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

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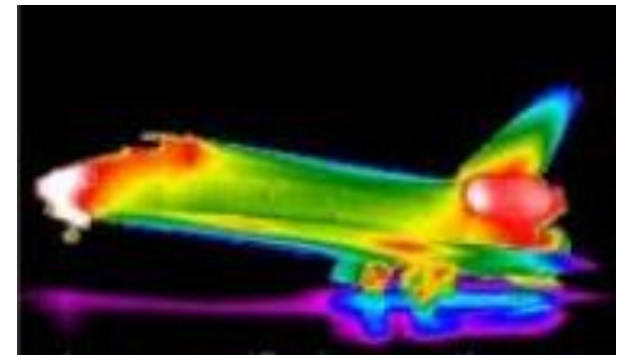
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# NAVAIR NDI



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



Method	Advantages	Issues
Coin tap	Low-cost	Large, near surface features only
Ultrasound	Excellent penetration Well-established standards and procedures	Point inspection or scanning required Requires contact, couplant
Radiography	Area inspection Excellent crack detection	Insensitive to many voids or delaminations
Thermography	Area inspection Provides information about flaw type	Operates in close proximity to aircraft Limited depth range
Shearography	Area inspection	Limited depth range Issues at edges and corners



# 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

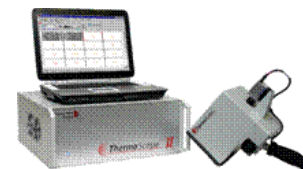
JENTEK® Sensors



imperium™  
Advanced Ultrasound Imaging



Thermal Wave Imaging 





# NAVAIR and Thermography



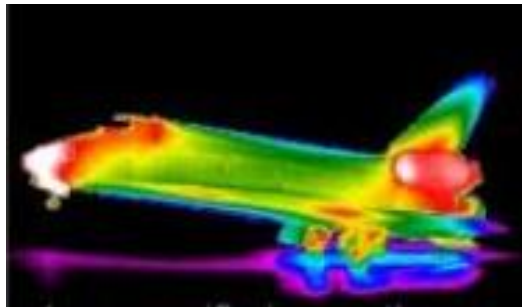
- Long history of support and development of thermography for NDI
  - Flash thermography
  - Modeling
  - Vibrothermography
  - Thermographic Signal Reconstruction (TWI)
  - Portable systems



