Large-Standoff Large-Area Thermography

LASLAT

Developed under SBIR NAVAIR N092-097

Maria Frendberg Beemer
Technical Lead
Thermal Wave Imaging, Inc.
Challenge: NDI of Large Scale Composite Structures

- Aggressive Non-Destructive Inspection (NDI) is integral to maintaining warfighter readiness
  - Effective NDI detects the earliest indication of defects
  - Components can be repaired or replaced before the structural integrity or performance of the aircraft is compromised

- NDI of composite aircraft presents challenges to current NDI methodologies
  - No visual indications of damage
  - Large areas must be inspected

More than 43% of the V-22 airframe is built with composite materials
Challenge: NDI of Large Scale Composite Structures

• Visual inspection
  – Only detects obvious problems that reach surface

• Coin-tap
  – Only useful for severe late-stage problems

• Ultrasonic (UT) A-scan (most widely used)
  – Point inspection, time and labor intensive for large area
  – Not sensitive to water ingress, foreign object debris
  – Does not perform 100% inspection

• Thermography
  – Area inspection
  – Tradeoff between sensitivity and area coverage

Currently used methods do not provide both large area coverage and adequate composite diagnostics
Flash Thermography

- Flash Thermography
  - Developed by TWI under NAVAIR SBIRs
  - Thermographic Signal Reconstruction (TSR)
    - Physics-based processing improves sensitivity
    - Winner, 2014 ASNT Research Innovation Award
  - Probability of Detection (POD) validation (2016 FAA / Sandia POD)
    - Outperforms UT A-scan baseline
    - Outperforms shearography, MAUS and other thermography
  - Unlike other NDI methods, Thermography can be applied from a distance.
    - Potential to perform a large area inspection from a single point

Stitched image of V-22 proprotor combines 36 shots after TSR processing using TWI MOSAIQ software
Challenge: NDI of Large Scale Composite Structures

A more effective NDI solution should **address the complexities of composite aircraft inspection**, and **perform fast, 100% area inspection of large aircraft structures**.

**Objectives**
- Minimize inspection turnaround time
- No gantry / robot or fixed installation required
- Easily adaptable for inspection of multiple platforms
- Simplify interpretation / analysis
- Operate in open hangar

(LASLAT (original concept))
The Solution - LASLAT

- Large area inspection from a fixed position
  - Automated area scan
    - Produces single image of entire area
  - Advanced signal processing provides simplified interpretation / analysis
  - No gantry, creeper or track
  - Operate in open hanger
  - Flat or curved surfaces
  - Easily configured for new inspection
  - Working Distance: 10 – 15 ft.
  - Coverage Area: 17 ft x 15 ft @ 15 ft standoff
  - Inspection Rate: 4.4 ft^2/min
  - Provides significant labor reduction
LASLAT Innovations

- Novel thermal projection optical system for highest efficiency excitation
- Optical correction over entire inspection field of Ch-46 main rotor allows for accurate defect sizing

Extended TSR signal processing

- LASLAT corrected
- Unprocessed
- TSR processed
V-22 Fuselage Inspection at FRC-E

Automated scan of inspection area
V-22 Fuselage Inspection at FRC-E

Automated scan of inspection area

Image is built as scan progresses
V-22 Fuselage Inspection at FRC-E

Automated scan of inspection area

Image is built as scan progresses
V-22 Fuselage Inspection at FRC-E

V22 Fuselage: 6’ x 15’ inspection area
V-22 Fuselage Inspection at FRC-E

V-22 Fuselage Inspection
Working Distance: 15 ft
Inspection Area: 6 ft x 15 ft
Inspection Time: 13 min

Zoom view of inspection area in MOSAIQ

Skin to frame disbond

Thermal Wave Imaging
### Key Features / Advantages / Benefits

<table>
<thead>
<tr>
<th>Features</th>
<th>Advantages</th>
<th>Benefits</th>
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</table>
| Large standoff distance   | Access to large structures without fixed gantry or immersion tank installation | • Reduced cost  
• Adapt to multiple inspections  
• Safe operation near fueled aircraft |
| Large inspection area     | No scanning apparatus required                                             | • Reduced installation cost  
• Reduced inspection time |
| TSR signal processing     | • Improved sensitivity  
• Single image of entire structure  
• Quantitative results       | • Assist operator flaw detection  
• Simplified analysis  
• Track condition over lifetime |
**Improvement over Current NDI**

