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ERSI

Quality Assurance and Data Management

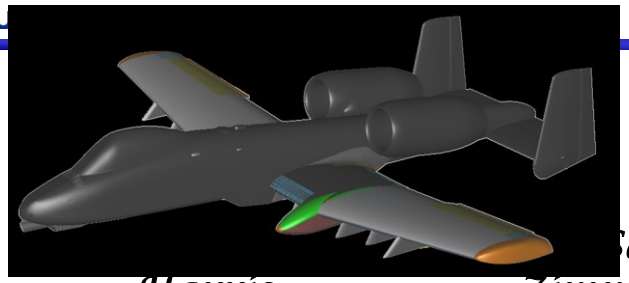
(Sept 12, 2019)

Kaylon Anderson

A-10 ASIP & Analysis, USAF

kaylon.anderson@us.af.mil

An Introduction to our Team



Harris (USAF – F16)	*Zimmerman* (FTI)	*Eric Lindgren* (USAF – AFRL)	*Kaylon Anderson* (USAF – A10)
Dave Forsyth (TRI-Austin)	*Doyle Motes* (TRI-Austin)	*Brandon Dierschke* (L3 MID)	*Phil Hoefert* (L3 Harris)
Chris Kirkpatrick (L3 Harris)	*Kim Jones* (USAF – F16)	*Hazen Sedgwick* (USAF – A10)	*Josh Hodges* (Hill Engineering)

Taking Full Credit for Engineering Residual Stress

Full Credit: being able to take advantage of the residual stress (RS) field in an analysis.

Quality Assurance **(QA)**:

Validating that the RS field is within spec. and imparted in the correct location.

Non Destructive Evaluation **(NDE)**:

Provides a qualitative description of the RS field.

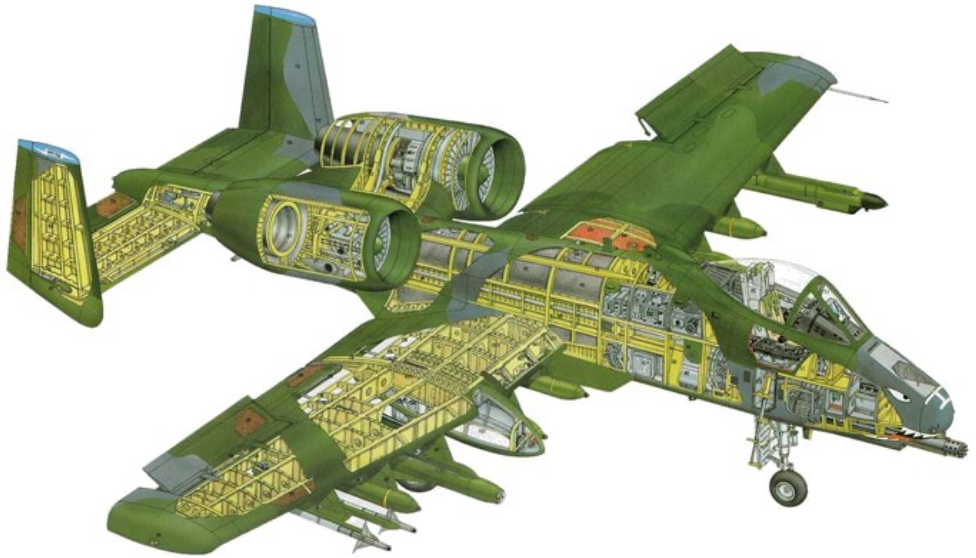
Validating where within the spec the residual stress field is.

QA/NDE World

QA / NDE Responsibilities

1. Validated QA/NDE method in Production & Sustainment
   a. I.e. An auditable trail to the imparted residual stress

2. QA/NDE needs to be documented such that it is Quantitative, Retained as a Permanent Record and Auditable.



Reference Slides from 2017 Residual Stress Summit, UDRI, C
Chuck Babish, "ASIP Perspective on Accounting for ERS in DTA"

Validated QA/NDE method

Validated QA/NDE method
(Basic Requirements)

