Automated, Rapid Non-Destructive Inspection (NDI) of Large Scale Composite Structures

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Early diagnosis and repair of structural problems based on Nondestructive Inspection (NDI) is essential for optimum platform performance and readiness.
Current Problem

The increasing use of composites in Navy aircraft presents numerous challenges to current NDI capability

- Traditional methods used in metals ineffective (visual, coin tap)
- Point inspection methods time consuming for large structures
- Special coatings and structures may complicate inspection
- Disassembly for inspection undesirable
- Composite inspections
  - Impact damage
  - Water entrapment
  - Delamination
  - Disbonding of joined structures
  - Heat damage
Fleet Requirements

- Decrease inspection time during scheduled maintenance of large aircraft structures
- Aid inspector in discriminating between flaw indications and normal variations
- Provide quantitative metric for operator decision
- Simplify operator training
# Current Approaches

<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 standards and procedures</td>
<td>Requires contact, couplant</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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<tr>
<td></td>
<td>Excellent crack detection</td>
<td></td>
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<tr>
<td>Thermography</td>
<td>Area inspection</td>
<td>Operates in close proximity to aircraft</td>
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<tr>
<td></td>
<td>Provides information about flaw type</td>
<td>Limited depth range</td>
</tr>
<tr>
<td>Shearography</td>
<td>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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</table>
Advanced NDI Development

- Aggressive support of new and emerging NDI technologies through SBIR / STTR programs
  - Portable imaging ultrasound (Imperium)
  - MWM Array Eddy Current (Jentek Sensors)
  - Portable and quantitative thermography (Thermal Wave Imaging)

- High success rate of commercialization and transition to fleet
NAVAIR and Thermography

• Long history of support and development of thermography for NDI
  – Flash thermography
  – Modeling
  – Vibrothermography
  – Thermographic Signal Reconstruction (TWI)
  – Portable systems
Thermography Advantages

- Non-contact
- Single side access (no disassembly required)
- Flat or curved surfaces (no critical alignment required)
- Area inspection
- Image result
Deployment Issues

- High end cameras required
  - expensive, large, delicate
- Limited operation in close proximity to aircraft
- Advanced signal processing required
- Training
- Time consuming for large area

An operator in close proximity to the aircraft inspects a small area with flash thermography.
Automated, Rapid Non-Destructive Inspection (NDI) of Large Scale Composite Structures
N092-097 Cherry Point

• Large area thermography at a large working distance from aircraft

• Apply advanced signal processing to non-standard signal

• Simplify / automate inspection and interpretation
Remote NDI: A New Paradigm

- NDI of large structures typically requires a fixed installation to scan a point inspection device that is in close proximity to the surface over a large area.

- We have developed a solution that is capable of inspecting a large area quickly, and a distance from the target, while offering sensitivity comparable to existing technologies.
LASLAT Projection NDI

- Rapid inspection of large structures
  - Noncontact
  - Results archived as single image
  - Quantitative flaw analysis

- Fixed or portable implementation
  - No fixed gantry or infrastructure required
  - Mount on tripod, cart, truck, boat etc.
  - Truck or boat mounted

- Performance comparable to close proximity methods
  - Detection of subsurface voids, delamination, moisture, corrosion

- Inspection of inaccessible or hazardous components
LASLAT

Baseline Approach

An operator in close proximity to the aircraft inspects a small area with flash thermography.

NDI system positioned far from aircraft to inspect large area.

LASLAT Projection Thermography

IR camera

heat projector

5-50 ft.

www.thermalwave.com
Fit raw log-log data with a smooth function and use the replica for analysis and further processing.

- Excellent fitting
- Conversion < 5 sec
- Temporal noise reduction
- Store coefficients of fit equation only
  - Smaller file size
  - Faster processing
TSR Derivatives

TSR

TSR 1\textsuperscript{st} derivative

TSR 2\textsuperscript{nd} derivative
Thermographic Signal Reconstruction

Raw thermography data

TSR processed

X-ray

Conventional Flash Thermography

TTU

TSR

Disbond
Extended Pulse Heating

Early behavior of signals of interest may be masked during heating period.

Heating and cooling occur simultaneously during extended heating.
# Performance

<table>
<thead>
<tr>
<th>Features</th>
<th>Advantages</th>
<th>Benefits</th>
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<tbody>
<tr>
<td>Large standoff distance</td>
<td>Access to large structures without fixed installation</td>
<td>Reduced cost and adaptation to multiple inspections</td>
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<tr>
<td></td>
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<td>Operation in fuel vapor areas</td>
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<tr>
<td>Large inspection area</td>
<td>No fixed scanning apparatus required</td>
<td>Reduced installation cost</td>
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<tr>
<td></td>
<td></td>
<td>Reduced inspection time</td>
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<tr>
<td>TSR signal processing</td>
<td>Improved detection sensitivity</td>
<td>Meet/exceed existing requirements</td>
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<td></td>
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<td>Verify/assist operator in flaw detection</td>
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TSR Processing

Proprietary Thermographic Signal Reconstruction processing extracts subsurface features that are undetectable in raw data.

Time sequence of carbon fiber honeycomb panel acquired with LASLAT system at 50°.

Skin-to-core disbond

Inter-ply delamination

Skin

Al core

Unprocessed
System Performance

- Operating range 5-50 ft from inspection surface
- Instantaneous coverage area: ~2 ft²
- Total coverage area: ~ 400 ft²

Comparison of projection system at 45' and close proximity commercial flash thermography system on a composite panel with hidden flaws.
Large Area Inspection

- Instantaneous coverage area: ~4 ft$^2$ 
- Total coverage area: ~400 ft$^2$ 
- 81 shots, 3-4 hr inspection time 
- Software controlled: creates full area image and flaw detection 

System software automatically combines far-field data into a single image.
Current State of Development

- Current state: TRL 3-4
  - Working prototype in lab environment

- Field demo scheduled Q1 2013
  - Target state: TRL 5
Questions?