



# Air Force Research Laboratory



## Nondestructive Inspection (NDI) Subcommittee Overview

### Engineered Residual Stress Implementation (ERSI) Workshop

13 September 2018

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**Integrity ★ Service ★ Excellence**



# Overview



- Summary of Current Knowledge
- Gaps
- ERSI 2017 Priorities
- Progress since 2017



# NDI Subcommittee Members



| Title | First Name | Last Name | Company/Organization  | Phone Number   | Email Address               |
|-------|------------|-----------|---|----------------|-----------------------------|
| Mr.   | John       | Brausch   | U.S. Air Force (AFRL - NDE Lead Engineer, Systems Support)        | (937) 656-9151 | john.brausch@us.af.mil      |
| Dr.   | Mike       | Hill      | Hill Engineering, LLC   | (530) 754-6178 | mrhill@hill-engineering.com |
| Mr.   | Fred       | Acosta    | U.S. Marine Corp (F-5 NDI Lead)                                   | (928) 580-5978 | alfredo.acosta.ctr@usmc.mil |
| Mr.   | Dave       | Campbell  | U.S. Air Force (Tinker AFB NDI Program Office Lead)               | (405) 736-5008 | david.campbell.2@us.af.mil  |
| Mr.   | Ward       | Fong      | U.S. Air Force (Hill AFB NDI Program Office Lead)                 | (801) 775-2483 | ward.fong@us.af.mil         |
| Mr.   | Dave       | Forsyth   | Texas Research International (TRI) - Austin, Inc.                 | (512) 263-2101 | dforsyth@tri-austin.com     |
| Dr.   | Carl       | Magnuson  | Texas Research International (TRI) - Austin, Inc.                 | (785) 766-8896 | cmagnuson@tri-austin.com    |
| Mr.   | Tommy      | Mullis    | U.S. Air Force (Warner Robins AFB NDI Program Office Lead)        | (478) 327-4122 | Roy.Mullis@us.af.mil        |
| Mr.   | Clint      | Thwing    | Southwest Research Institute (SwRI)                               | (210) 522-3989 | clinton.thwing@swri.org     |
| Mr.   | Mike       | Reedy     | U.S. Navy - NAVAIR - Compression Systems Engineer                 | (301) 757-0486 | michael.w.reedy1@navy.mil   |
| Mr.   | Bryce      | Harris    | U.S. Air Force (F-16 ASIP Manager)                                | (801) 777-9381 | bryce.harris@us.af.mil      |
| Mr.   | Jacob      | Warner    | U.S. Air Force (F-22 System Program Office - Structural Analysis) | (801) 586-8181 | jacob.warner@us.af.mil      |
| Mr.   | Leo        | Garza     | L3 Communications - RC-135 Fleet Manager                          | (903) 457-4595 | leo.garzaii@L-3com.com      |
| Dr.   | Teodor     | Dogaru    | Southwest Research Institute (SwRI)                               | (210) 522-3139 | teodor.dogaru@swri.org      |

