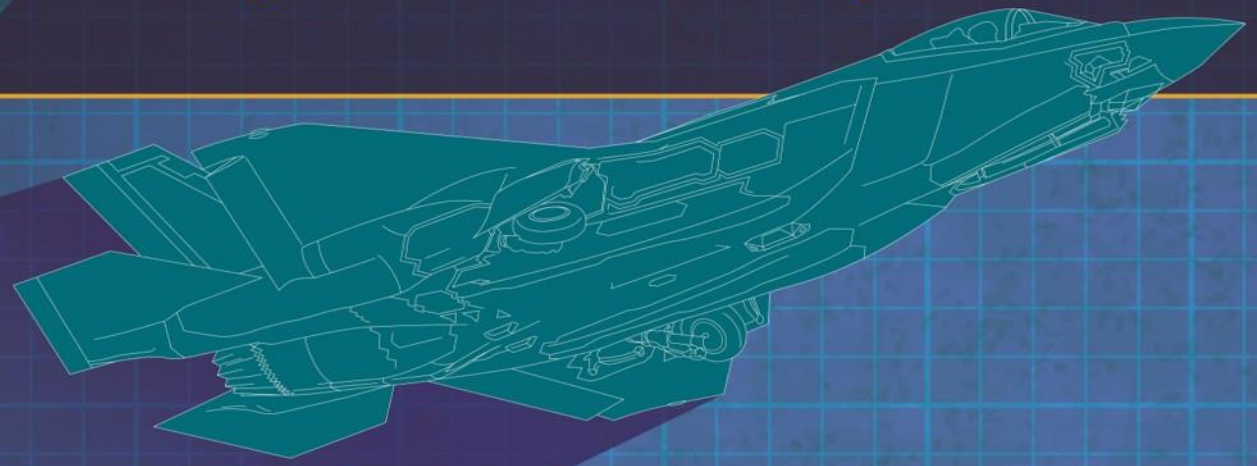
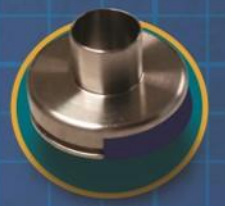
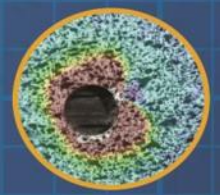
PART WORKS

Reinventing The Future Of Cold Expansion™

COLLABORATE WITH US
FOR EARLY ACCESS TO OUR
PATENT-PENDING* WORK







# Enhanced Technology Repair for Corrosion and Fatigue Damage in Hybrid Aerostructure

Authors:
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Jude Restis

ICAF 2023
Presented by Jude Restis
June 2023

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# Galvanic Corrosion of Hybrid Structure

Widespread galvanic corrosion damage experienced on multiple programs with composite over aluminum in the presence of moisture



US Navy Inspector General Report
As reported in Navy Times
By Diana Stancy Correll
Oct. 5, 2021

> "Between FY17 and FY20, corrosion costs accounted for $2,086,796,553, amounting to 29.4 percent of the total maintenance cost for [F-18C-G] aircraft."

From "In-service Corrosion Issues in Sustainment of Navy Aircraft" briefing, R. Mendoza, Aug 2012

## F-18's Awaiting Depot Induction at North Island

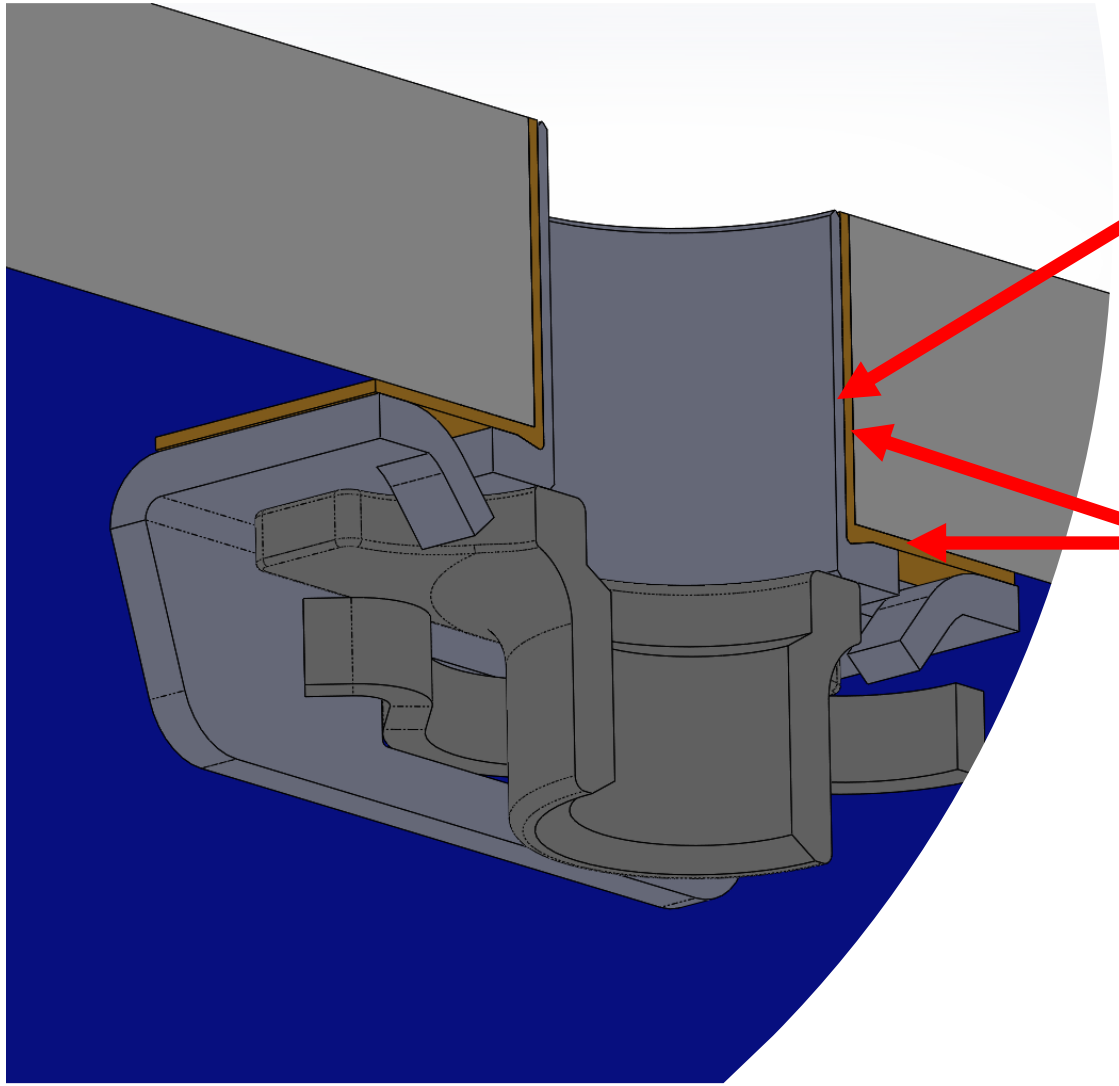
Typical repair:

- Ream hole to remove all corrosion
- Perform analysis
- Install oversize fastener or bushing

Navy indicated to repair a single corroded bolt hole may take several weeks and cost many thousands of dollars

Leveraging years of experience and extensive knowledge of airframe design and repair, Partworks conceived of better way to repair corroded fastener holes

# PartWorks Repair – Thin Wall Bushing or Nut Plate



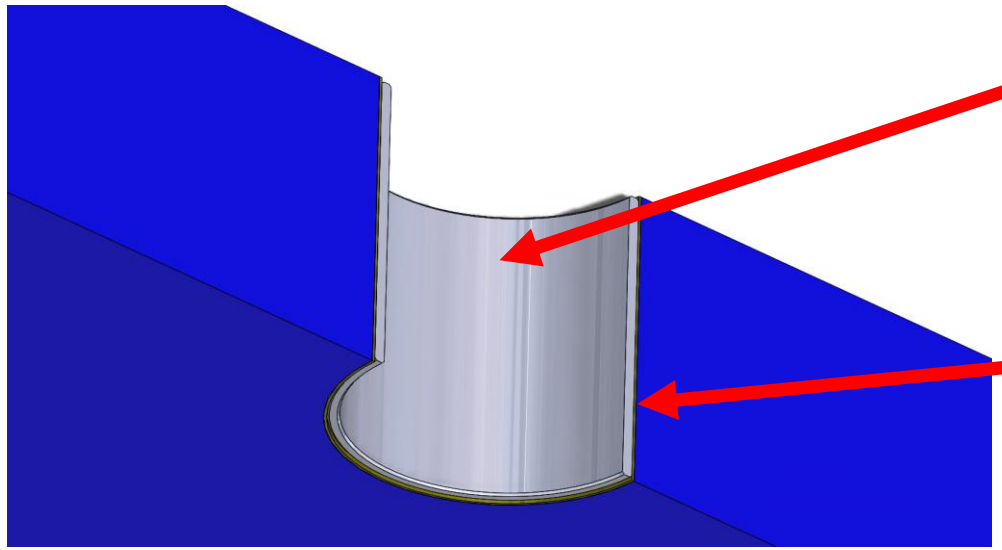
**Thin wall**

- CRES barrel
- Minimizes material removal
- Maximizes e/D
- Maximizes engineering residual stress (cold expansion) in the structure