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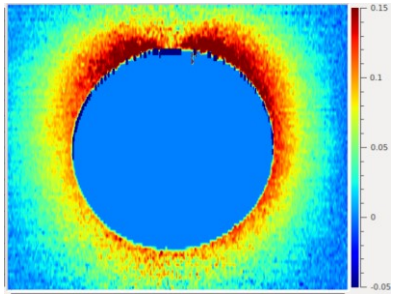
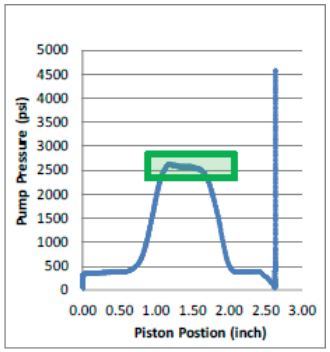
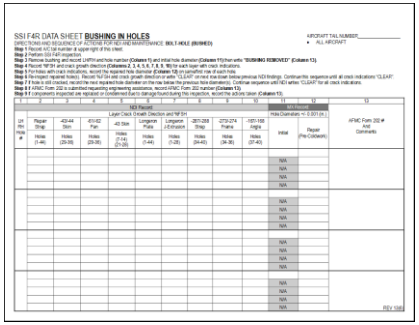
Two basic requirements:



1. <u>The Residual Stress Field is to be verified</u>
   a. Go No Go Gauge (FTI standard spec)
   b. Instrumented puller
   c. Volcano characterization
   d. Eddy Current NDE



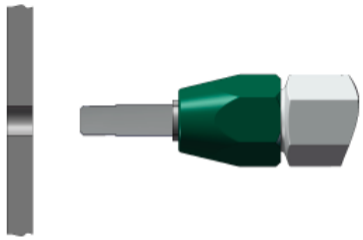
2. <u>The location of the RS is to be know</u>
   a. Manual entry
   b. Automated Locating



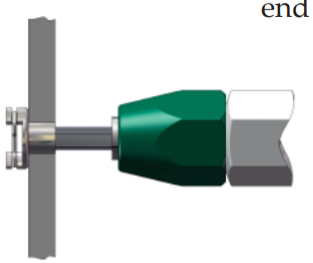
Validated QA/NDE method
(Go No Go Gauge)

A check to determine if the hole was expanded to the correct size.

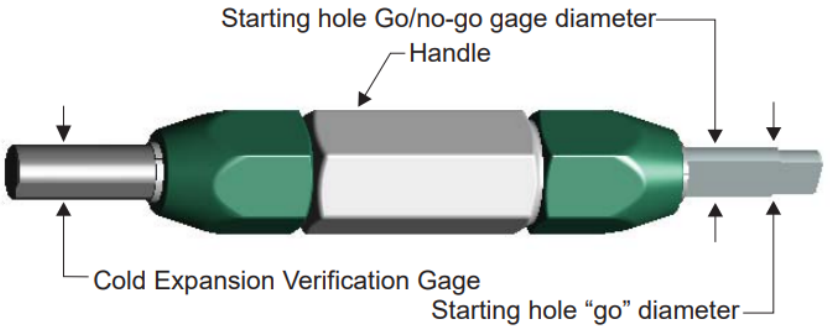
<u>For Full Credit the Residual Stress field correlated to the lower bound of FTI's spec would be used.</u>



Check the starting hole using blade end of the combination gage.

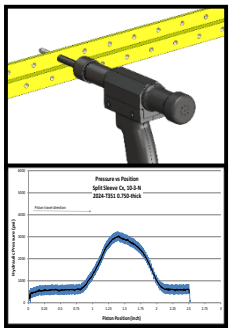


Check the final hole diameter using the round end of the combination gage.

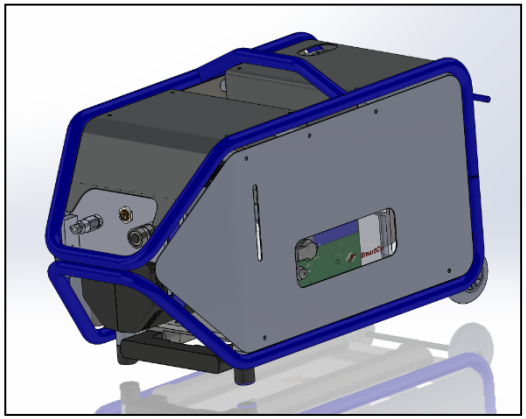


Validated QA/NDE method
(Instrumented Cx Tools - FTI)

New Hydraulic Puller and PowerPak integrating instrumentation with proprietary data analysis



- Fully electric operation,
- Monitors load vs piston stroke data,
- Integrated process validation (Go/No Go),
- Process data logging for archive records,
- Allows tool life tracking, lockout and other digitized tool management
- Integration to networked factory (IoT),
- Compatible with legacy FTI processes,
- Compatible with Data Spatial Positioning (DSP) systems.