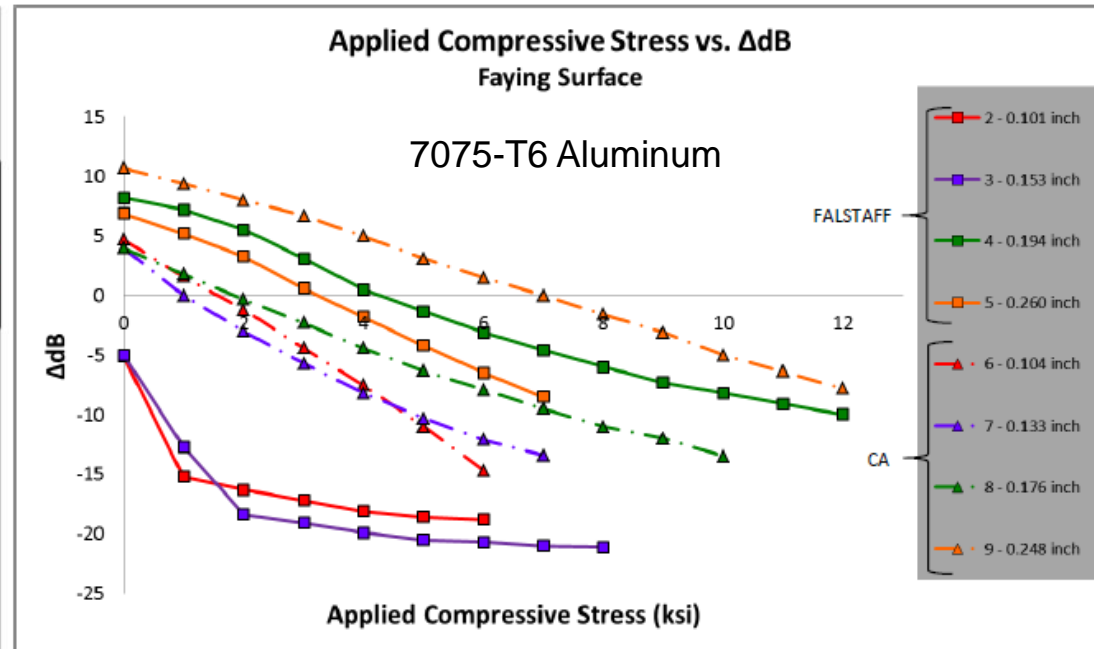
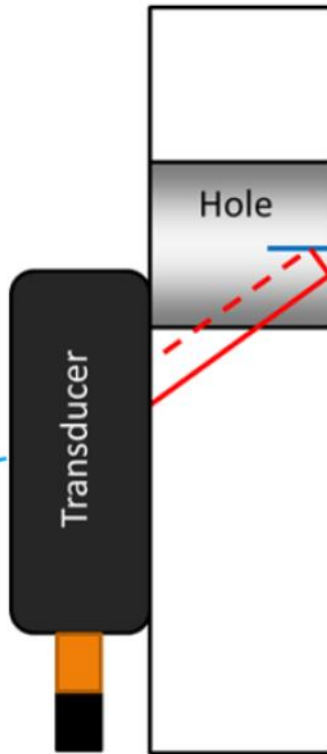
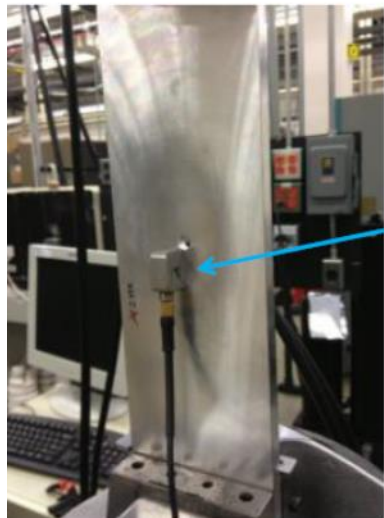


# Applied Compressive Stress

## Shear-Wave Ultrasonics



Ultrasonic response from fatigue cracks under applied compressive stress.



Henry, T. "Correlating Ultrasonic Responses of Fatigue Cracks Propagated Under Different Load Spectra."

**Significant Impact**  
**~6dB (50%) signal reduction per 4 ksi applied compressive stress.**



# Laser Shock Peening

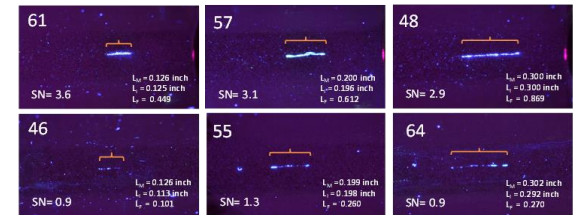
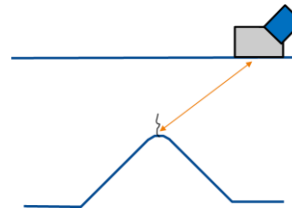
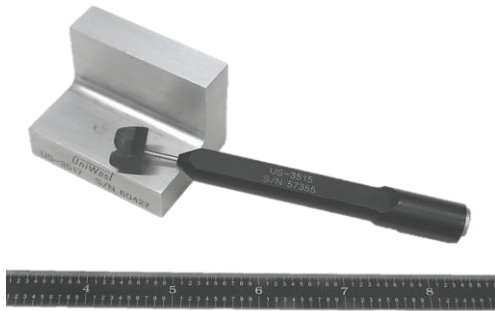
## Eddy Current, Ultrasonics, Fluorescent Penetrant