**Adhesive**

- Maximizes torque-out and push out
- Galvanic barrier
- Minimal surface preparation

# PartWorks Bushing Repair



## Thin wall

- CRES Bushing barrel
- Minimizes material removal
- Maximizes e/D
- Maximizes cold expansion to the structure

## Adhesive

- Galvanic barrier
- Minimal surface preparation

# Test Program

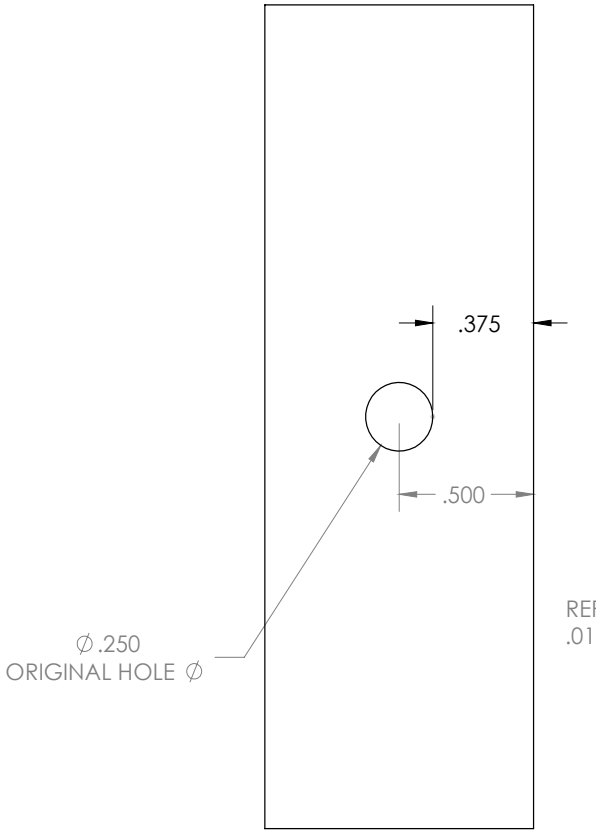
Carried out in Conjunction with:

- University of Dayton Research Institute (UDRI)
- Goose Meadow Engineering at Montana State University
- Georgia Tech

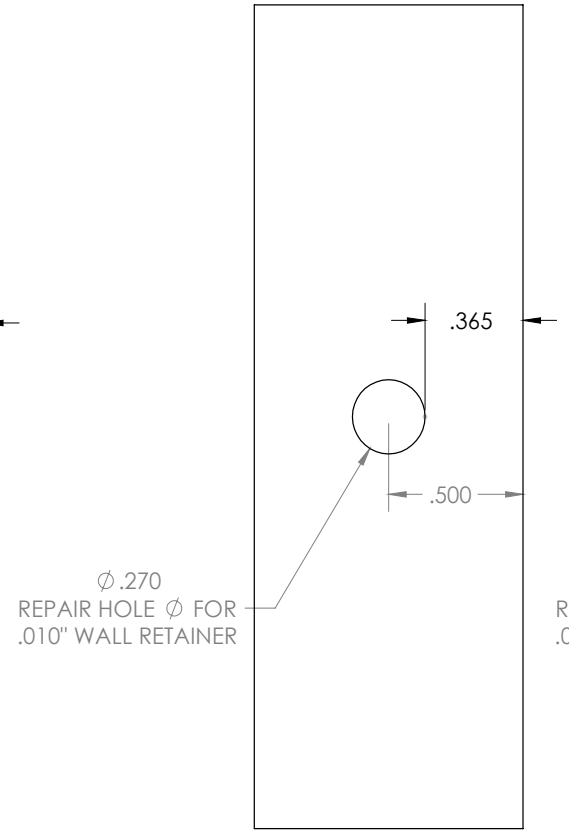
- Quantify damage experienced in USN & USAF Fleets due to galvanic corrosion
- Develop techniques to replicate corrosion damage on test coupons
- Perform fatigue testing to assess debit/enhancement in fatigue life due to corrosion and Partworks repair
- Perform computational analysis to correlate fatigue behavior and predict residual stress
- Evaluate residual stress field using Digital Image Correlation (DIC) and correlate with X-Ray diffraction measurements and FEA
- Develop tooling and measurement techniques to allow taking credit for repair (in-process measurements)
- Develop Adhesive & Sealant to prevent corrosion

