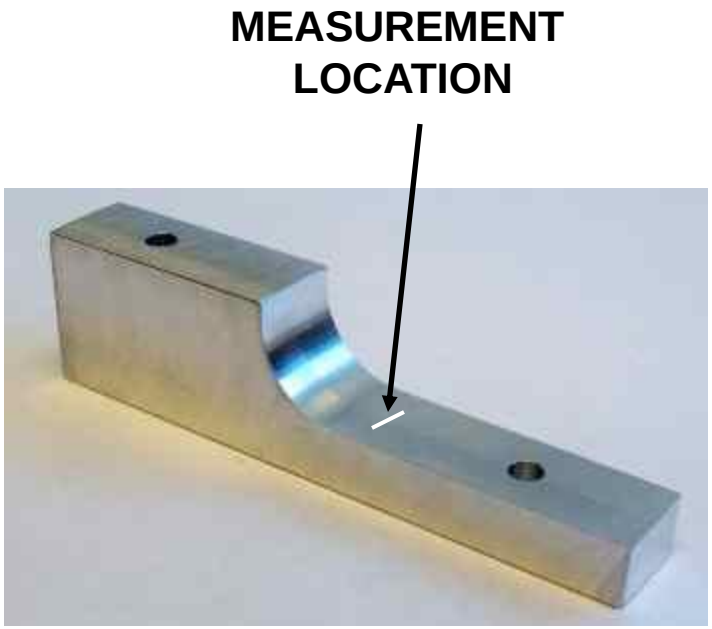
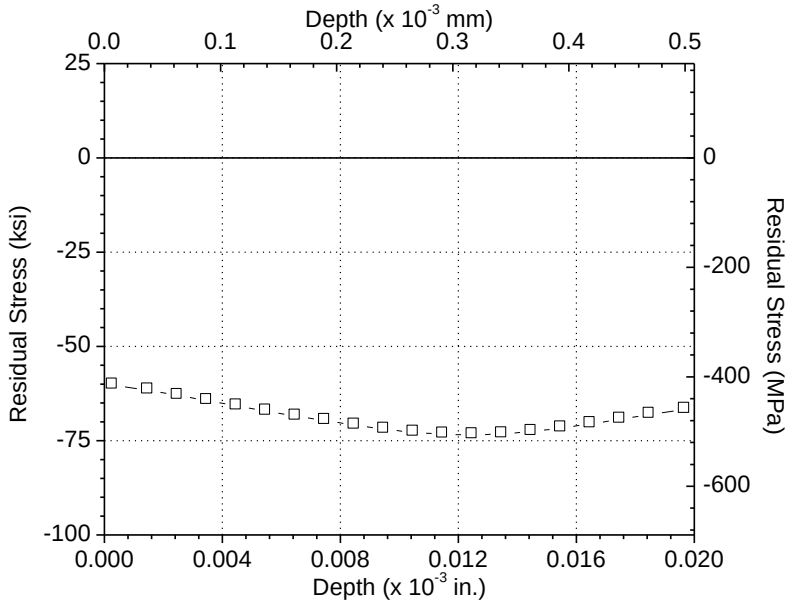
RS Measurement

Cracks 2 and 3 Feature Specimen





Achieved –75 ksi at a depth of 0.010”
Compared to the required –60 ksi

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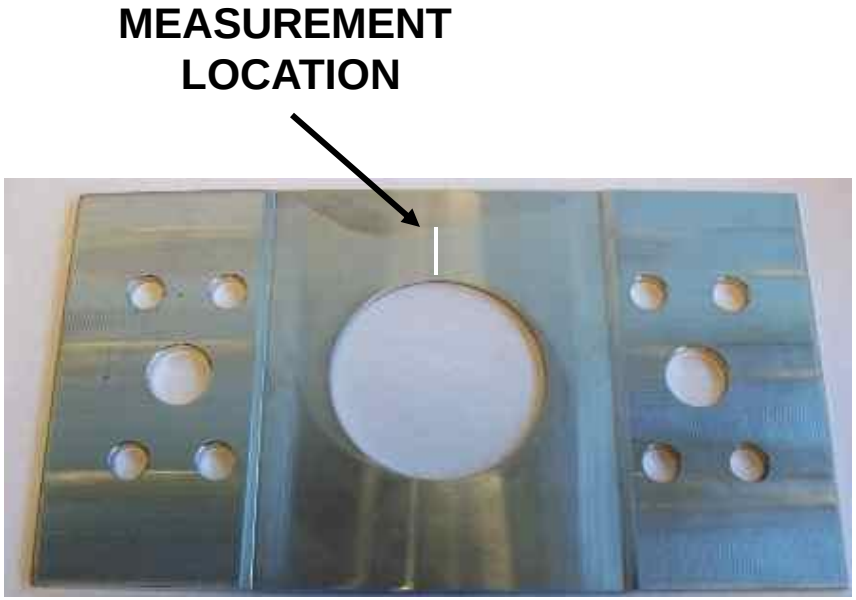
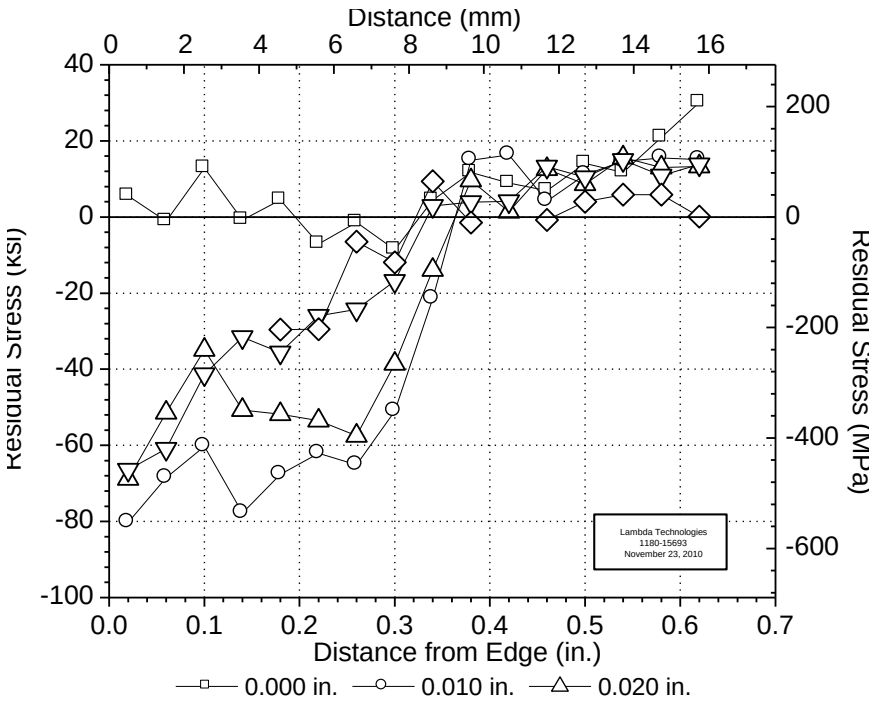
RS Measurement