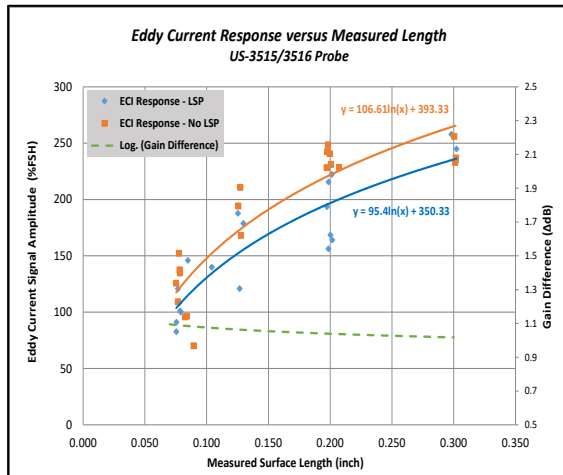
### Eddy Current

### Ultrasonics

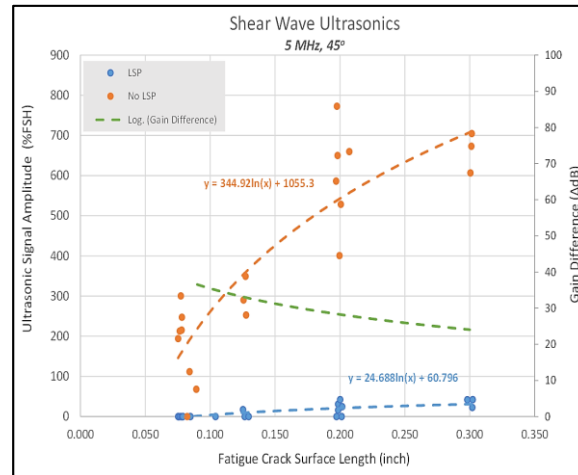
### Fluorescent Penetrant



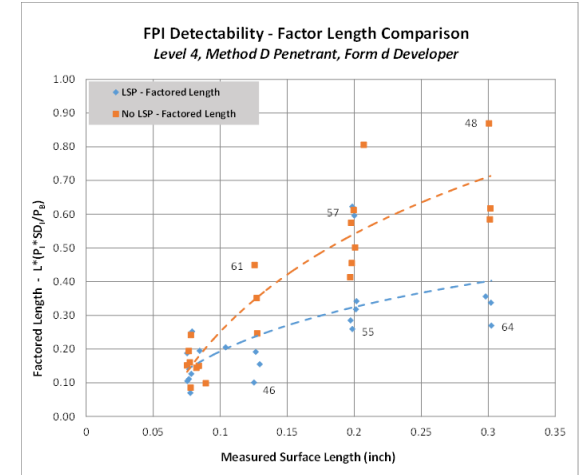
0.5 inch



Minimal Impact



Significant Impact



Significant Impact





# Hole Cold Working

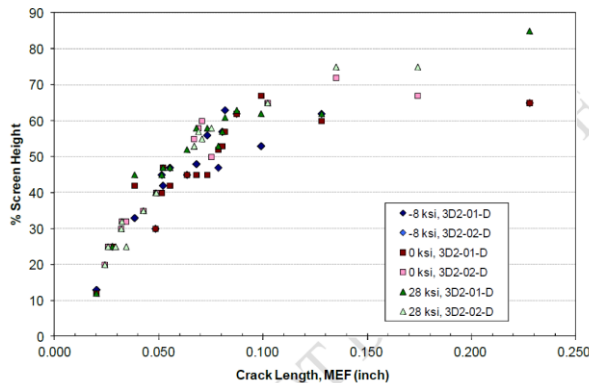
## Eddy Current, Ultrasonics



### Rotary Hole Eddy Current

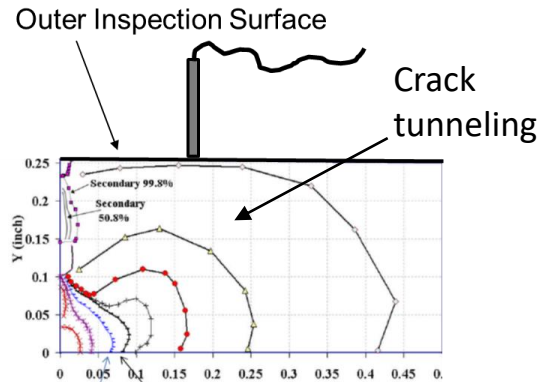


Eddy Current Results