# Preserve Edge Margin

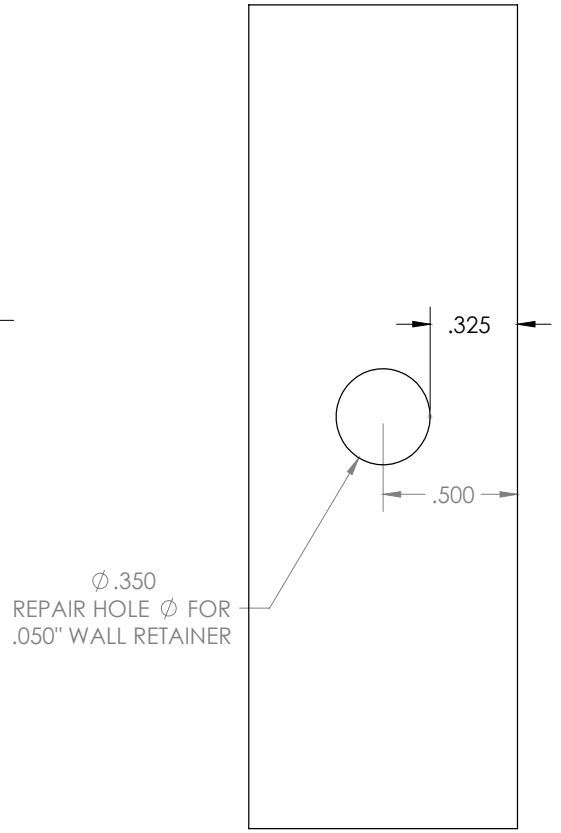
## Ideal Design
e/D = 2.0




## PartWorks
e/D=1.85

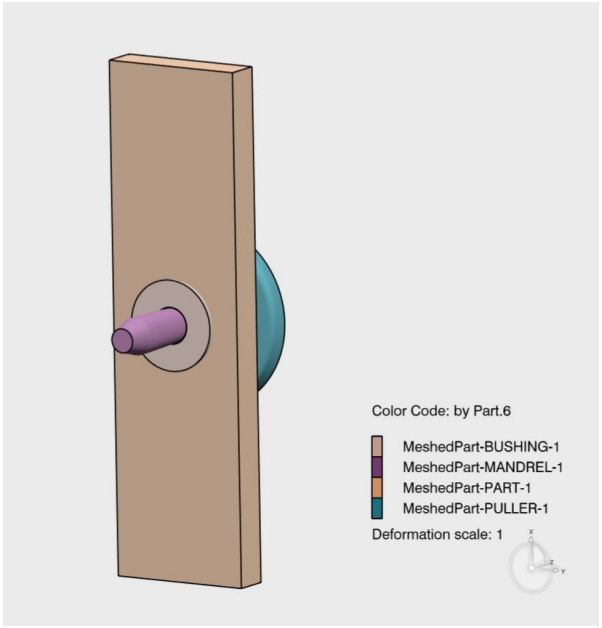


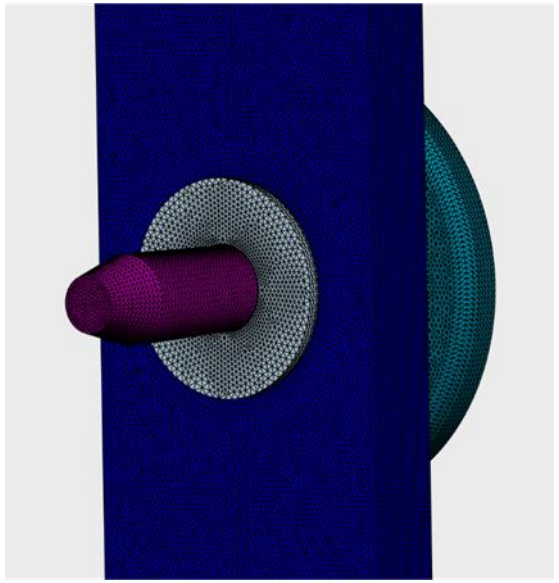

## Status Quo
e/D = 1.43

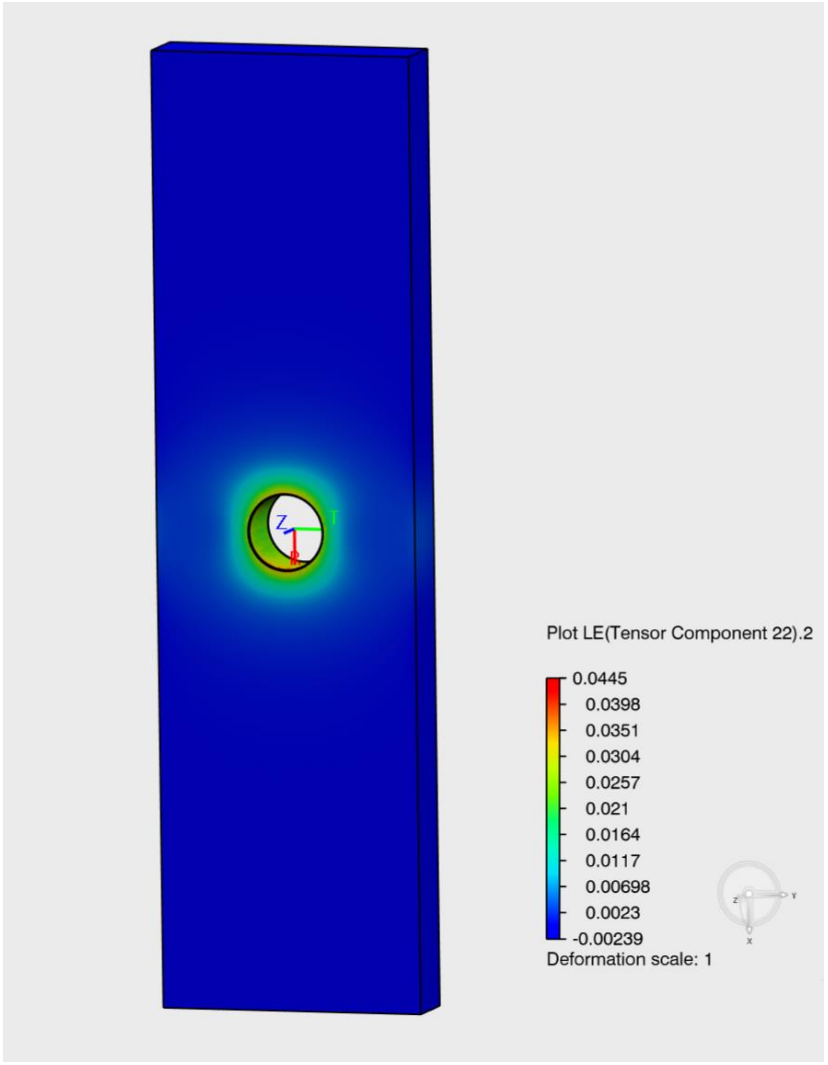


# FEA - Process Simulation

- 3-D Pull Through Model
- Elastic-Plastic Properties of the Material

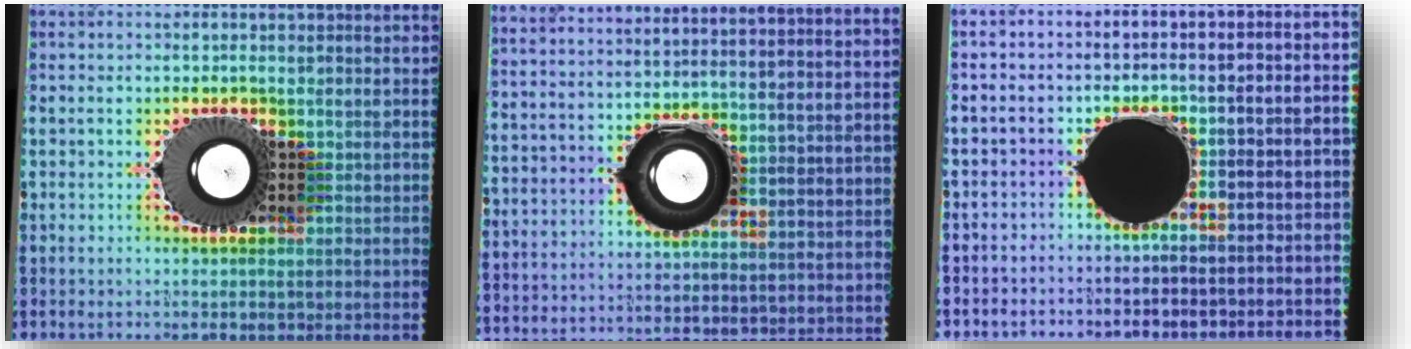


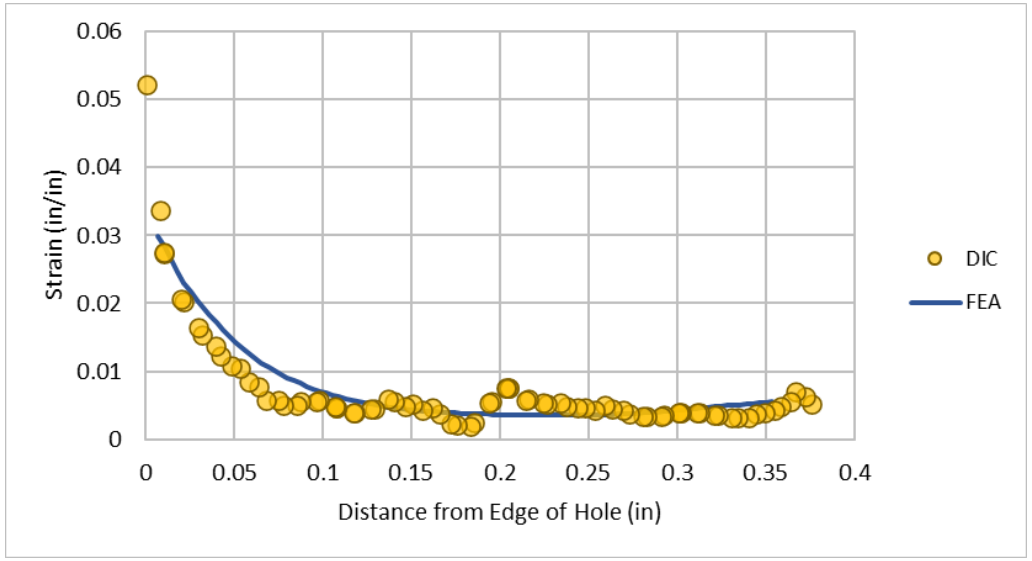





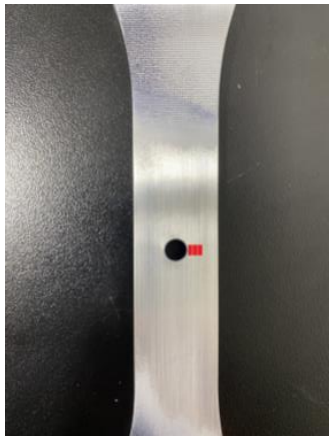
## Residual Strain Visualization with DIC

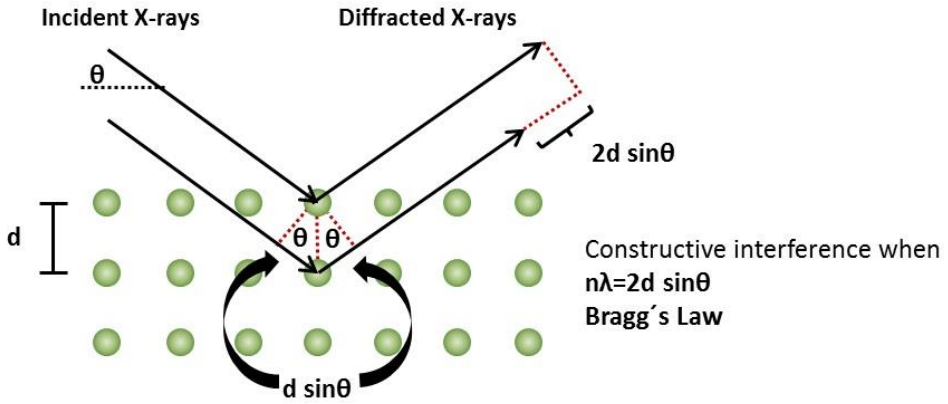
- Image Capture:  Before, during and after repair
  - On-tool image capture
- DIC used to correlate residual strain with FEA
- Will also be correlated to X-Ray diffraction