# Thermography Advantages



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



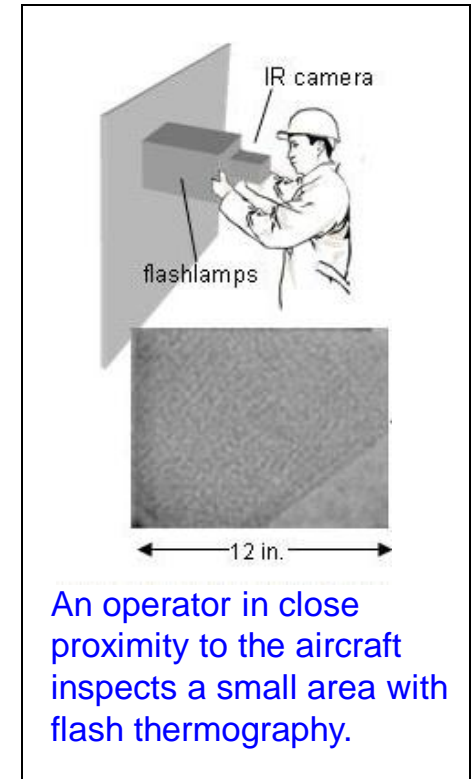




# Deployment Issues



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





# NAVAIR Phase II SBIR



## Automated, Rapid Non-Destructive Inspection (NDI) of Large Scale Composite Structures N092-097 Cherry Point

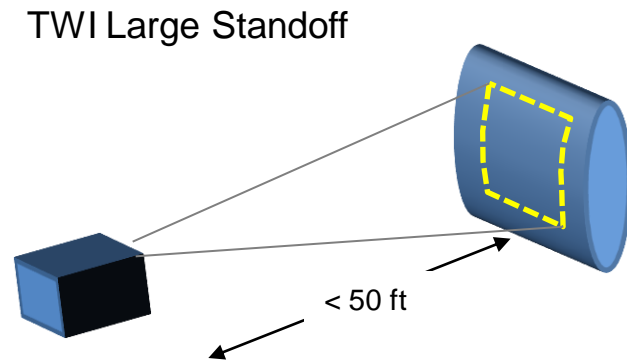
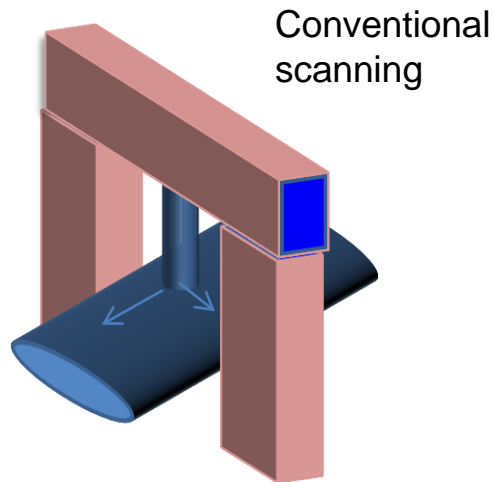
- Large area thermography at a large working distance from aircraft
- Apply advanced signal processing to non-standard signal
- Simplify / automate inspection and interpretation



# 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.



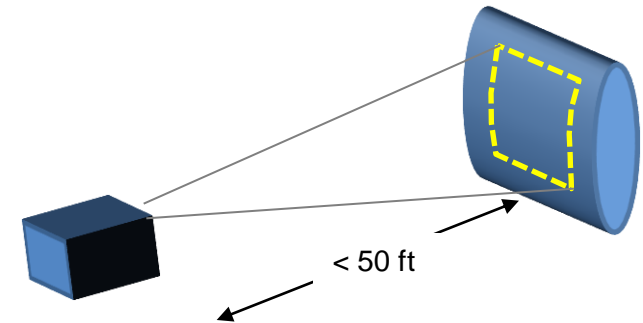


# LASLAT Projection NDI



- 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

## Large Standoff / Large Area Thermography (LASLAT)



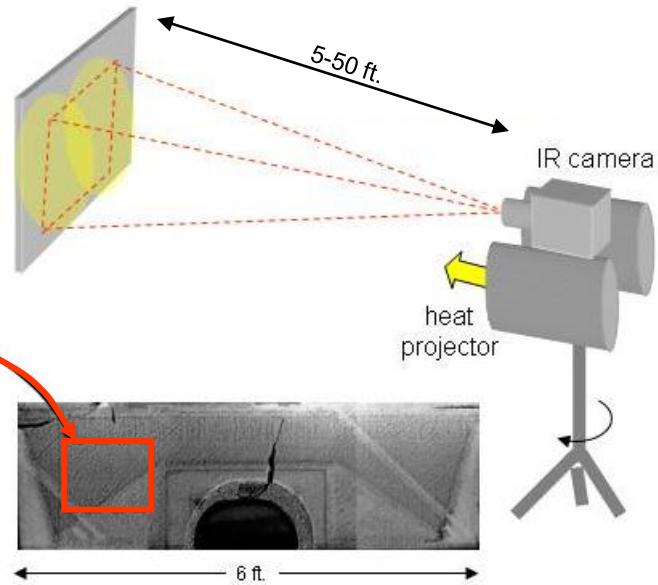
*LASLAT uses TWI Thermographic Signal Reconstruction to provide laboratory quality results in a far-field system*