Crack 4-5 Feature Specimen





Achieved –80 ksi at a depth of 0.010”
Through-thickness compression

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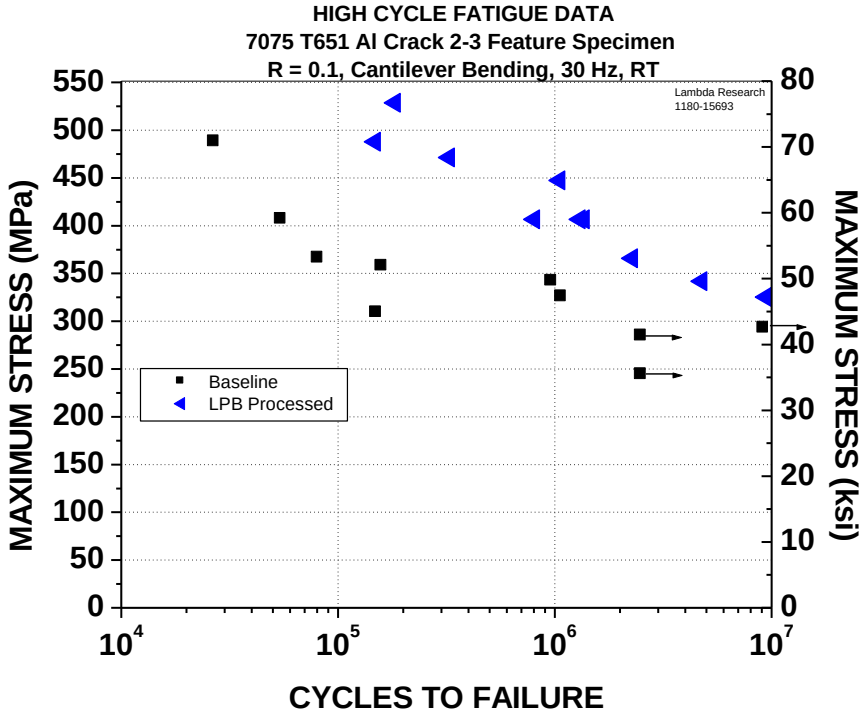
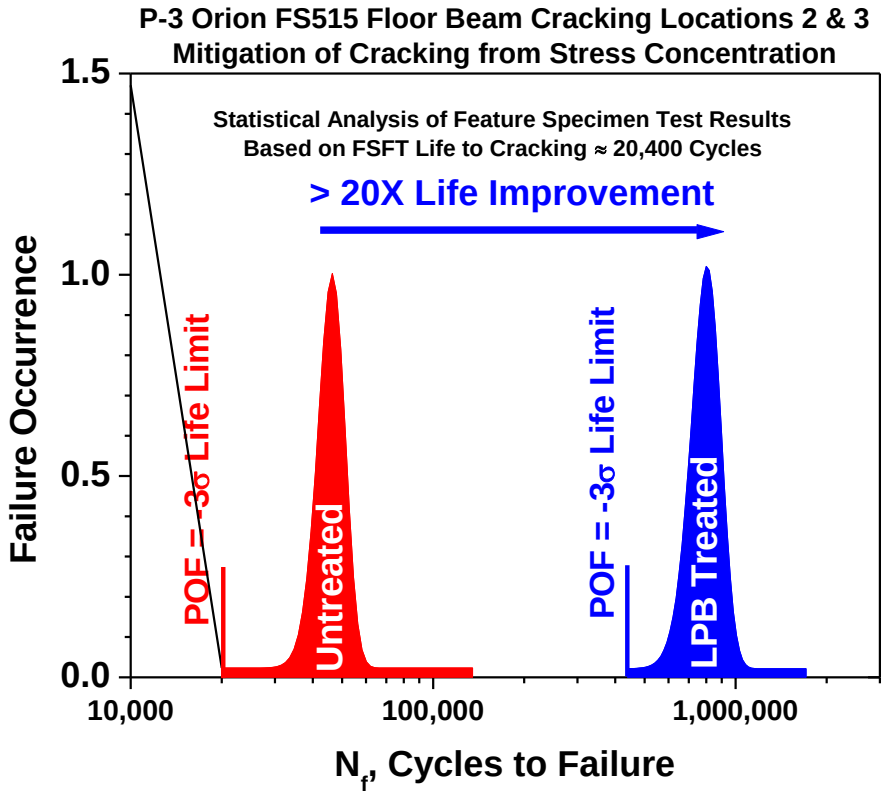
Fatigue Performance Cracks 2 and 3