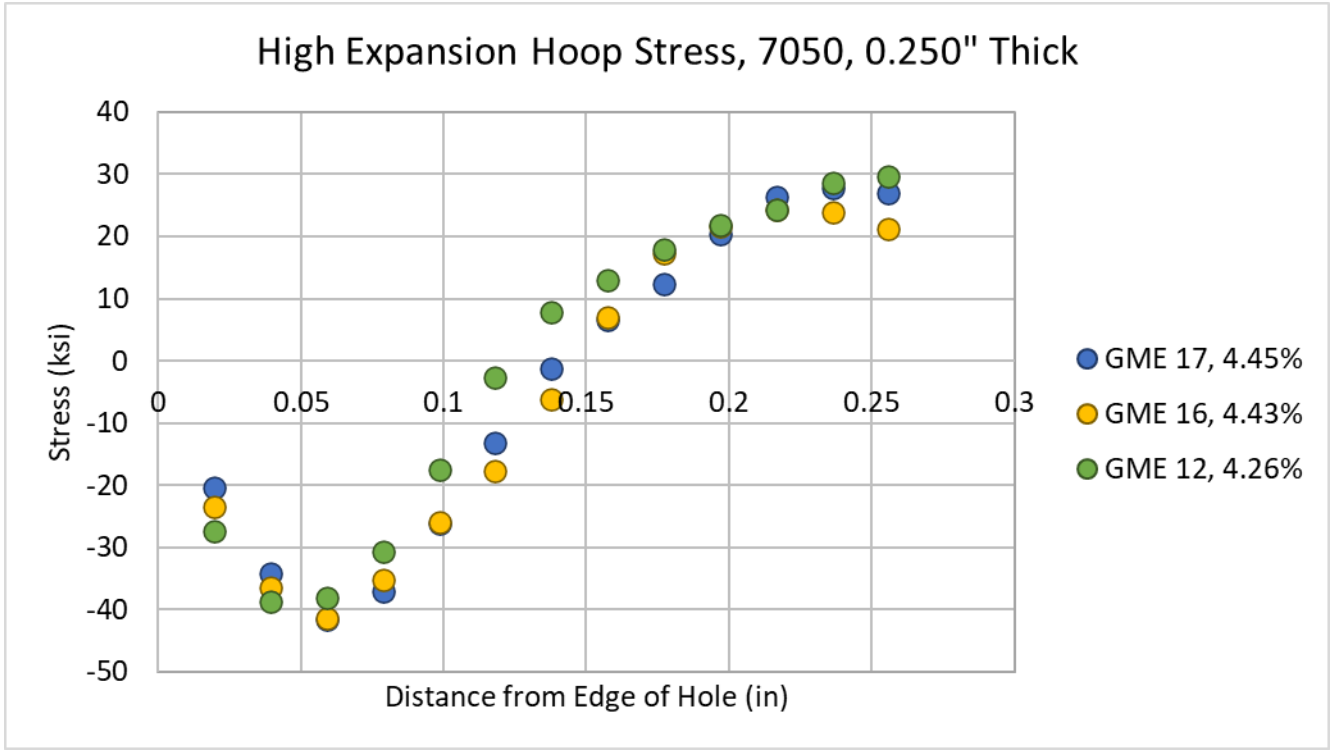




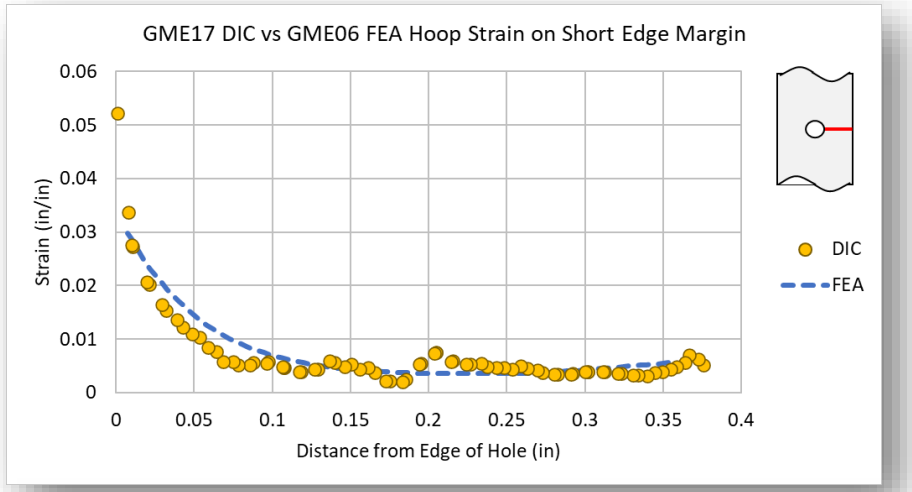
# X-Ray Diffraction

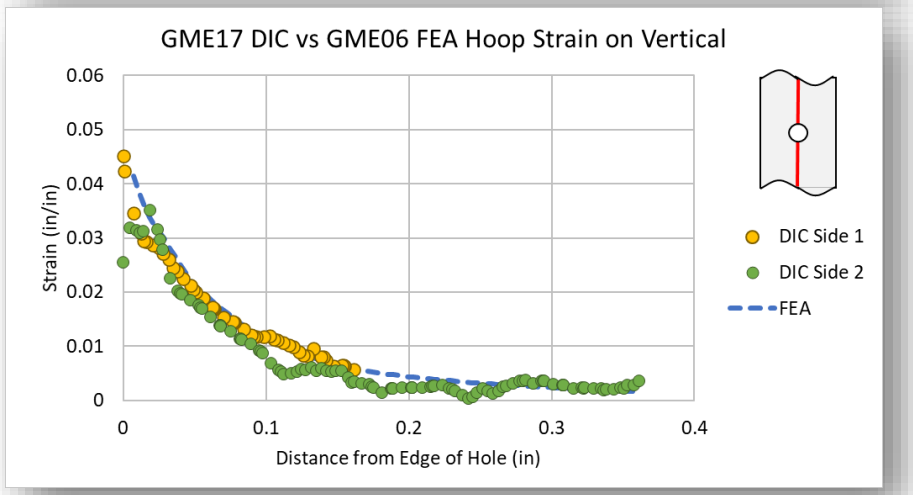


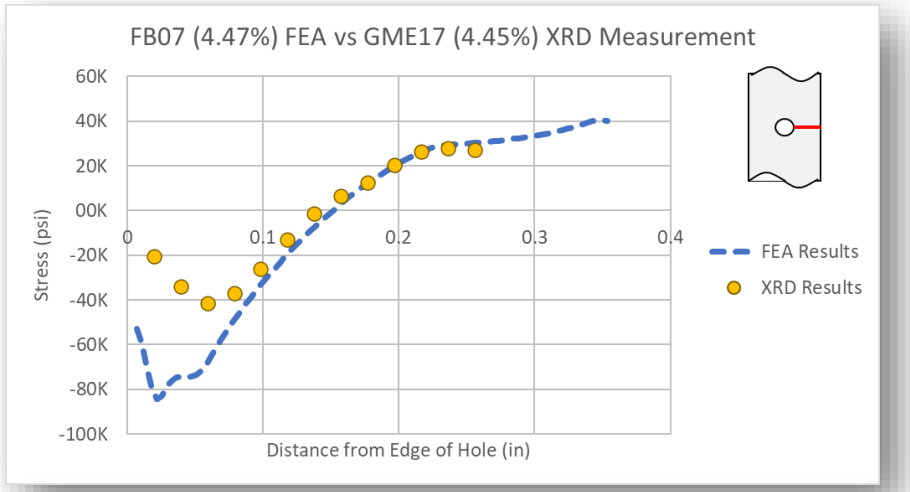


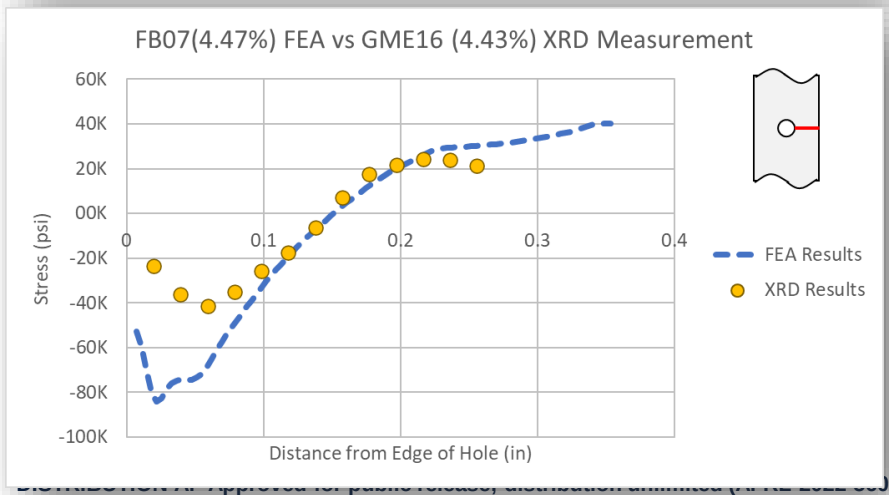



- Correlation – FEA, Digital Image and X-Ray Diffraction



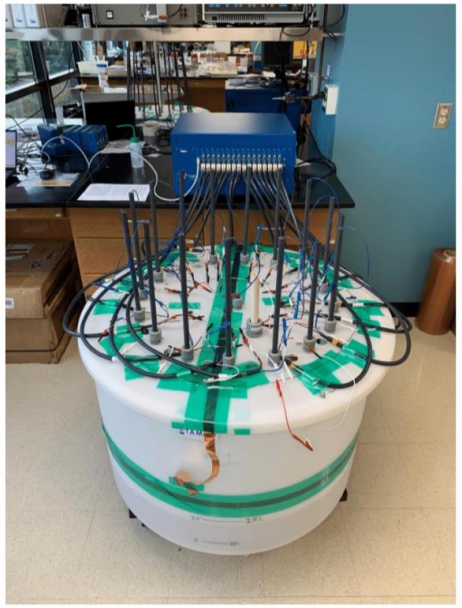



# USAF Test Program

- Testing
  - Corrosion
  - Fatigue

# Corrosion Protocol Development



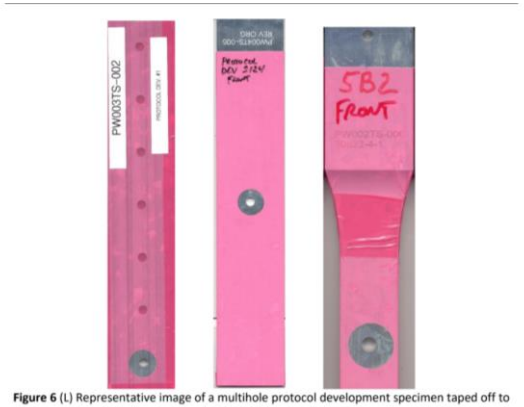



**Figure 6** (L) Representative image of a multihole protocol development specimen taped off to expose one bore hole for corrosion testing; (C) Representative image of a single hole protocol development specimen taped off to expose one bore hole for corrosion testing; (R) Representative image of a dog bone fatigue test specimen taped off to expose the bore hole for corrosion testing (note: only top 2/3 of dog bone visible in scan image, although entire dog bone was taped).