## Baseline Approach



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

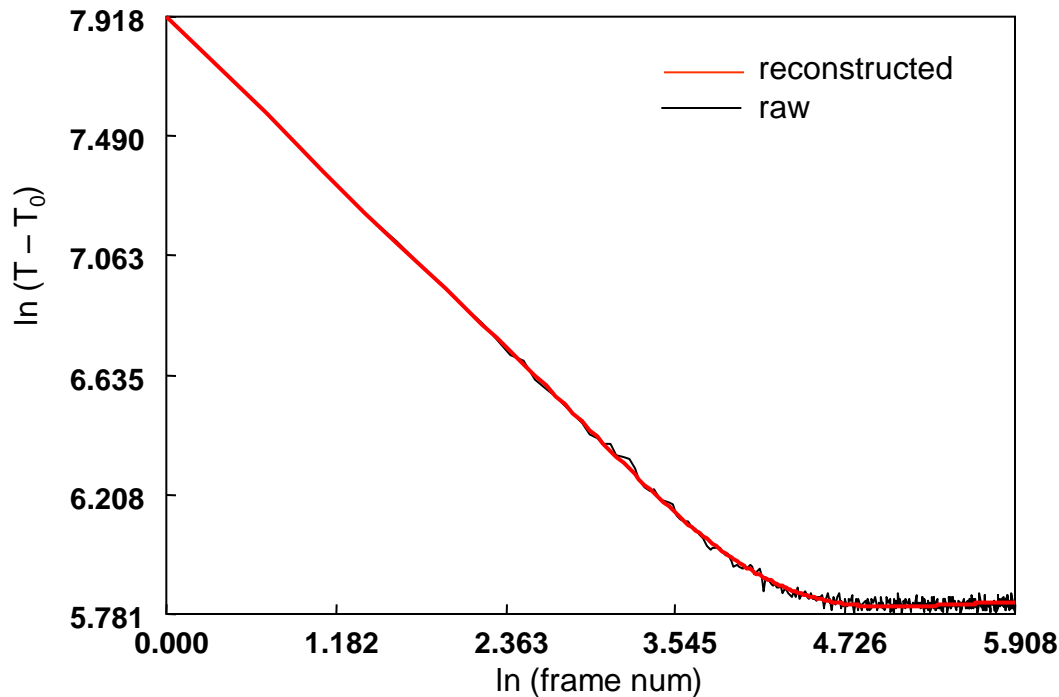
## LASLAT Projection Thermography



NDI system positioned far from aircraft to inspect large area.



# Thermographic Signal Reconstruction (2000)



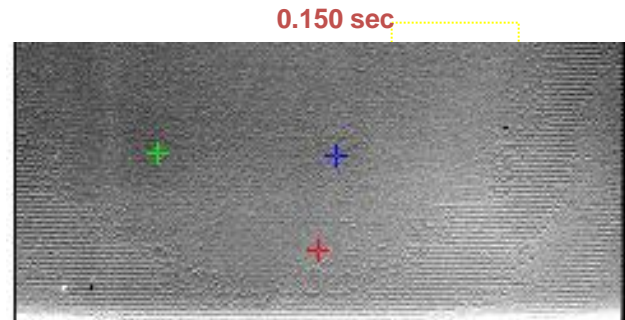
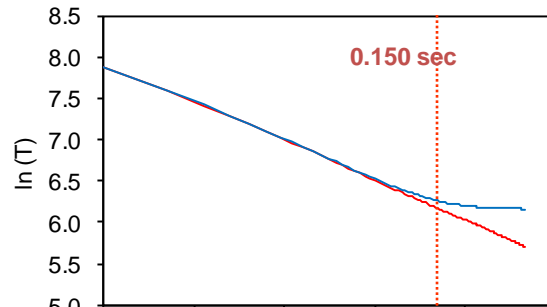
Fit raw log-log data with a smooth function and use the replica for analysis and further processing.