20x Fatigue Life Improvement





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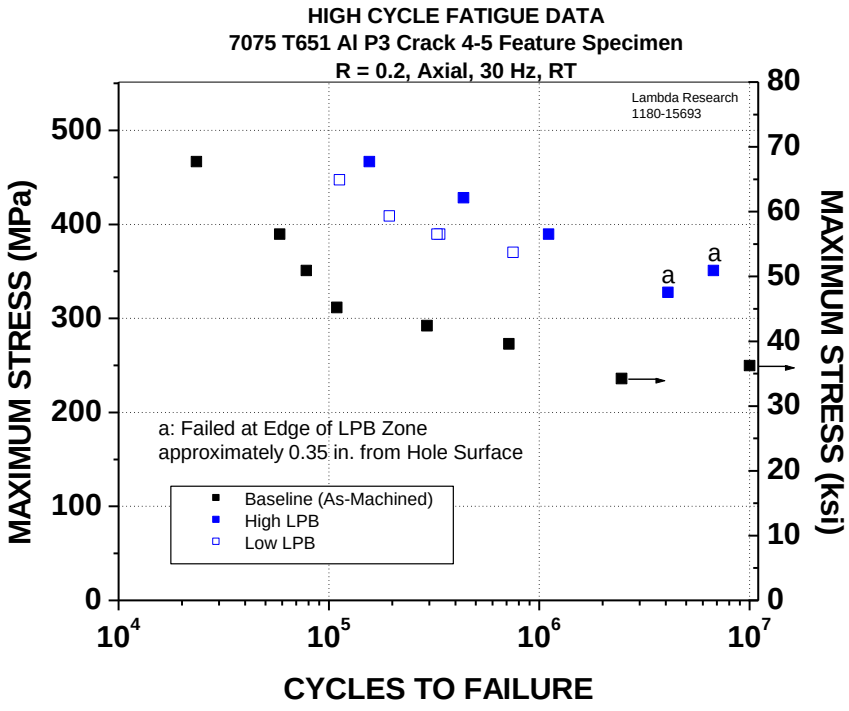
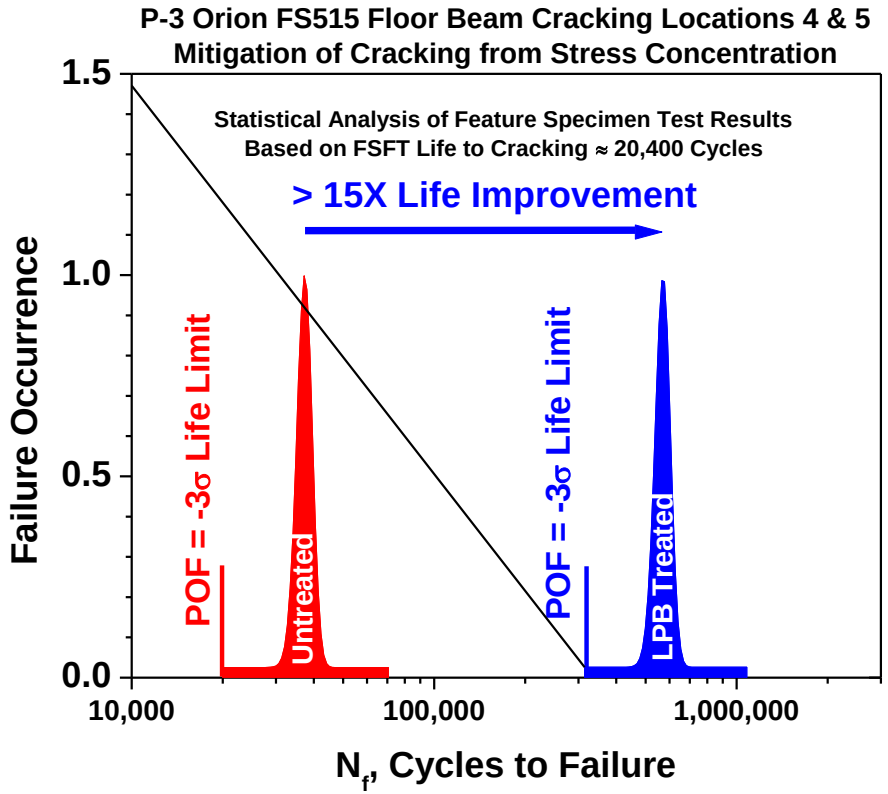
Fatigue Performance Cracks 4 and 5