- NaCl and NaAlO2 solution
- Dogbones masked with electroplaters tape
- 0.25 in dia. hole, 0.75 inch dia. surface exposure each side of dogbone

# Corrosion Protocol Development

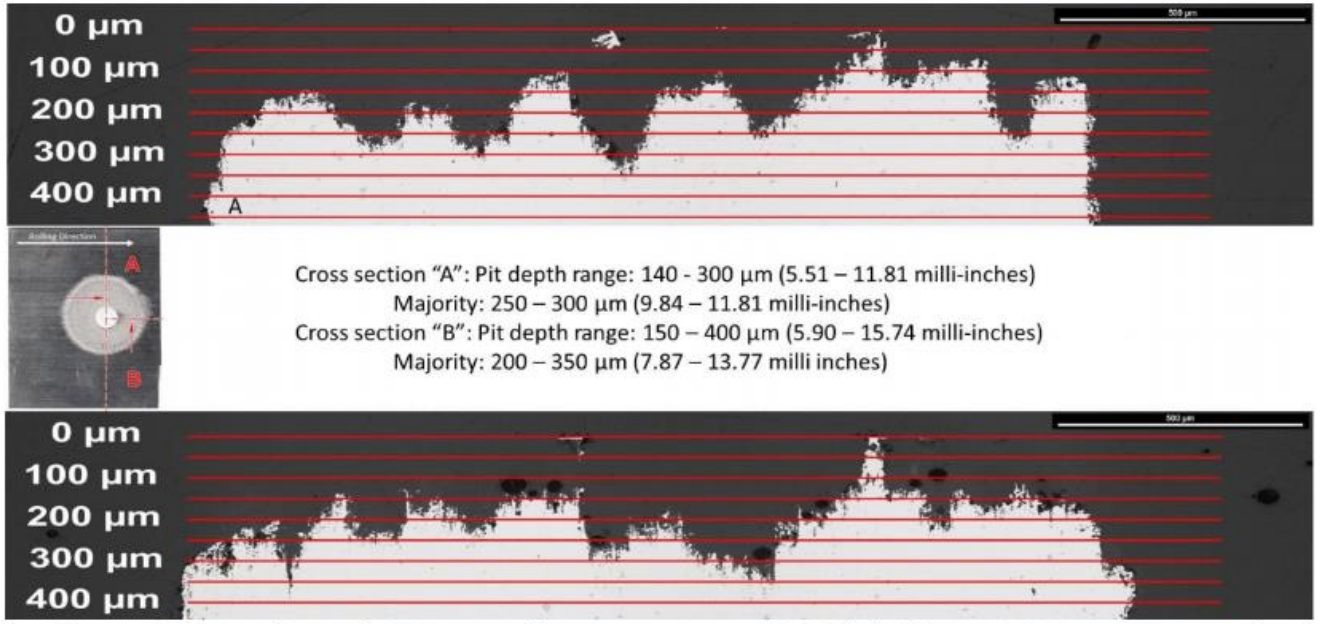
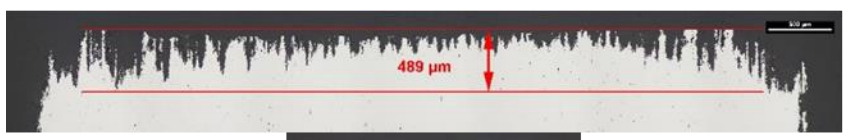
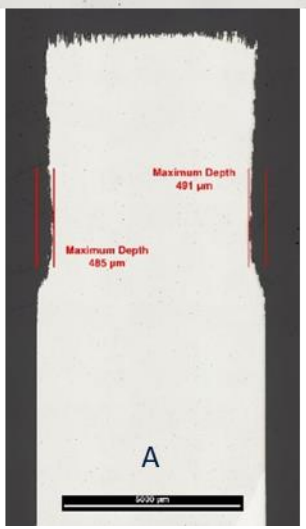


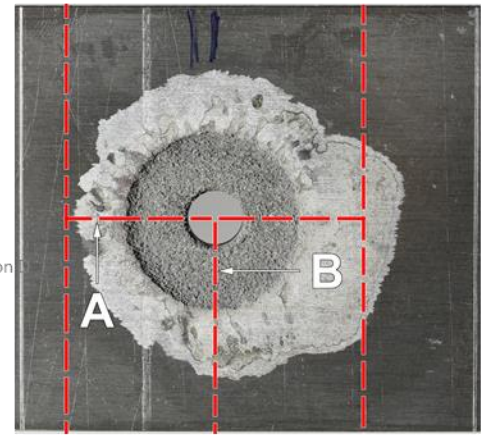

**Figure 14.** Metallographic images of cross-sections of 0.06" thick AA7050-T7541 protocol development specimens along the bore hole wall at "A" orientation (Top) and "B" orientation (Bottom) after 120 hours of corrosion testing.

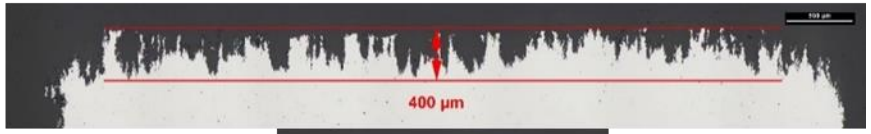
0.06 thick 7050 – 120 hour corrosion protocol

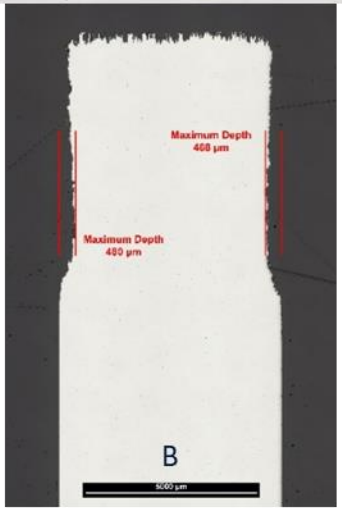
# Metallographs of Plate Surface and Fastener Hole Wall



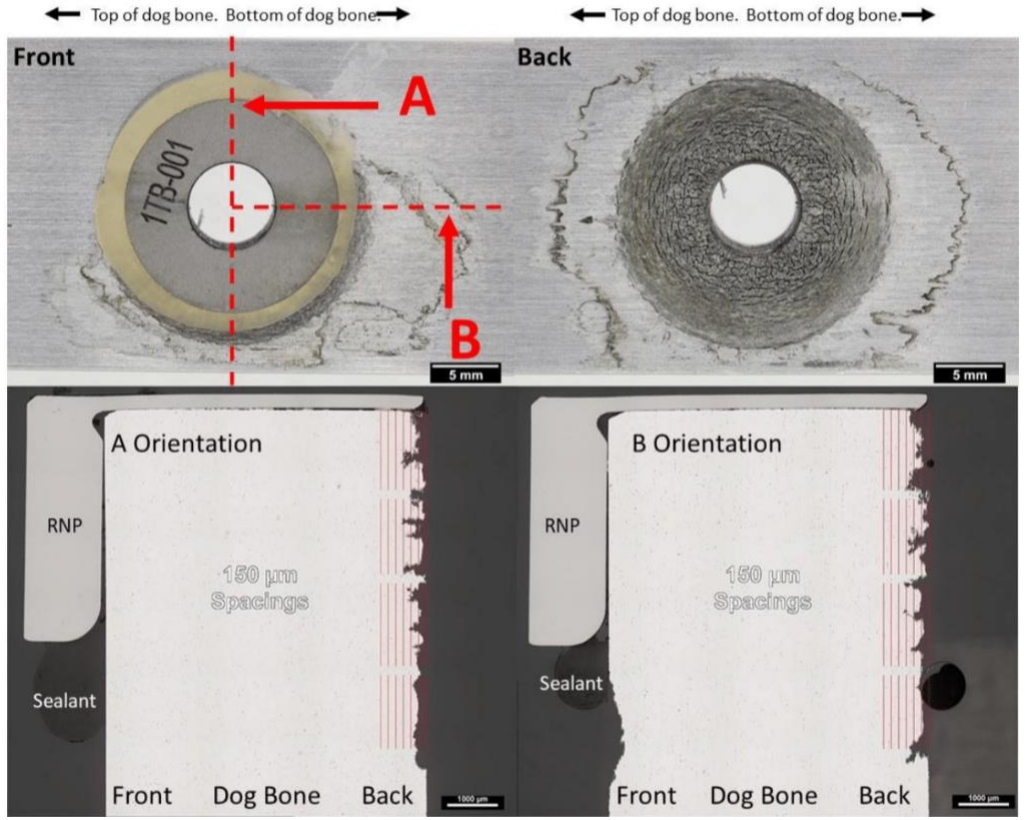



# Adhesive - Galvanic Barrier






7050 material – 120 hour corrosion protocol

University of Dayton Research Institute
CONTRACT FA8650-21-C-5230
Final Technical Report