Used by permission from FTI

Validated QA/NDE method
(Instrumented Cx Tools, FTI – Full Credit Road Map)

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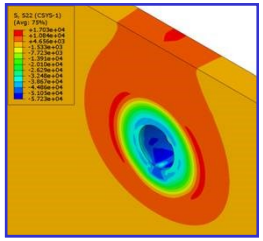
For Full Credit the Residual Stress field correlated to the puller force would be used.

Hole Cold Working

Analysis & Measurement

Predicted E.R.S.

- Several methods and tools in use and under development



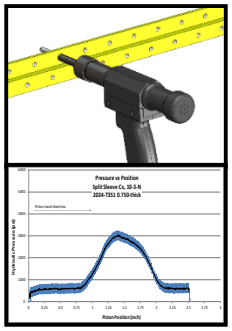
FCGA and other industry

hods

MAXIMUM CONFIDENCE

met

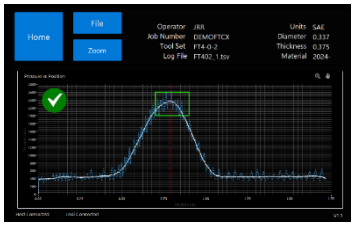
Next Gen Cx Tooling



FTI Smart Tablet

Cx Process Raw Data

- Unique "digital signature" of discrete Cx event
- Provides traceable, archival process data

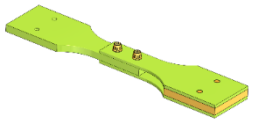


Cx Process Validation

- "Go/No Go" post-process evaluation
- Proprietary algorithms validate process

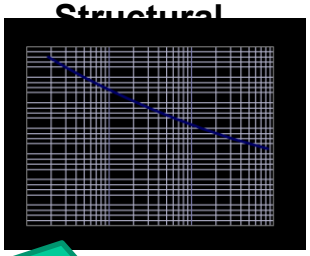
Fatigue Testing

Application-specific



S-N Curve

Predicted Structural



INCREASED CONFIDENCE

Validated QA/NDE method
(TRI Austin's FastenerCam™)

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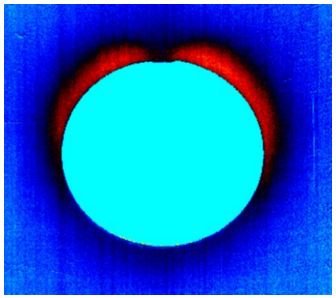
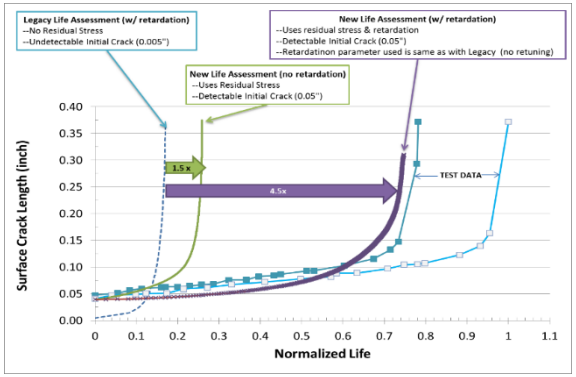
For Full Credit the Residual Stress field correlated to the surface deflections would be used.

1. FastenerCam™ is designed to support the "third leg" of the ERSI "stool" - Q/A)
2. Characterizes the residual stress field by quantifying the surface deformation around a cold-expanded hole
3. Features:
   1. Easy to use, handheld, and lightweight (9 lbs total)
   2. Low power laser profilometer to verify and digitally document newly expanded aircraft fastener holes (assess the volcano)
   3. Provides an effective method of establishing Pass/Fail for cold expansion of straight shank holes
4. TRI has successfully produced a ruggedized, manufacturing prototype scanner (MRL 7) from Phase II SBIR
5. Next activity would be to complete a repeatability and reliability (R&R) study and integrate FastenerCam™ into TOs for an aircraft of interest



TRI Austin's manufacturing prototype FastenerCam™



Validated QA/NDE method
(NDE for QA)

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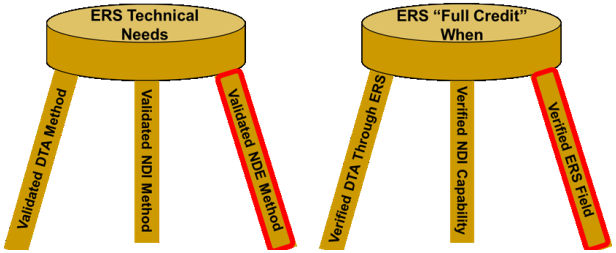
- Background
  - Validated NDE methods are needed to achieve:
    - "Full credit" recurring inspection interval benefit for Cx holes
    - Additional tools for production Quality Assurance (QA)
  - Questions to resolve:
    - Was the ERS applied correctly (QA process step)?
    - What level of ERS is present?
    - Is the expected ERS still present after years of operational usage?