15x Fatigue Life Improvement

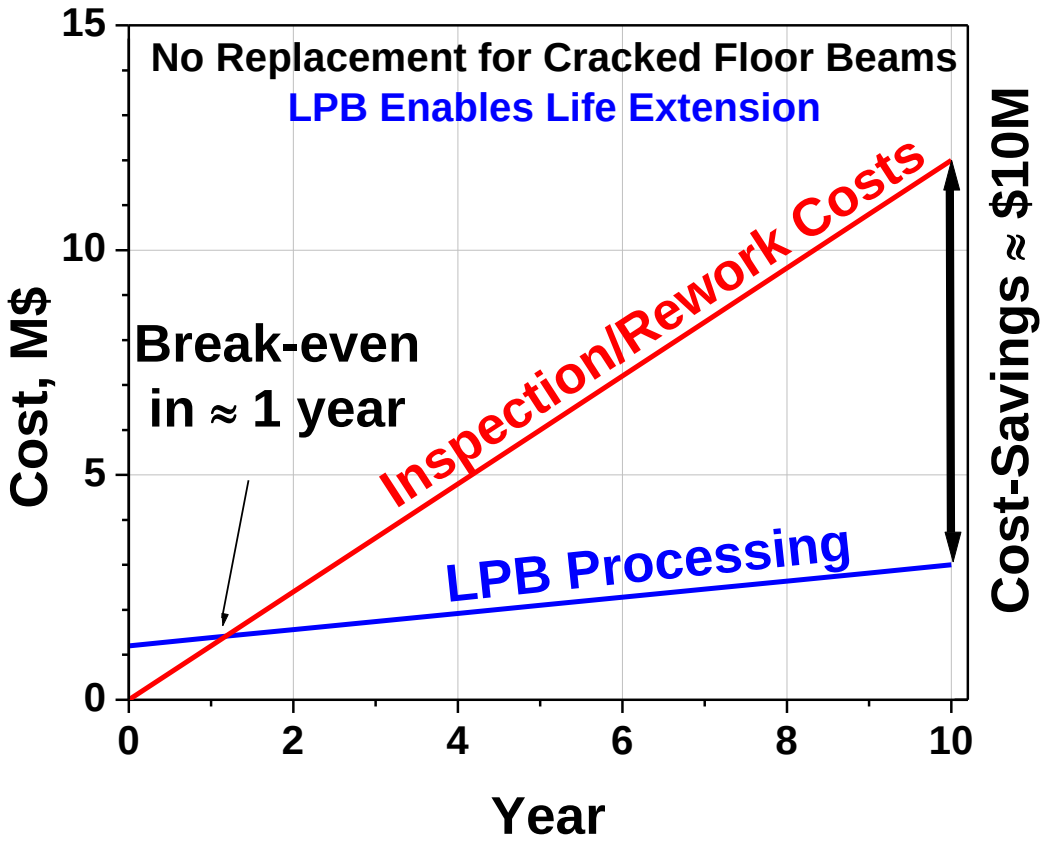




Cost-Benefit Analysis

ASSUMPTIONS:

- 150 aircraft in the fleet
- Maintenance Costs (estimate)
  - 4 inspections till end of life of a/c at $20,000 per inspection
  - No replacement for cracked floor beams
- LPB Processing Costs (estimate)
  - 15 a/c to be LPB treated per year at $12,000 per a/c
  - Initial Non-recurring Costs = $1.2M



Projected Cost Savings ≈ $10M

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Summary – Floor Beam

LPB Processing

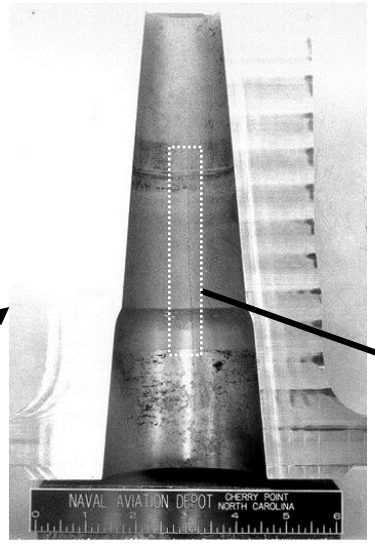
- 15-20X Fatigue Life Improvement
- Extended Service Life Would Reduce or Eliminate Need for Inspections
- Estimated Savings of $10M on Maintenance

LPB Program Phase I complete
Ready for transition to production

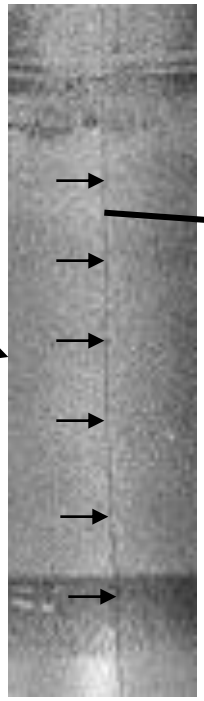
LPB Application to Propeller Bore

SCC in P-3 Propeller Blade Bore

Propeller blade

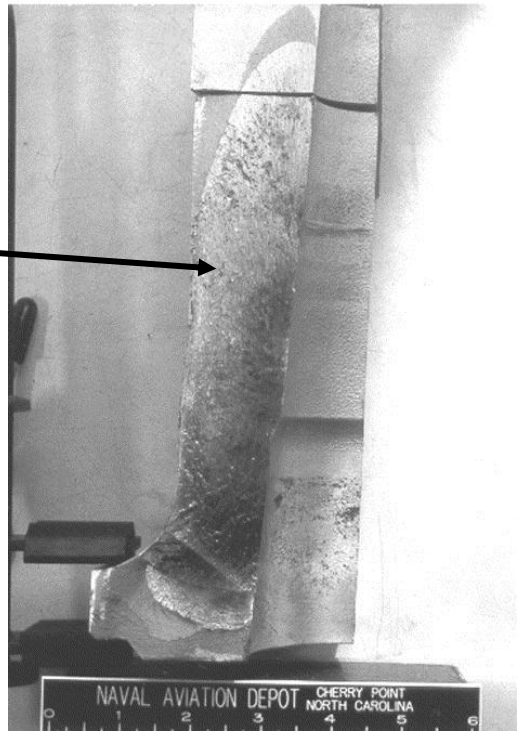


Cross sectional view of the bore prone to SCC



Arrows Indicate the Fracture Face Shown on the Right

Close-up view of the crack (arrows)