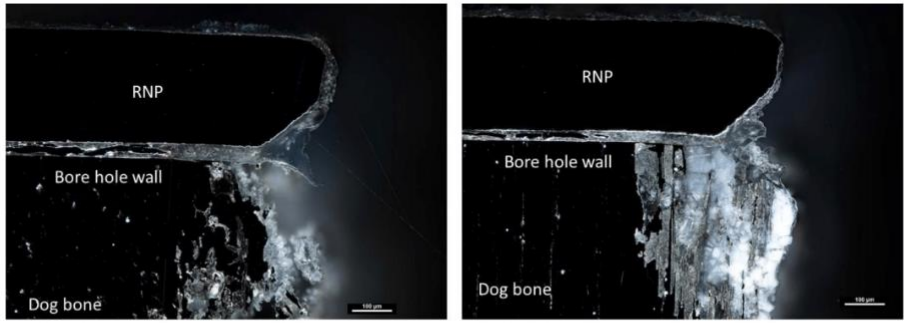
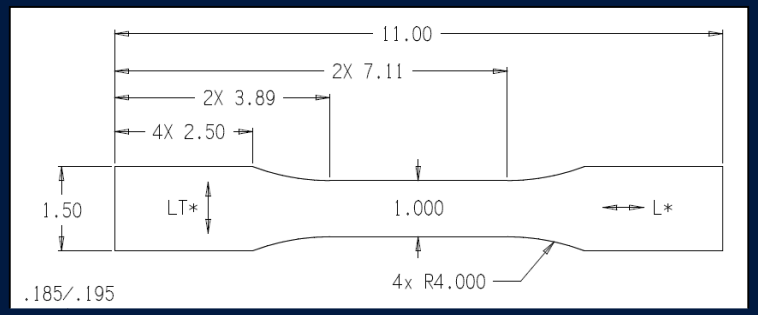



**Figure 24.** Dark field image of RNP-sealant/bore hole wall interface on back of dog bone. (Left) Orientation "A". (Right) Orientation "B".

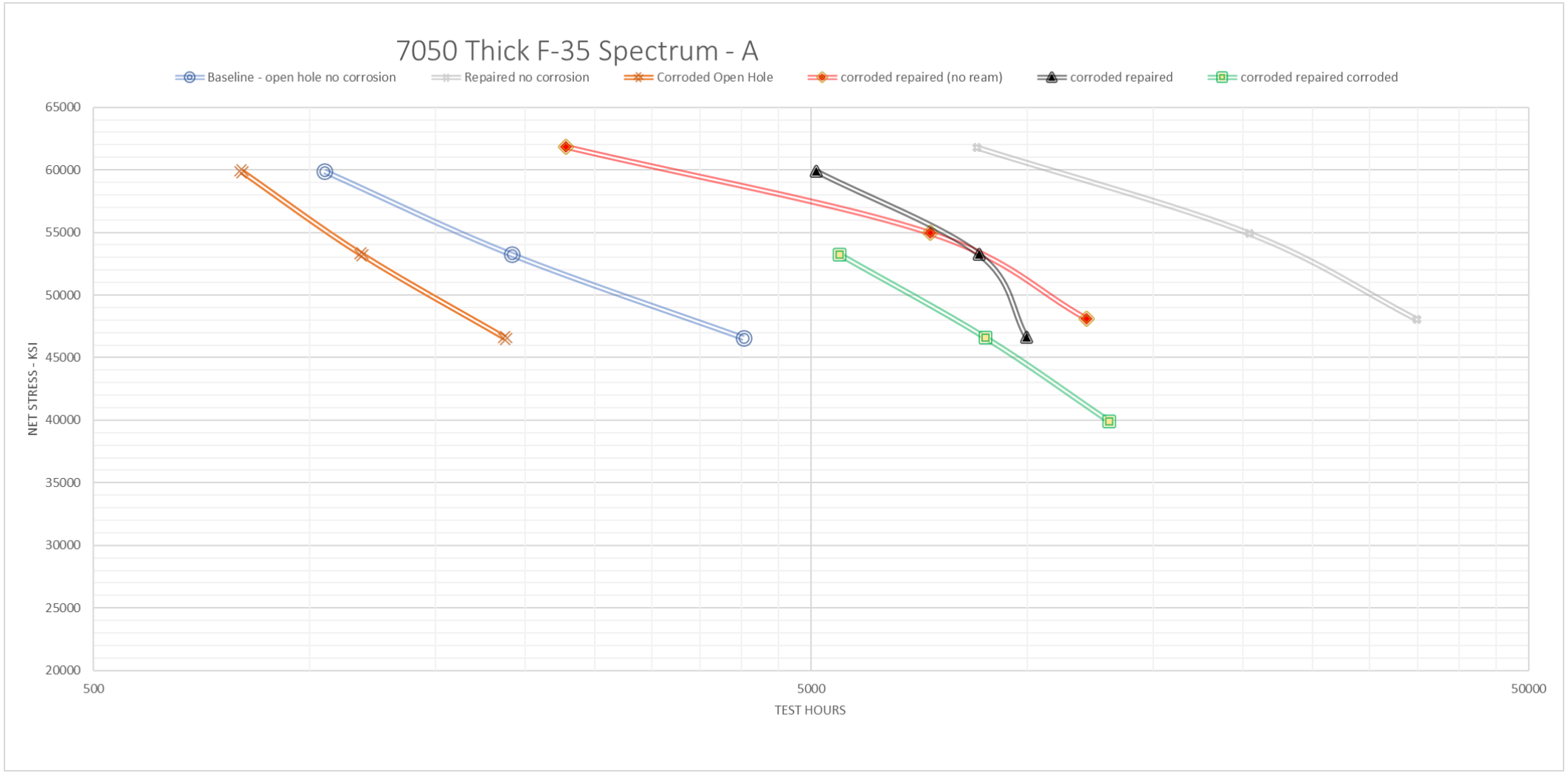
# Fatigue Test Program

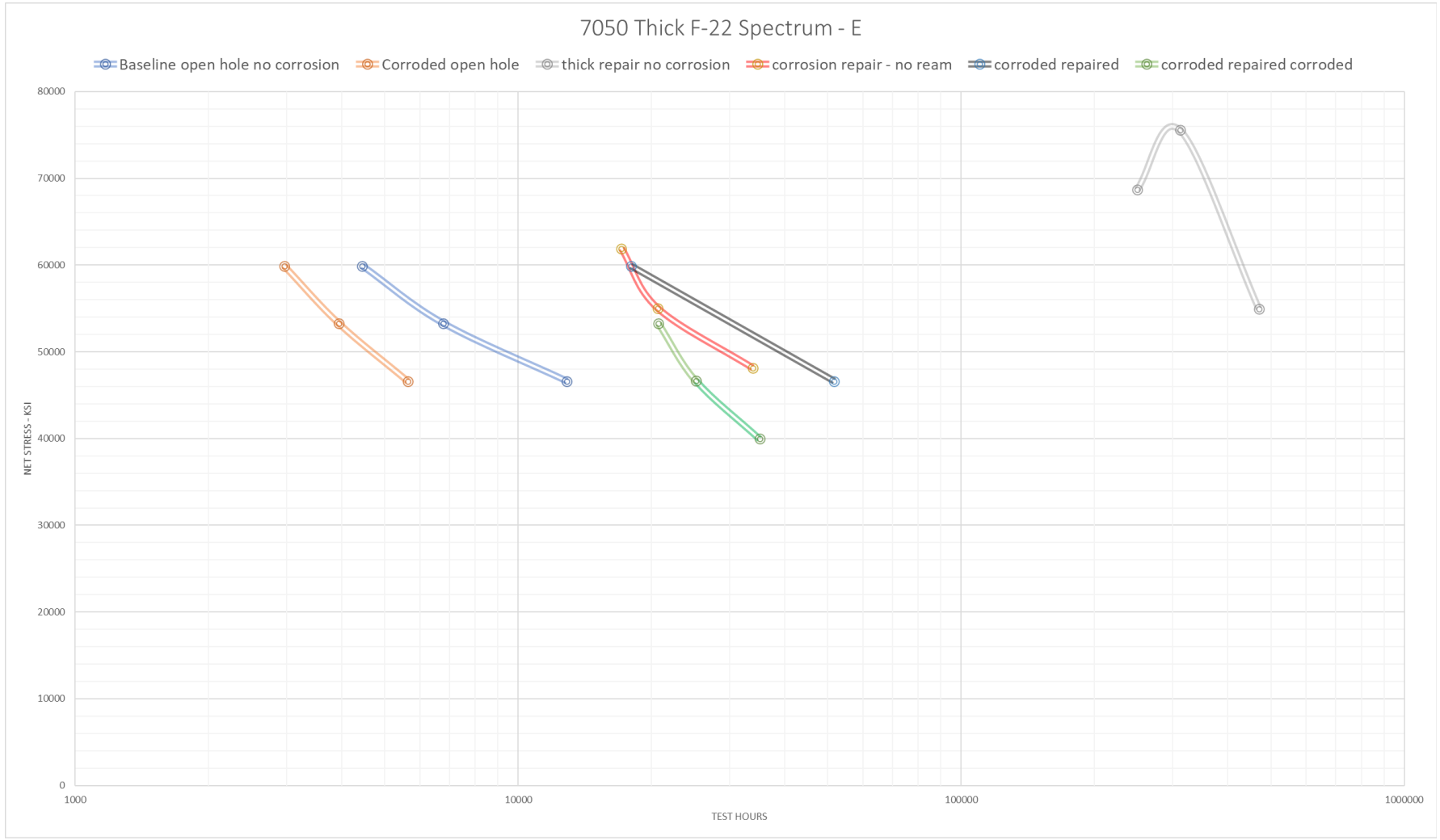
| Load Spectrum | Parent material |
|---|---|
| F-35 | 7050-T7451 |
| F-35 | 2124-T8151 |
| F-22 | 2124-T8151 |
| F-22 | 7050-T7451 |