- Objective
  - Develop NDE techniques to quantify cold expanded (Cx) hole residual stress during in-process QA and in-service fleet surveillance applications

Team:
AFRL/RXC,
Hill Engineering,
Southwest Research Institute



Babish, C., (2017). Aircraft Structural Integrity Program (ASIP) Perspective on Accounting for Engineered Residual Stress in Damage Tolerance Analysis, 2017 ASIP Conference, Jacksonville, FL.

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Validated QA/NDE method
(Manual - Entry)

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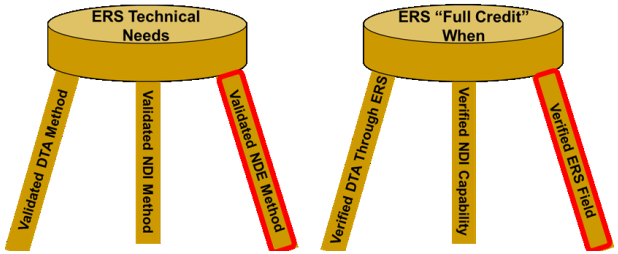
Location of RS is to be Know
(Automated – Data Spatial Positioning (DSP))

- **Background**
  - **Quality assurance methods are needed to achieve:**
    - **"Full Credit" for Engineered Residual Stress (ERS) at cold expanded (Cx) holes**
  - **Questions to resolve:**
    - **Has each critical hole been cold expanded?**
    - **Was the work performed properly?**
    - **Has NDI been accomplished at each critical hole?**
    - **Is the ERS validation traceable?**
- **New Rapid Innovation Fund (RIF) program establishes a digital thread for critical fastener holes that builds and maintains process records for NDI and Cx and makes them available in fleet management processes**

Team:
A-10 ASIP Team
Hill Engineering
Etegent Technologies, Ltd
Fatigue Technologies, Inc



Babish, C., (2017). Aircraft Structural Integrity Program (ASIP) Perspective on Accounting for Engineered Residual Stress in Damage Tolerance Analysis, 2017 ASIP Conference, Jacksonville, FL.

Validated QA/NDE method
(NDE for QA)

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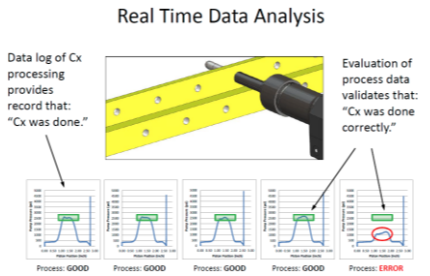
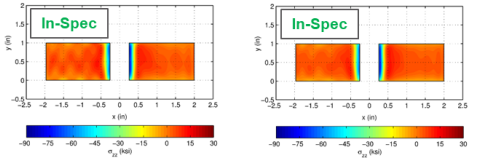
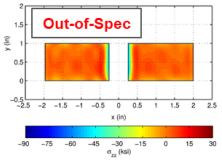
Approach



- Build on the NLign tool for the digital thread
- Adapt commercial Data Spatial Positioning (DSP) technologies
- Integrate DSP into smart tools for critical maintenance actions
  - Cx process
  - NDI process



- Enable compliance indicators and storage of process rec
  - Real-time feedback indicator to Mx personnel
  - Storage of smart tool outputs and in-process data (NDI and Cx)
  - Feeds a digital thread for Cx holes and NDI