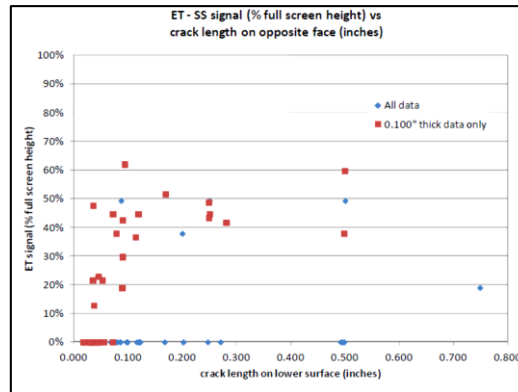


Minimal Impact

### Surface Eddy Current

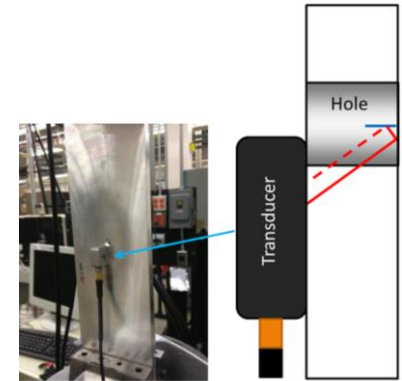


Forsythe, D., Mills, T. "Results of Study of Applied Stress and CX Process on Detectability of Fatigue Cracks"

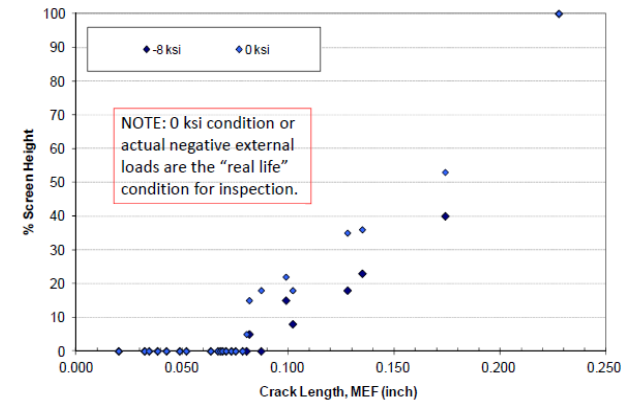


Significant Impact

### Ultrasonics



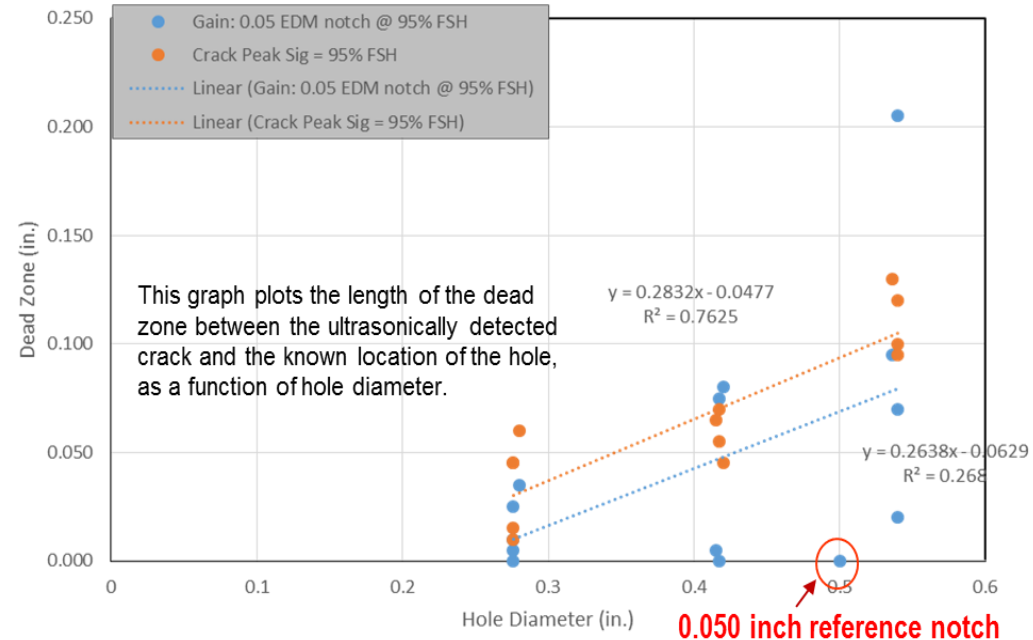
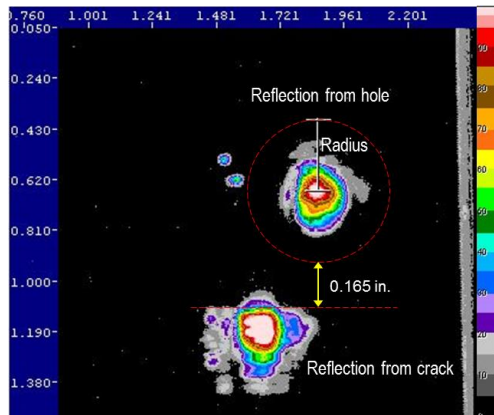
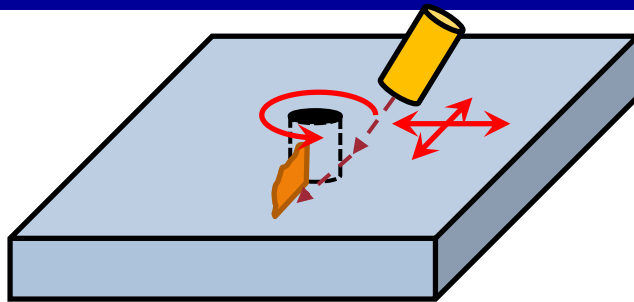
Ultrasonic Inspection Results (variable gain)