Macro fractograph of the fracture surface

Current Repair/Overhaul Practice:

Repeated Heavy Shot peening + Reaming + Re-machining

Blades Scrapped after 3 SP + Reaming Overhaul ~ $35,000 per Blade

Estimated Cost of Current Overhaul Practice : >$1,000 per Blade

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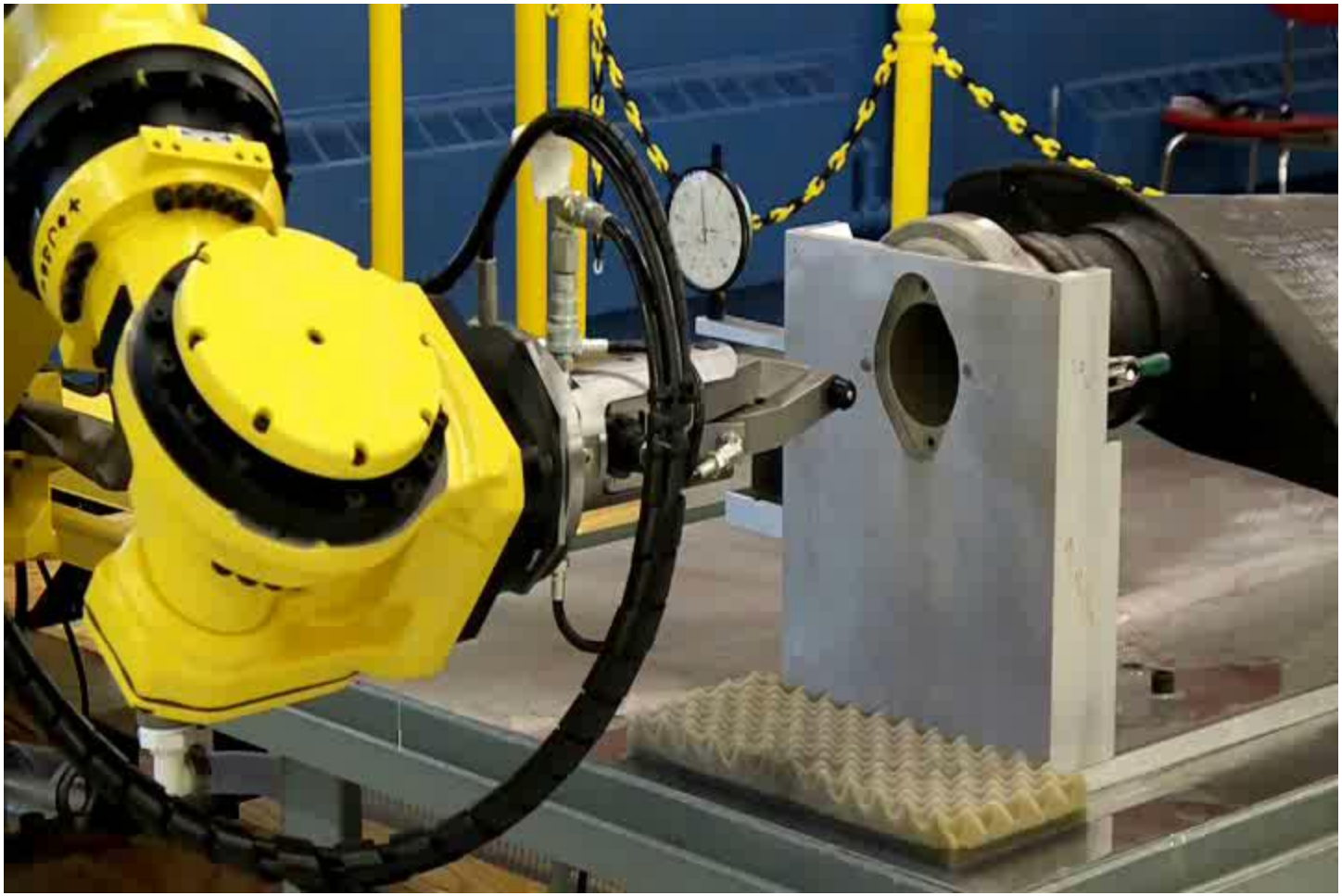
Robotic LPB Treatment of P-3 Propeller Bore