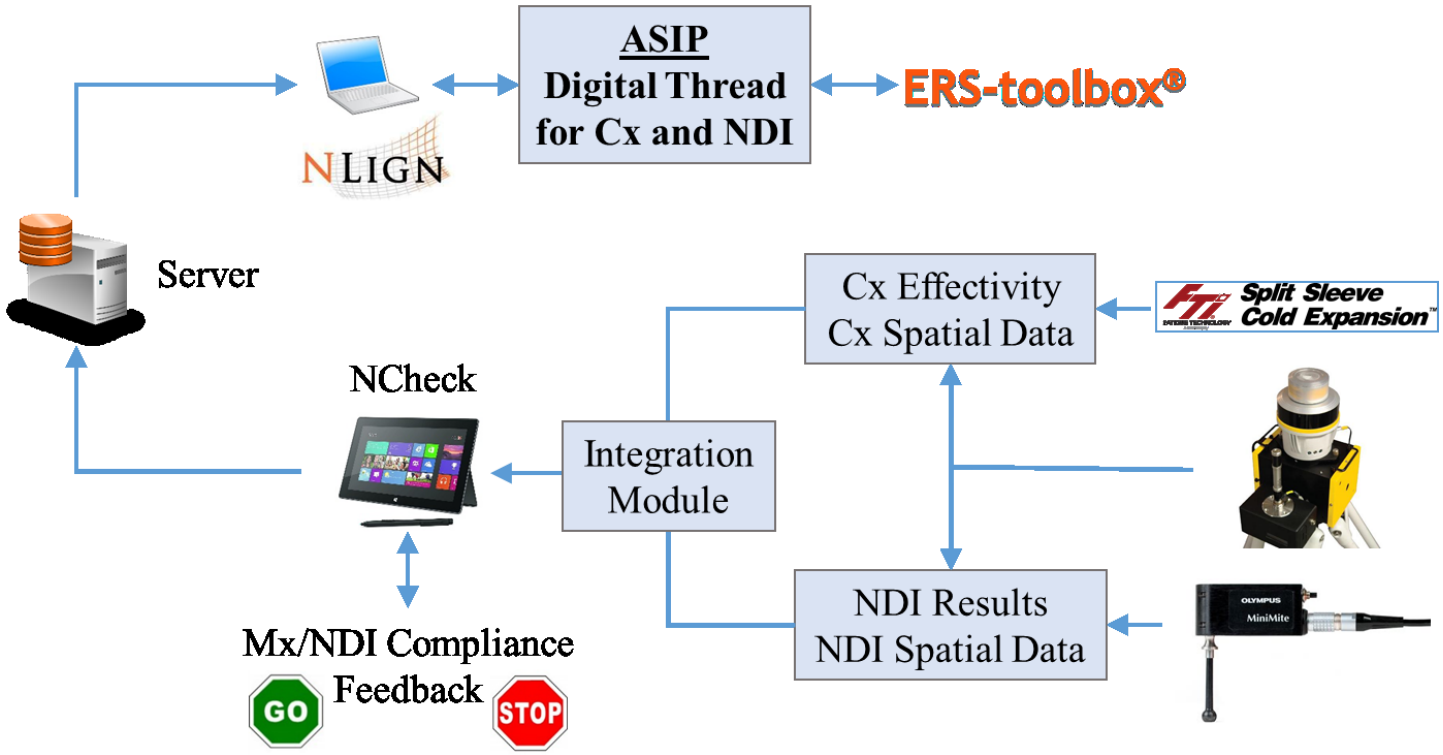


- Document Cx process effectivity
  - In-process Cx data, post-process Cx data
  - Translate to residual stress for use in fleet management

Validated QA/NDE method
(NDE for QA)

- **Conceptual technology integration**

If only these tools were smart!!!



QA / NDE

Documentation of Data

QA/NDE needs to be documented
(Auditable Data)

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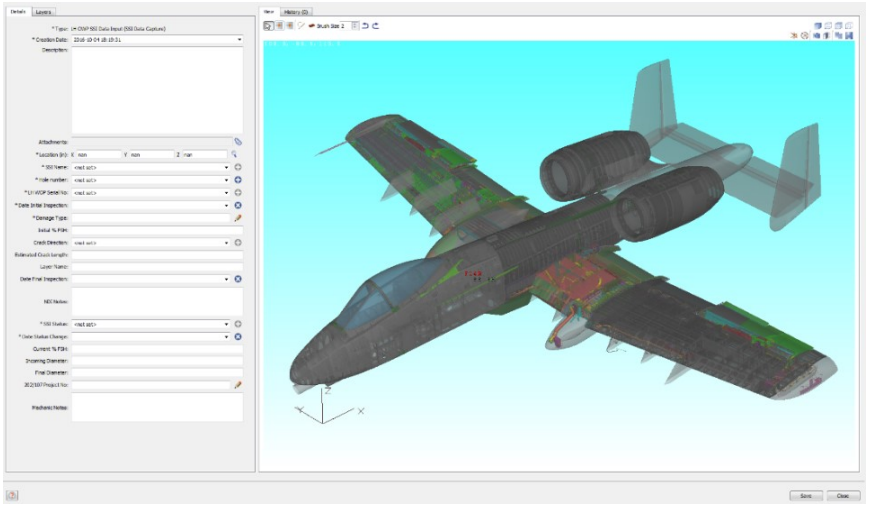
Auditable Data