Significant Impact



# Ultrasonic “Dead-Zone” in Cx Holes



$$DZ = 0.3219 * Diameter - 0.038$$

- Dead zone proportional to hole diameter but scatter suggests other influencing factors.
- Use upper bound of UT dead zone estimates to correct UT POD estimates for Cx holes.
- Ultrasonic inspections must be designed to interrogate beyond the tangency of the hole.

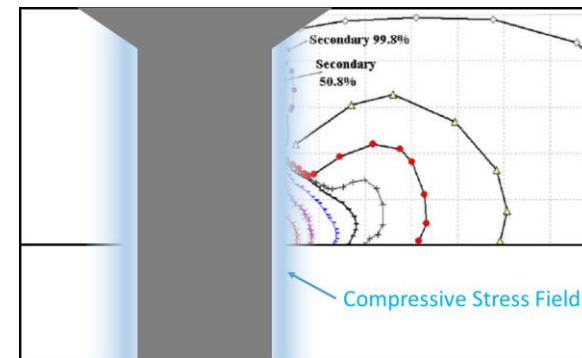
**Ultrasonic “dead zone” proportional to hole diameter.**



# Gaps



- Ultrasonic “Dead Zone” at Cx Holes
  - Quantify UT “Dead Zone” for a range of Cx applied expansion ranges
  - Investigate causes of “Dead Zone” variability
  - *Define UT POD correction factors for Cx holes*
  - *Define optimum UT system design for Cx holes*
- Fastener Installation on UT Detectability
  - Taper-Lok fasteners
  - Interference fit fasteners
  - Interference fit fasteners installed at Cx holes
- Other ERS Surface Treatments and Materials
  - Shot peening, low plasticity burnishing – on aluminum and titanium (UT and FPI focused)
  - Laser Shock Peening (LSP) on titanium alloys







# NDI Subcommittee Priorities



## Priority I. Quantify UT dead zone in Cx holes. Develop UT POD correction factors.

- **Map UT dead zone for Cx holes – range of thicknesses and diameters**
- T-38 wing skin coupons – generate cracks in aircraft skins
  - Production Cx
  - TCTO Cx
- **Capture data w/ existing UT inspection systems – Validate optimum inspection process.**
  - Rotoscan
  - AFIS (USAF and Navy)
- **Measure residual stresses in subset of specimens using contour method**
  - Fractographically size subset of specimens

## ✓ Priority II. EN-SB-008-012 Update

## Priority III. Investigate the impact of fastener installation on ultrasonic fatigue crack detectability?

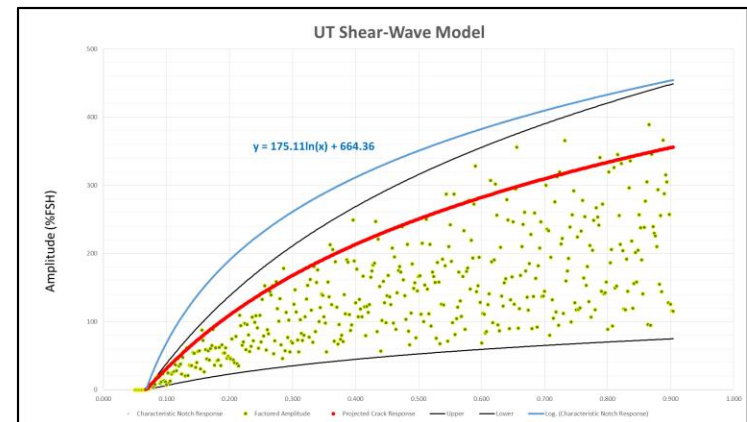
- **Taper-Lok fasteners – A/C program priority**
- Interference fit fasteners
- Interference fit fasteners installed in cold worked holes.