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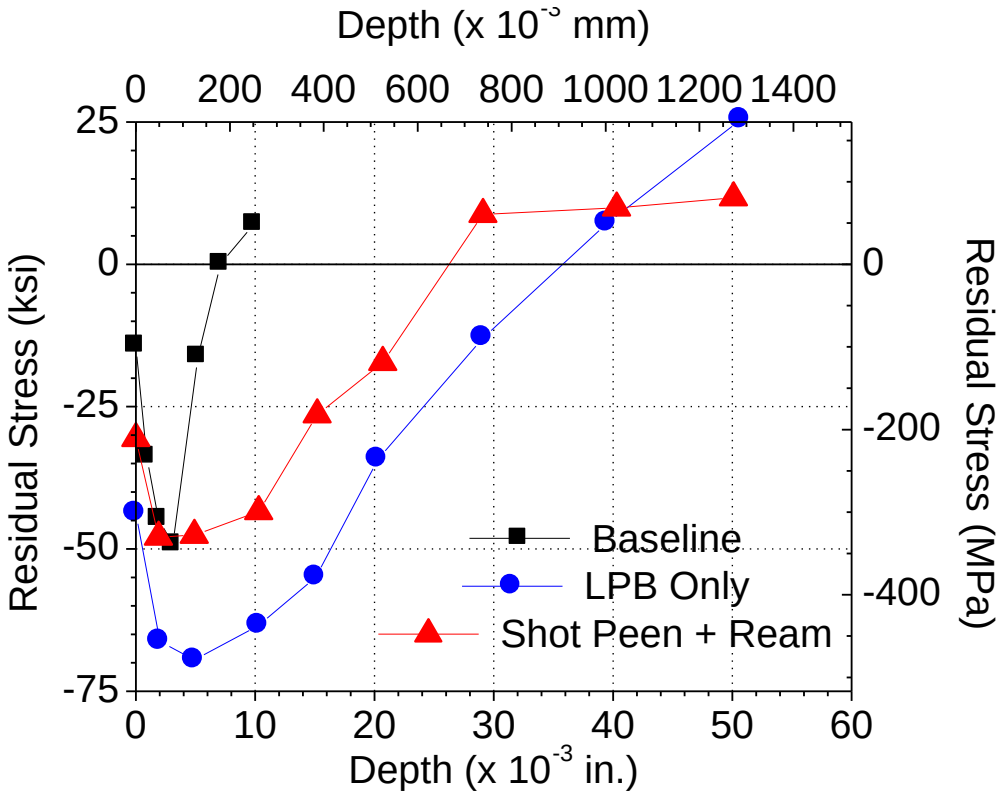
Residual Stress



LPB PRODUCED DEEPER AND HIGHER MAGNITUDE COMPRESSION THAN SHOT PEENING

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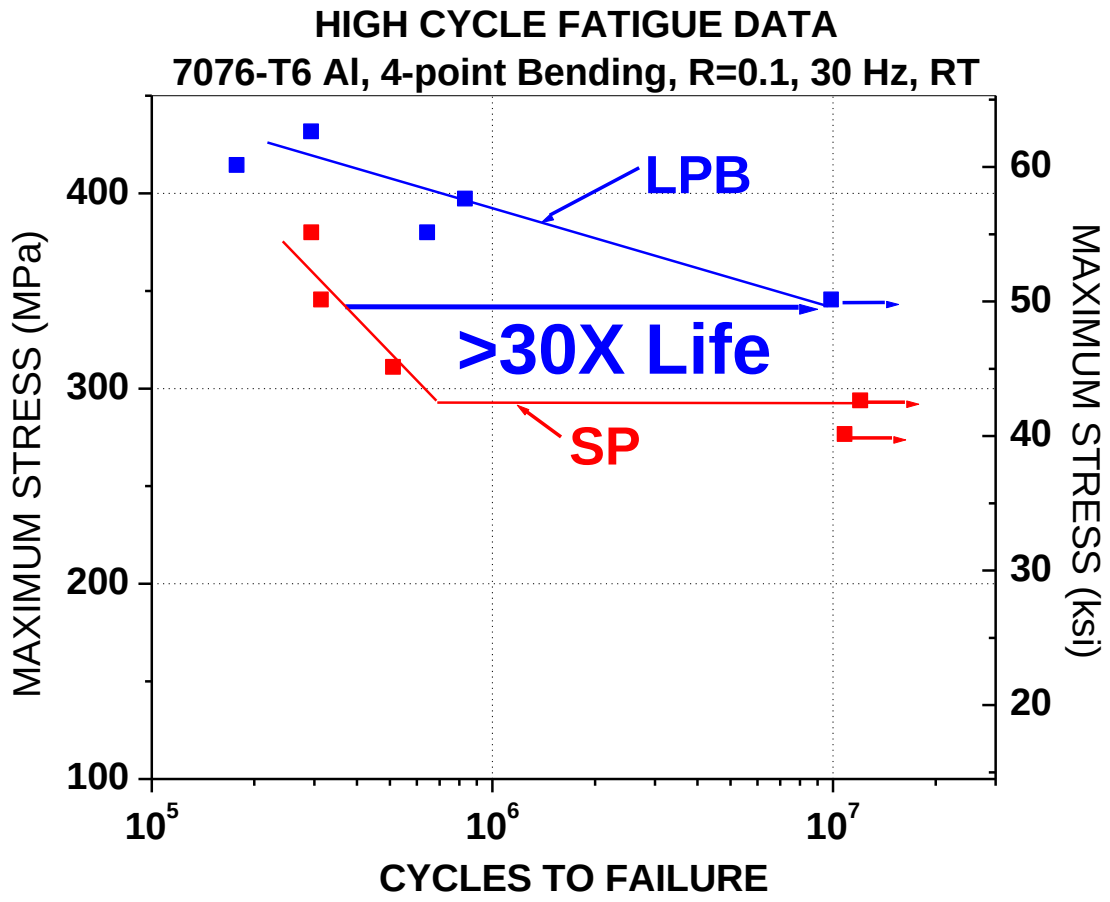
Baseline Fatigue Performance