1. Requires data storage (NLign, FSS,SMXG, Blue Quartz, Teamcenter, etc)
2. Requires predetermined data format (figures, metadata fields, etc)
3. Required to be quantitative (values that can be searched, tracked, and trended)



Best Practice Guide (High Level Needs)

1. Outlines the method(s) to validate the ERS
2. Describes processes/guidelines necessary for the QA options
3. Describes the required data to be documented
4. Provides insight into the RS that can be used, which is associated with the QA option. Provides probably of missing the correct hole
    a. *For example manual location entry would have a probability of not entering the correct location vs automated location entry.*
5. Provides examples for validating the ERS accomplished by different weapon systems

QA/NDE
(Summary Table)

Document QA Options similar to the DFS values in EN-SB-08-012

QA Option (RS Field, how much?)	Process / Guideline	Data Requirements	RS field Used
Go No Go Gauge	Paragraph x.xx	• Yes/No	Low end of Spec
Instrumented Puller	Paragraph x.xx	• Pull Force	Correlated to pull force
Volcano Characterization	Paragraph x.xx	• Surface Deformation • %Cx	Correlated to Surface Deformations
Eddy Current NDE	Paragraph x.xx	• Measured Profile	

QA Option (Location of RS, where?)	Process / Guideline	Data Requirements	Prob of Missing
Manual Location Entry	Paragraph x.xx	• Hole Number • Spatial Coordinates	
Automatic Location Entry	Paragraph x.xx	• Hole Number • Spatial Coordinates	

QA / NDE

Points of Consideration

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Points of Consideration

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As we consider QA options the following points should be considered:

- **Some platforms do not have Periodic Depot Maintenance (PDM)**
- **Some platforms are located in numerous places around the world.**
  - **Any requirement for new field-level tooling / processes / procedures has to have a slam-dunk return on investment**
- **For some platforms using partial credit is currently sufficient.**
- **The time constraints to set up tooling on the shop floor.**
- **Access to areas in or around the aircraft**
- **Cost to the depot to purchase tooling**
- **training for new tooling**
- **Etc.**

In summary, will the result of using “full credit” be sufficient to offset the costs (time and money) to capture the data needed for “full credit”.

Summary of Programs in Work

Validated QA / Documentation Process

Work Accomplished or being Accomplished

Instrumented puller – *FTI*

1. Records puller force and provides a go/no-go for maintainer

Data Collection / Documentation – *NLign, F-16 product, SMXG, Blue Quartz, etc.*

1. Data Collection for maintainer
2. Documentation for engineering

Data Spatial Positioning System (RIF) – *Summer 2019*

1. Provide real time location compliance feedback
2. Connect to instrumented Cx puller
3. Associate puller outputs to measured residual stress
4. Data will go directly from the puller to data collection system

NDE for QA and Surveillance of CX Fastener Holes (AFRL/RXC) – *Summer 2019*

1. Develop NDE methods to measure residual stress at a CX fastener hole

Thank you!

Backup Slides

Vision for Digitized Cold Expansion Tools

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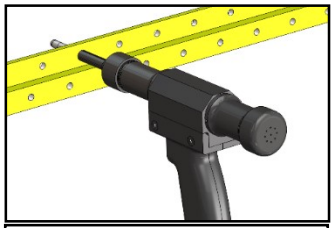
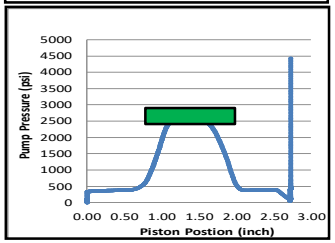
QUALITY
- Increased process confidence and reduced quality risk
- Integrated process check ("Instant" Go/No Go)

PLANNING
- Pre and Post Cx process data sharing
- Active monitoring of KPI's and advanced analytics



FTI Instrumented SsCx Tooling



Automated Quality Assurance

Networking within Modern Factory

Data Sharing

Advanced Data Analysis

PROCUREMENT
- **Real-time tooling and consumables data**
- **Advanced tool tracking**

ENGINEERING
- Greater confidence in design allowables
- Traceable digital Cx data records (Digital Twin)

CUSTOMER SATISFACTION
- Increased quality at higher rates
- Potential for extended PM schedules
- Traceability and advanced data

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Maintenance Data Spatial Positioning (DSP) Program