**V-22 Proprotor Blade Inspection at FRC-E**

**Current: Flash Thermography**

- 4 hours
- 36 shots
- Close proximity

System is manually repositioned after each shot

**LASLAT**

- 9 minutes
- 18 shots
- 15 ft standoff

Blade is automatically scanned by system at fixed position
Benefits

Direct Benefits

• FY17 FRC-E deployment for V-22 Blade Inspections
  – Estimated labor reduction: 7-10 hrs/blade
  – Man-Hour savings/ year: 525-750 labor-hrs
  – Cost Reduction/ year: $68K-$98K

Anticipated Benefits

• H-1 main rotor blade work
  – Estimated 875-1250 labor-hour avoidance => $116K - $167K / yr cost avoidance

• Large area laminate inspections:
  – AV-8B wing: Estimated 320 labor-hour avoidance => $43K / yr cost avoidance
  – V-22 Mods: Estimated 80 labor-hour avoidance => $10K / yr cost avoidance

• Other potential targets include:
  – H-53K fuselage, V-22 wing, F-35 fuselage, F-18 wing/fuselage

Thermographic image of RAM coating disbonds under F/A-18 wing.
Challenges & Risks

• Innovation Maturity:
  – Proven technology that has been validated by independent comparison and POD studies

• DoD Community Awareness / Exposure:
  – Technology use within NAVAIR since 1998 and since is used by FRCs, USAF, Army, Coast Guard and primes

• Risk: Low-risk, high reward
  – LASLAT is an extension of proven flash thermography method

• Most significant challenge: Establishing equivalence with existing inspections
  – Quantifying inspection requirements
  – Overcoming culture / inertia (from UT and tap test)
  – Training / certification (programmatic evolution)
Innovation Status

• Technology Readiness Level:
  – TRL 7, successfully demonstrated on application

• Initial deployment:
  – FRC-E Capital Improvement Program (FY17), SBIR Phase III

• Alternate solutions:
  – Laser ultrasound
    • High sensitivity yet expensive, requires fixed installation
  – Linear Array ultrasound (roller probe)
    • High sensitivity yet slow, extensive equipment setup and analysis

• Applications:
  – Maintenance or manufacturing quality assurance
  – DOD
    • All fixed and rotary wing platforms
    • Older platforms with composite upgrades
  – Civilian Sector
    • Commercial aircraft operators
    • Wind turbine industry
    • Composite manufacturers of large structures
    • Detection of Foreign Object Debris (FOD)
    • Energy / infrastructure inspection
Looking Ahead

- LASLAT bridges gap between advanced technology used in manufacturing QA and the realities of the maintenance hangar
  - Same high standards for both, but flexibility and TAT needed for maintenance
- Phase II.5 – Expansion work (2017-2019)
  - General Use Process Controls
  - Accelerate Acquisition/Data Processing
  - Investigate Real-Time Capability
  - Investigate Thru-Transmission Capability

Expect significant reduction in inspection time.
Questions

Thermal Wave Imaging
(248) 414-3730
## Comparison to Alternatives

<table>
<thead>
<tr>
<th>Method</th>
<th>Advantages</th>
<th>Issues</th>
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<tbody>
<tr>
<td>Coin tap</td>
<td>Low cost</td>
<td>Large, near surface features only</td>
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<tr>
<td>Ultrasound</td>
<td>Excellent penetration</td>
<td>Point inspection or scanning required</td>
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<tr>
<td></td>
<td>Well-established</td>
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<tr>
<td>Radiography</td>
<td>Area inspection</td>
<td>Insensitive to many voids or delaminations</td>
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<td></td>
<td>Excellent crack detection</td>
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<tr>
<td>Conventional Thermography</td>
<td>Noncontact area inspection</td>
<td>Operates in close proximity to aircraft</td>
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<tr>
<td></td>
<td>Provides information about flaw</td>
<td>Limited depth range</td>
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<tr>
<td></td>
<td></td>
<td>Not for use near fueled aircraft</td>
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<tr>
<td>Shearography</td>
<td>Noncontact area inspection</td>
<td>Limited depth range</td>
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<tr>
<td></td>
<td></td>
<td>Issues at edges and corners</td>
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<tr>
<td>LASLAT</td>
<td>Noncontact large area inspection</td>
<td>Requires development of training, standards and procedures</td>
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<tr>
<td></td>
<td>Automated scanning</td>
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</tr>
<tr>
<td></td>
<td>No gantry or contact with aircraft</td>
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<td>OK for use near fueled aircraft</td>
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