LPB PRODUCED >30X LIFE IMPROVEMENT

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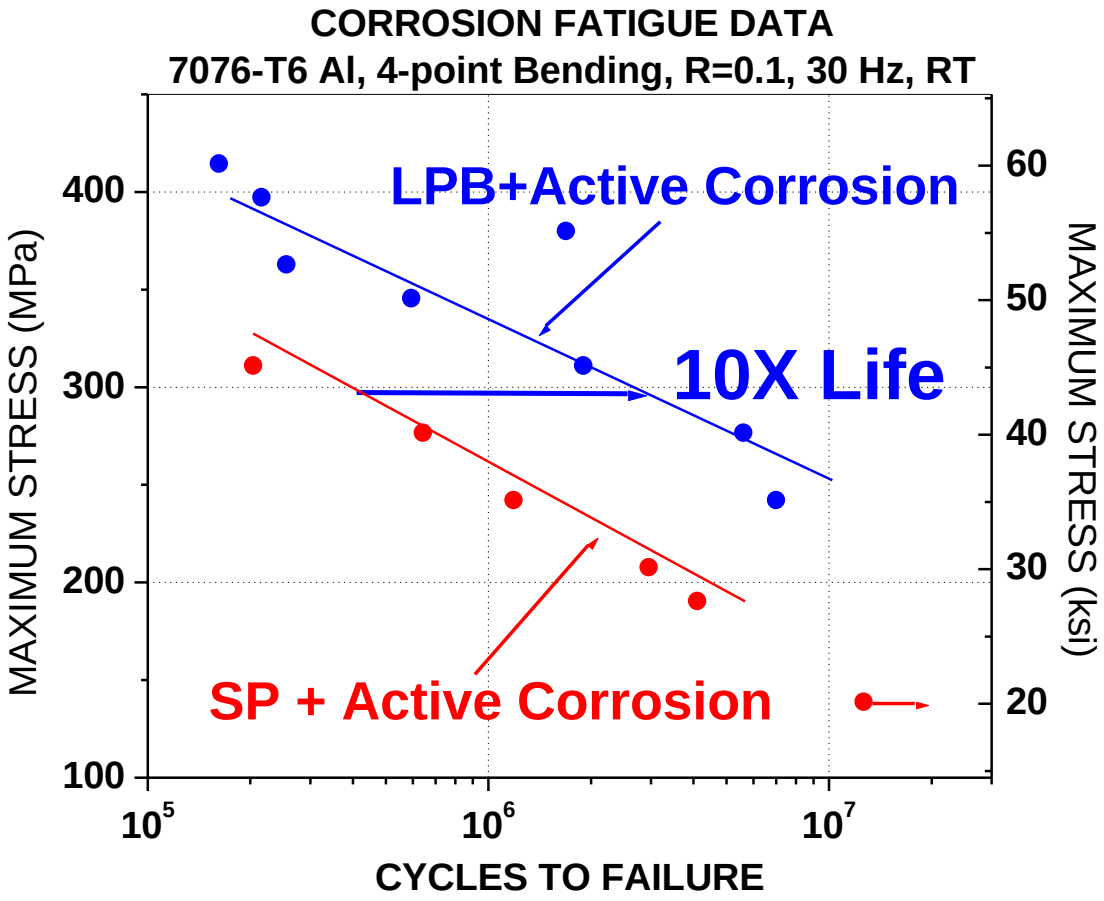
Active Corrosion Fatigue Performance



LPB PRODUCED 10X LIFE IMPROVEMENT

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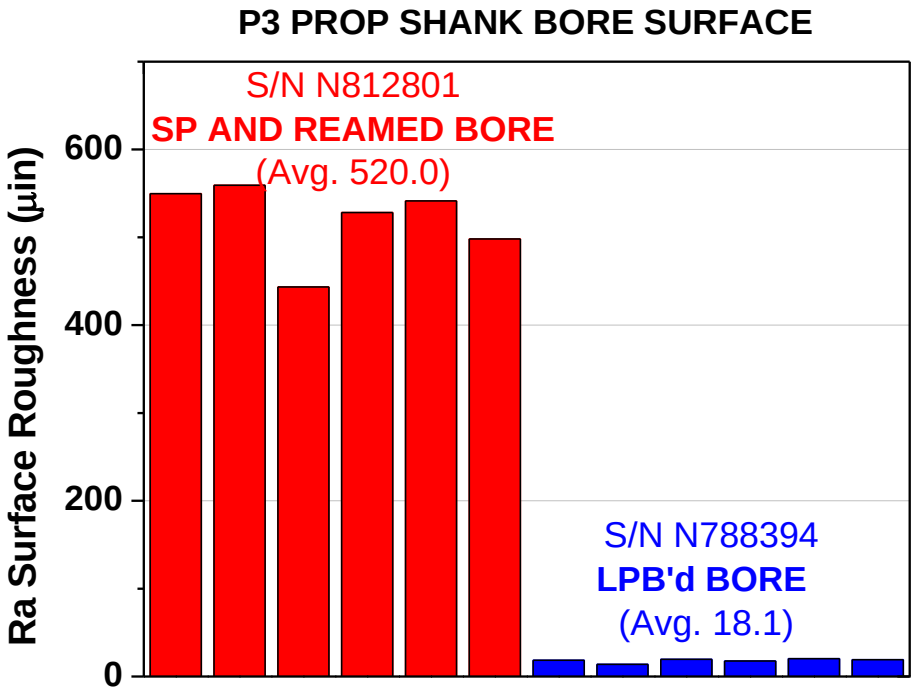
Surface Roughness