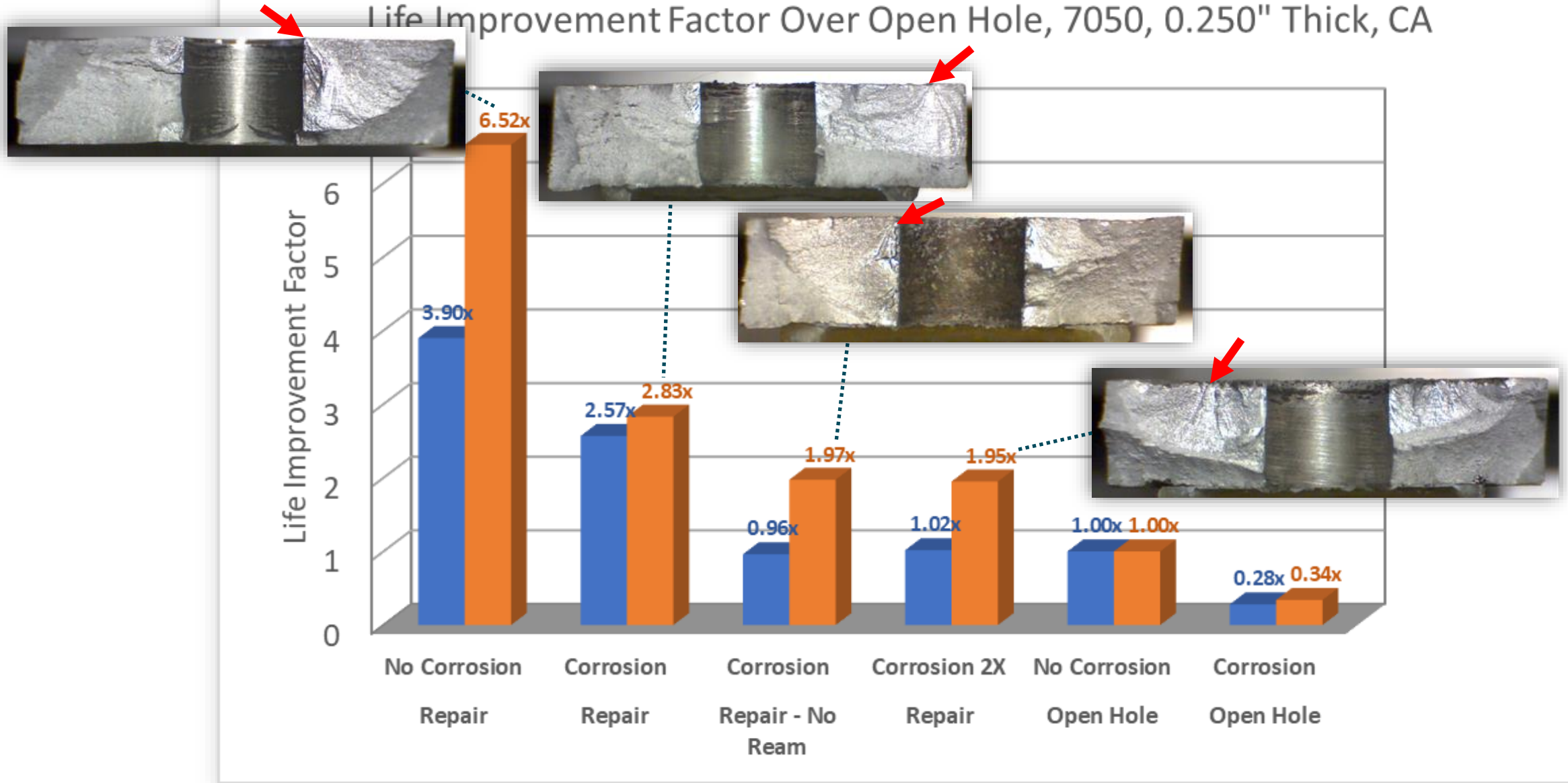



| |
|---|
| **Baseline – open hole, no corrosion** |
| **Corroded - open hole** |
| **Repair - no corrosion** |
| **Corroded, reamed repaired** |
| **Corroded, reamed, repaired, corroded** |
| **Corroded, repaired (no ream)** |
| **Repaired when new, cycle for 10K cycles, then corrode and cut coupon in half to look for potential corrosion between bore of hole and barrel of thin wall bushing** |

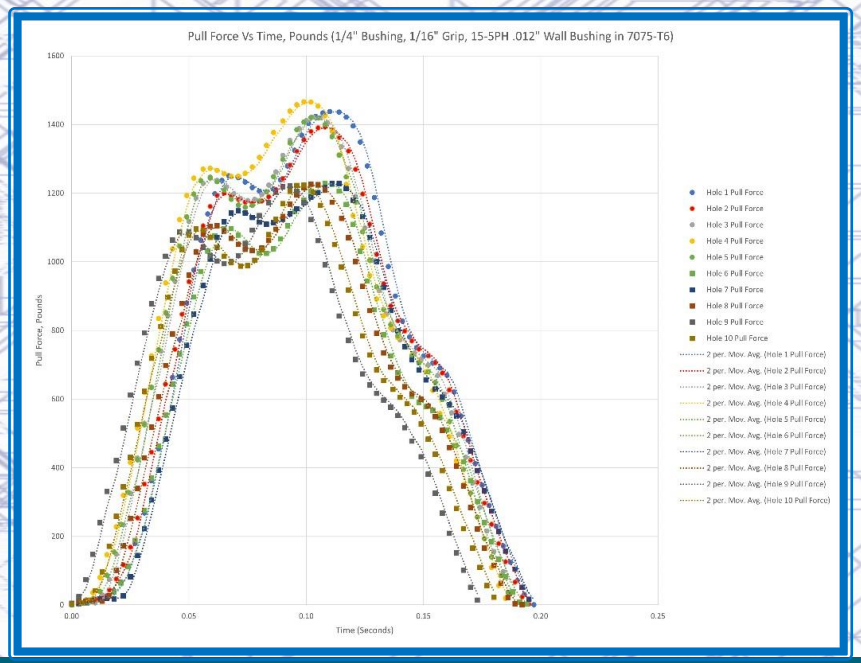
# Fatigue Testing






Life Improvement Factor Over Open Hole, 7050, 0.250" Thick, CA
Life Improvement Factor
0
1
2
3
4
5
6
3.90x
6.52x
2.57x
2.83x
0.96x
1.97x
1.02x
1.95x
1.00x
1.00x
0.28x
0.34x
No Corrosion Repair
Corrosion Repair
Corrosion Repair - No Ream
Corrosion 2X Repair
No Corrosion Open Hole
Corrosion Open Hole

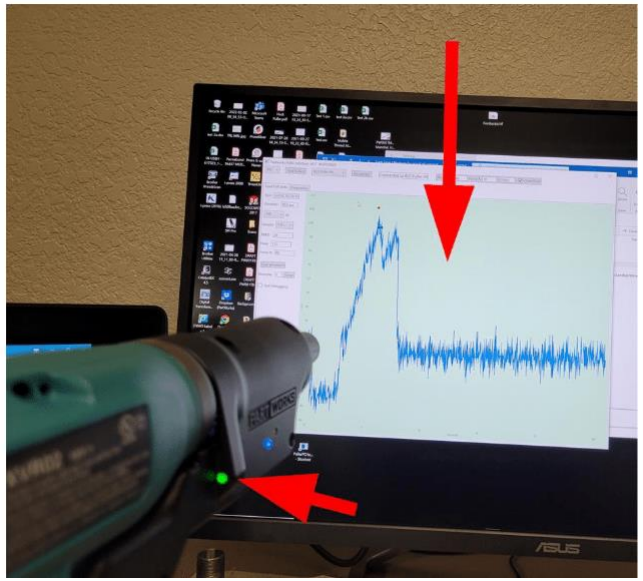
# Process Verification - In Tool Measurement and Feedback