- Objectives
  - Develop methodology, technology, hardware, and software for:
    - Smart NDI tool with sensor outputs that document inspection effectiveness
    - Smart Cx tool with sensor outputs that can be used to quantify process effectiveness
    - Integrating DSP with smart tools for Cx and NDI processes
      - Capture positional data
      - Associate data to aircraft coordinates
      - Push data to digital thread
    - Translating Cx tool outputs to process effectiveness (i.e., residual stress)
    - Defining maintenance flow by location and providing feedback for compliance
  - Mesh individual technology elements into a complete system for advanced maintenance practices
  - Validate the performance of the integrated system showing the ability to:
    - Quantify process effectiveness
    - Assign it to the correct spatial location
    - Populate the digital thread
    - Demonstrate use of the Cx digital thread for structural integrity evaluation
  - 2-year effort to demonstrate the performance of the integrated system

Non-Destructive Evaluation for Quality Assurance and Surveillance of Cold Expanded Fastener Holes

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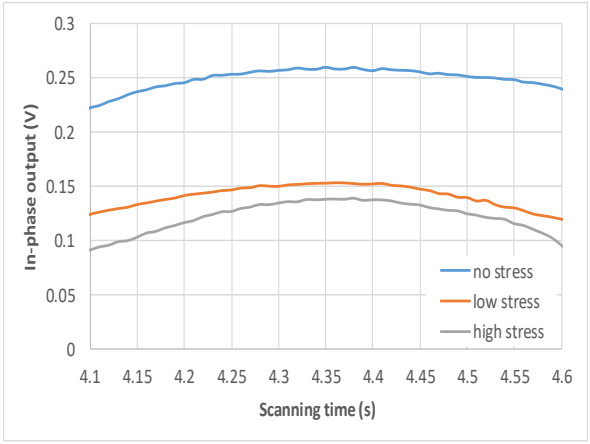
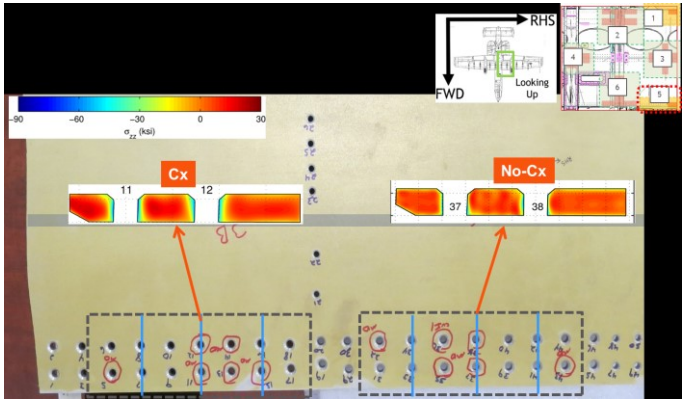
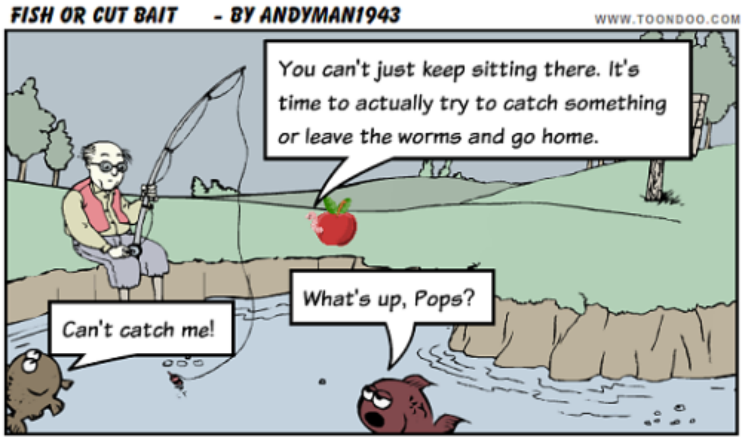
- **Approach**
  - Assess/develop NDE techniques for QA of Cx
    - Leverage existing technology and tailor to the unique characteristics of Cx holes
  - Evaluate NDE techniques across Cx process bounds
  - Develop in-process QA/NDE for in- vs. out-of-spec Cx
  - Investigate confounding factors and NDE response impacts
  - Develop NDE for in-service Cx holes
  - Validate QA and NDE for Cx holes
- **Challenges**
  - Confounding factors complicate the NDE response making the segregation of residual stress difficult