# Progress Since 2017



- Published EN-SB-008-012 Rev D, April 2018
  - Impact of Cx on surface eddy current inspection
  - Impact of Cx on ultrasonic inspection of Cx fastener holes
    - Estimates of dead zone for POD correction
  - Restrictions for use of FPI and UT on Laser Peened AI structures
- Incorporated current knowledge into UT POD model
  - Applied compressive stress
  - Ultrasonic dead zone in Cx holes
- Supporting a/c program in the development of empirical ultrasonic inspection data for inspection around taper-lok fasteners – contract action pending.





# QUESTIONS?



# NDI/QA/Data Subcommittees

## 2017 Breakout Attendees



| Name                 | Company/Organization                                       |                       |
|----------------------|--|-----------------------|
| Mr. John Brausch*    | U.S. Air Force (AFRL - NDI Lead Engineer, Systems Support) | NDI Subcommittee Lead |
| Ward Fong            | U.S. Air Force - Hill AFB NDI Program Manager              |                       |
| Doyle Motes          | Texas Research International (TRI) - Austin, Inc.          |                       |
| Nick Bunnell         | U.S. Air Force - Robins AFB NDI Level 3                    |                       |
| Tommy Mullis         | U.S. Air Force - Robins AFB NDI Program Manager            |                       |
| Mike Dubberly        | Consultant   |                       |
| Eleazar Morale       | AFSC/ENSI-NDI Engineering                                  |                       |
| Tom Driscoll         | AFLCMC/LPSE - Propulsion NDI Engineering                   |                       |
| David Campbell       | Tinker AFB NDI Program Manager                             |                       |
| Josh Hodges          | Hill Engineering   |                       |
| Mike Brauss          | Proto Mfg Inc.   |                       |
| Taylor Thompson      | Proto Mfg Inc.   |                       |
| Teodor Dogaru        | SouthWest Research Institute                               |                       |
| Maj Joseph Wahlquist | AFRL-RXCA Branch Chief                                     |                       |
| Eric Lindgren        | AFRL-RXCA Research Lead                                    |                       |
| Bryce Harris         | F-16 ASIP Program Manager                                  |                       |
| Leo Garza            | L3 Tech  |                       |
| Walt Matulowicz      | AFLCMC/EZPT USAF NDI Program Office                        |                       |
| Mark Kassan          | AFSC/ENSI  |                       |
| Mike Paulk           | AFLCMC/EZPT NDI Program Office - Chief                     |                       |



# NDI Subcommittee Refined Priorities



## Priority I. Quantify UT dead zone in Cx holes. Correlate to hole D and T.

- Round Robin - Map UT dead zone for Cx holes – selected specimens
  - RXSA, RXCA, AFSC/ENSI
  - **Need stress profiles from Val/Ver Test Subcommittee – T. Mills**
- Measure surface stress/deformation profiles on select Cx specimens
  - PROTO via Navy SBIR, Fastener Cam via USAF SBIR
- Machine countersink, install interference fit fasteners
  - Measure stress profiles of select specimens – PROTO via Navy SBIR
  - Re-measure UT dead-zone on selected Cx specimens
- Capture data w/ existing UT inspection systems - Validate optimum inspection PAUT process – all available specimens Cx vs non-Cx AFRL/RXSA coordinates with NAVAIR/Hill AFB.
  - Rotoscan
  - AFIS (USAF and Navy)



# NDI Subcommittee Refined Priorities



## **Priority II. Investigate impact of Taper-Lok fastener installation on ultrasonic fatigue crack detectability?**

- **Model Taper-Lok stress field – Needed from Modeling Team**
- Empirical measurements of UT response under planned a/c program effort

## **Priority III. Characterize impact of laser-peening on titanium.**

- Integrate measurements into planned a/c qual. programs