MIRROR-LIKE SURFACE FINISH FROM LPB ELIMINATES THE NEED FOR REAMING AND RE-MACHINING

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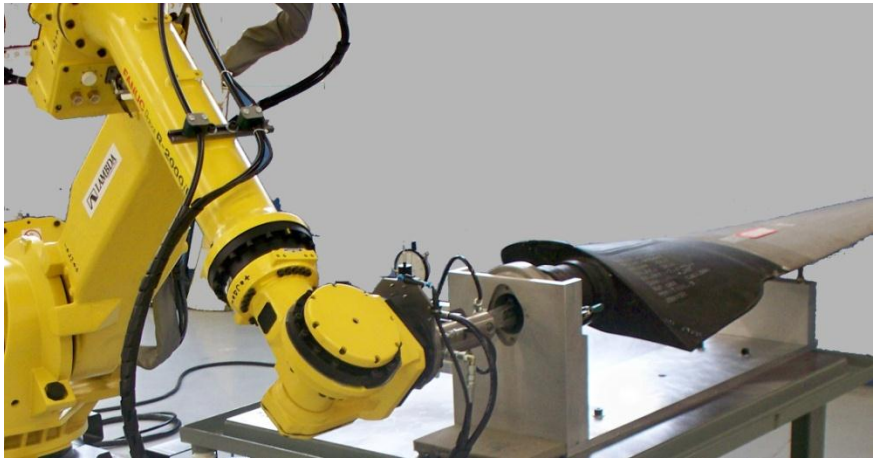
Substitution of LPB for SP

- 30X improved baseline fatigue life
- 10X improved corrosion fatigue life
- Mirror-like surface finish
- One-step process with no loss of material

Saves $1,000 per blade processed
Eliminates 3-cycle scrap rate for $35,000 blade

Integration Into Production

1. NAVAIR – Cherry Point
   - P-3 Overhaul
2. Pacific Propeller Intl.
   - P-3 & C-130 Overhaul
3. Robins AFB
   - C-130 Overhaul



Robotic LPB systems were placed into three MRO facilities. Over 1,000 blades are expected to be processed each year.

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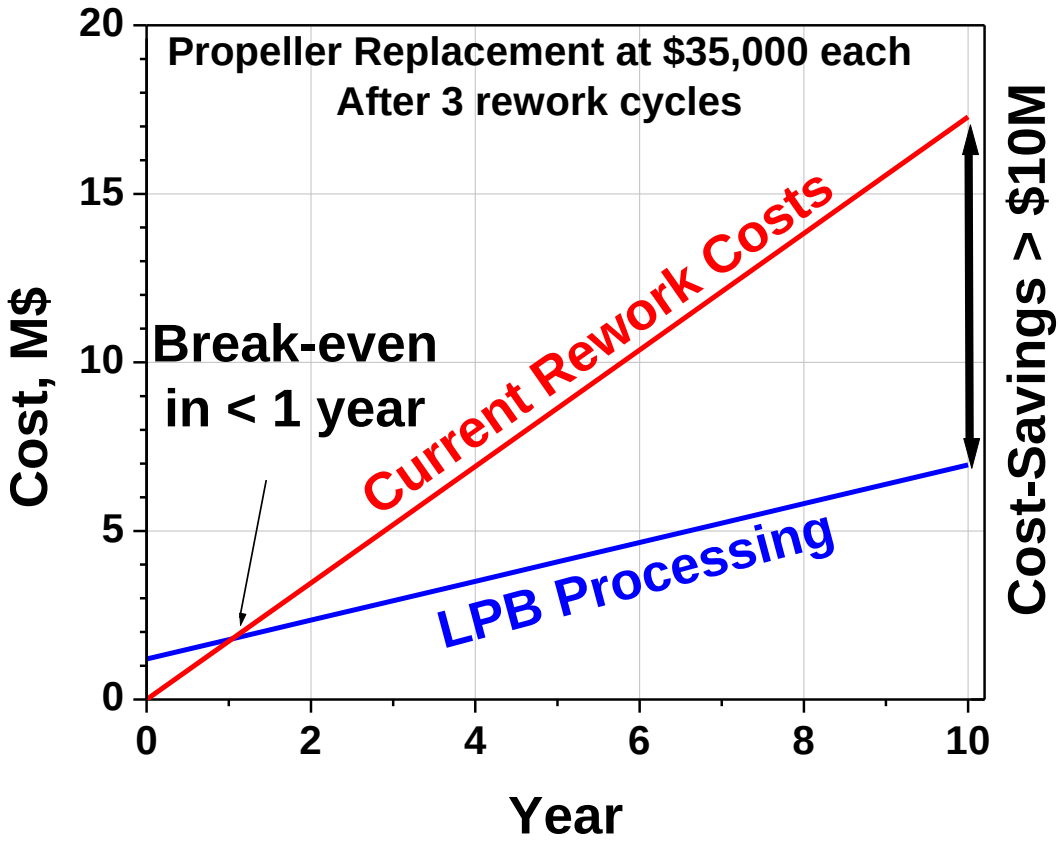
Cost-Benefit Analysis

ASSUMPTIONS:

- Maintenance
  - Repeatedly Shot peened and reamed
    - Blade retired and replaced after 3 rework cycles
- Costs
  - $1,500 per blade
  - $35,000 per blade for replacement
- LPB process costs per year
  - 1,152 Blades per year
  - Initial Non-recurring Costs = $1.2M



Projected Cost Savings = $10M

Projected Cost Avoidance Through Replacement = $35,000 per blade

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Summary – Propeller Bore

LPB reduces maintenance costs by an estimated $1M annually

Elimination of 3-cycle scrap rate is estimated to yield $10M in cost avoidance each year