Control Point Analyses

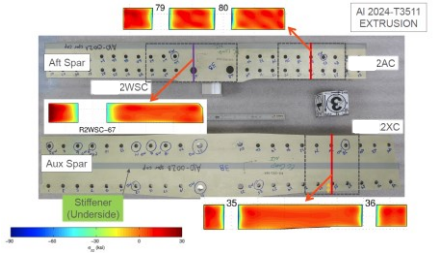
- **Objectives**
  - Utilizing state-of-the-art methods and inputs, update DTAs for select Control Points (CPs), explicitly incorporating residual stress
  - Compare/contrast with reduced flaw size predictions (partial credit)
  - Identify gaps and refine best practices
  - Define initial ground rules



- **Approach**
  - Select candidate locations (3)
    - Typical & extreme locations
  - Review baseline input data/methods
  - Complete baseline analyses
  - Complete multi-point analyses w/ RS
  - Compare/contrast predictions
  - Provide conclusions and recommendations

Control Point Analyses

- Inputs and Results
  - Oversized conditions
  - Variations in residual stress
  - Variation in stress spectrum



Location 1 residual stresses

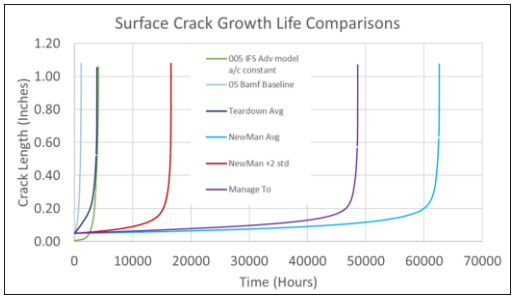
Analysis Details

Location	Description	Material	Thickness (in)	Hole Size (in)	Edge Margin (e/D)	Max Stress (ksi)
1	Lwr Fwd Skin, Repair config	2024-T3511	0.300	0.625	2.256	31.2
2	Lwr Fwd Skin, Redesign config	2024-T3511	0.420	0.562	2.508	24.0
3	Lwr Fwd Skin at Mid Spar, Repair config	2024-T351	0.300	0.328	1.981	42.4

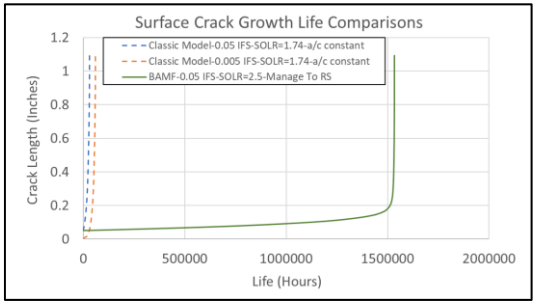
Residual Stresses

Location	New Manufacture Mean	Teardown mean	New Manufacture +2 Std	Teardown +2 Std	Manage To
1	x	x*	x		x
2		x			
3	x	x	x	x	

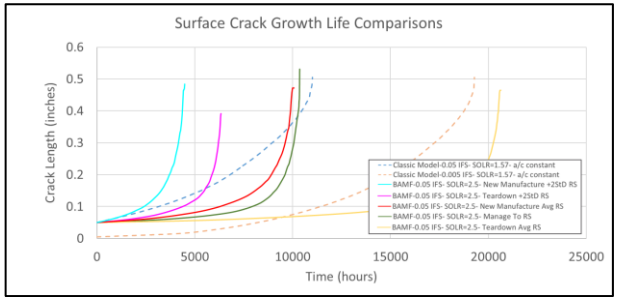
Location 1 Predictions



Location 2 Predictions



Location 3 Predictions



Control Point Analyses

- **Conclusions**
  - **Peak spectrum stress has a key influence on the LIF at Cx holes**
  - **The LIF from traditional DTA methods, that also have high applied stresses and are account for the benefit of Cx, could be unconservative if utilizing 0.005" RIFS**
  - **Cx benefit is significantly reduced for locations with peak spectrum stresses greater than 85% of the yield strength. Experimental results demonstrate minimal benefit.**
  - **Appropriate crack retardation values with explicit residual stress range from 2.5-4.0 based on initial evaluations**
    - **Retardation parameters established from non-Cx holes should not be used for Cx hole analyses**
    - **Retardation values derived from 0.05" tests may not be appropriate for modeling RS with the RIFS assumption (0.005-inch)**
  - **The residual stress utilized for analyses is critical for the predictions and must be considered closely, considering the impacts of in-service degradation and statistical variation**
  - **The "Manage-To" approach results in a reasonable conservative prediction of the residual stress (as intended)**

Control Point Analyses

- **Results and Conclusions**