- Cold Expansion process parameters and pull-force documented in tool
- Pull-force data correlated to:
  - DIC
  - Test data
  - Material properties and geometries
- Good / Bad feedback provided to operator

# Process Verification - In Tool Measurement and Feedback

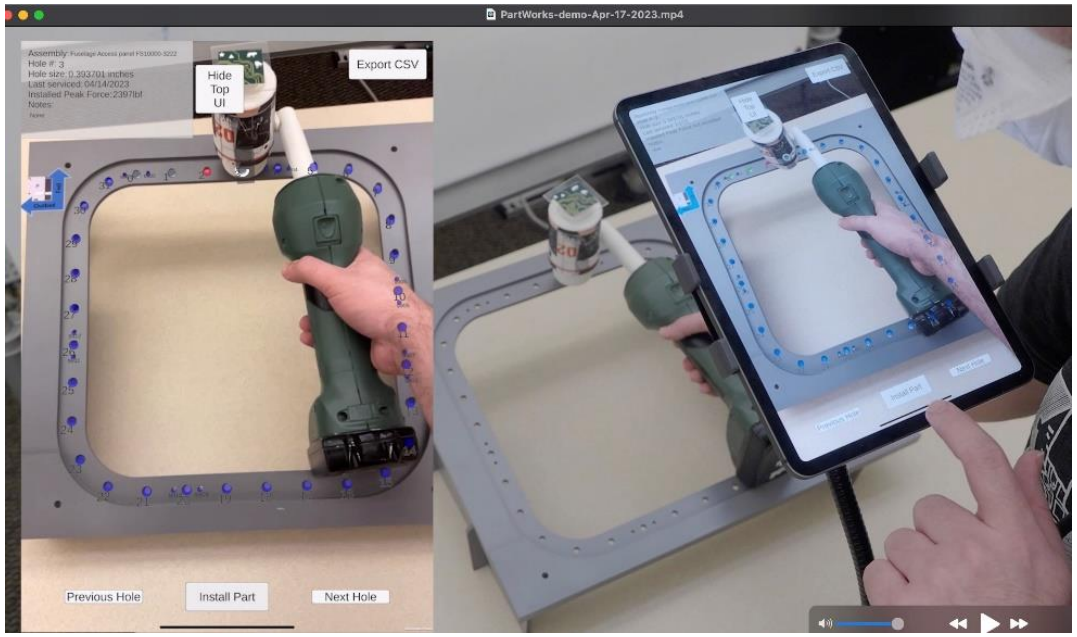

Handheld Puller with Process Control Electronics Incorporated

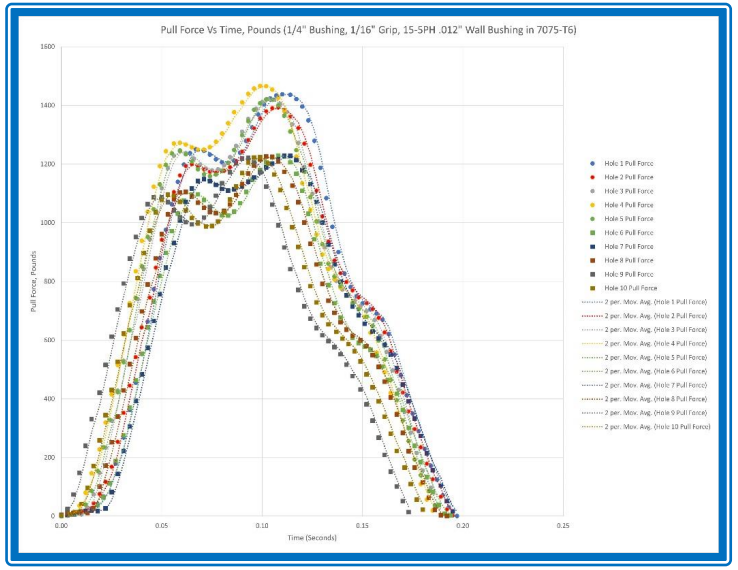


Process Control Software Identifying Successful Installation

Process Control Software Identifying Unsuccessful Installation with LED and Red Graph

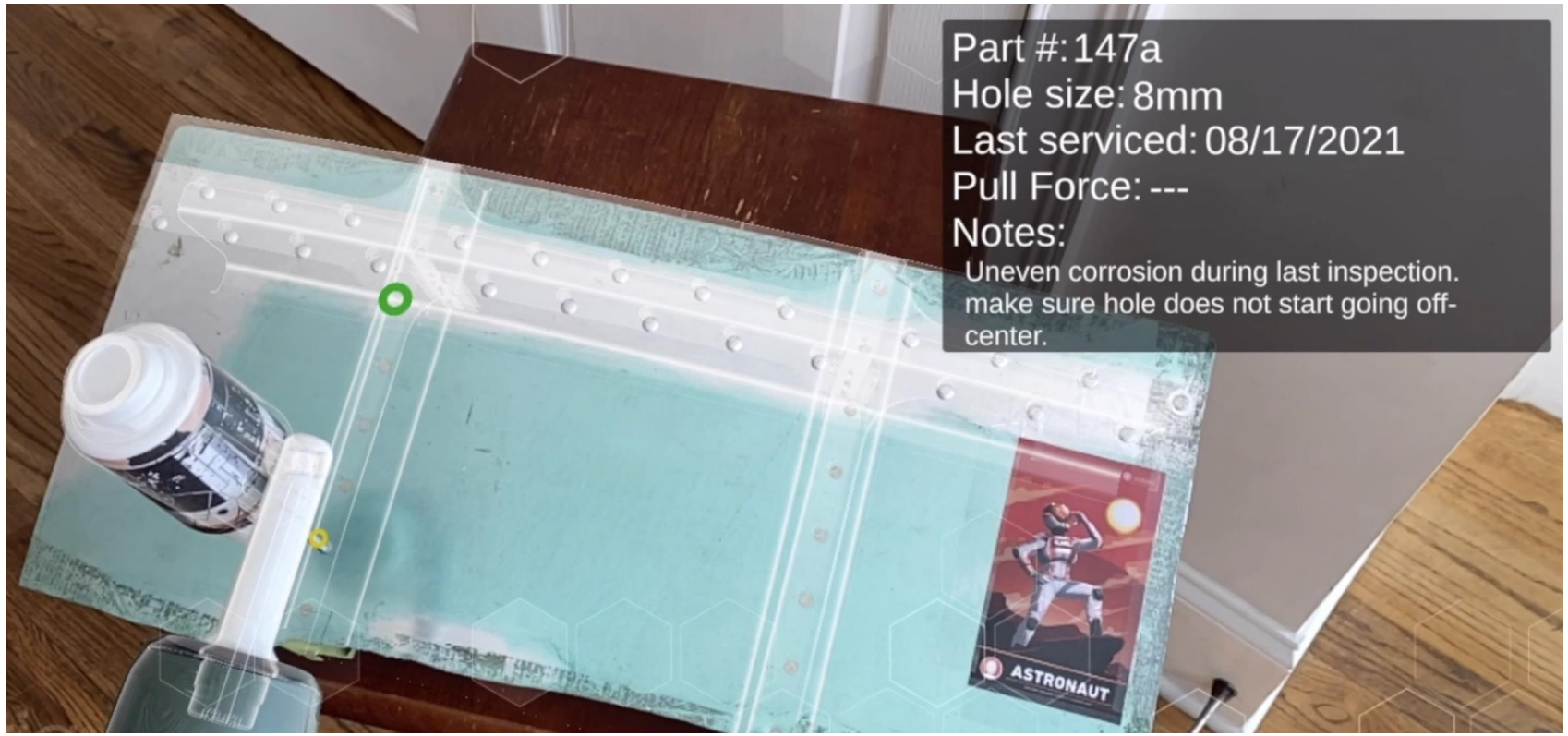
# Augmented Reality for Repair Tracking




- Record data real-time without operator intervention
- Validate correct hole repaired with right tooling
- Simple set up with out complex calibration process
- Integrated scanning and mapping holes to database
- Compatible with phone/tablet/glasses/goggles
- X-ray view/Peel-away for parts where 3D model available (not required)

# Augmented Reality for Cold Expansion



# PartWorks Augmented Reality Demo

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# Considerations for New Production

USN F-18 program spends $690M / year on corrosion (30% of total maintenance budget)

Hybrid structure of some of the newest aircraft have similar corrosion problems

**Prevent today's corrosion problems from becoming tomorrow's.**

PartWorks solution incorporated in new production can mitigate corrosion in fastener holes

Thank you

**partworks.com**

**jhrestis@partworks.com**