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

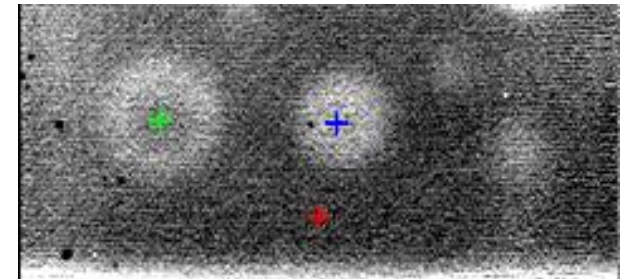
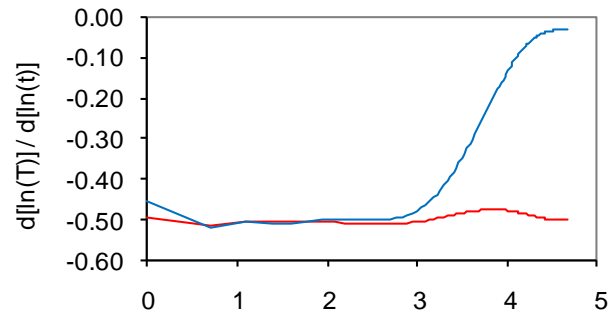
U.S. Patent 6,516,084

# TSR Derivatives

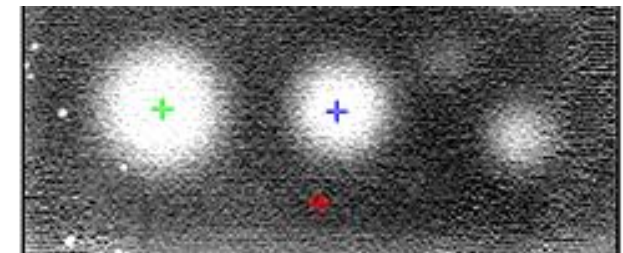
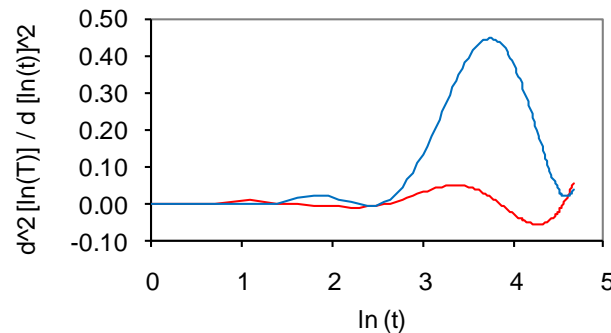
TSR



TSR  
1<sup>st</sup> derivative



TSR  
2<sup>nd</sup> derivative

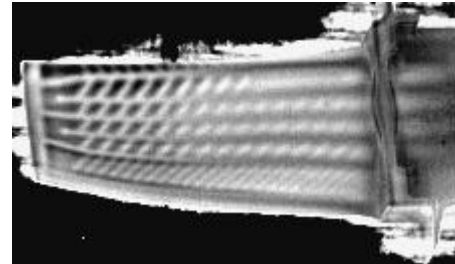




# Thermographic Signal Reconstruction

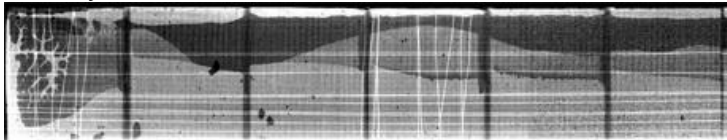


Raw thermography data

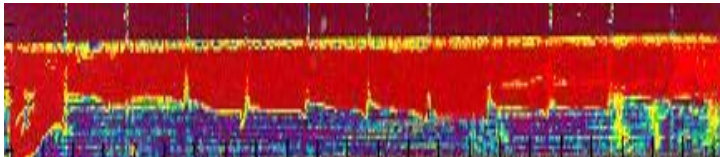


TSR processed

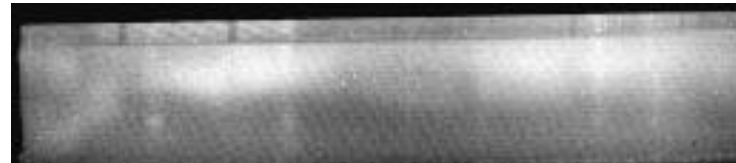
X-ray



TTU



Conventional Flash Thermography



TSR

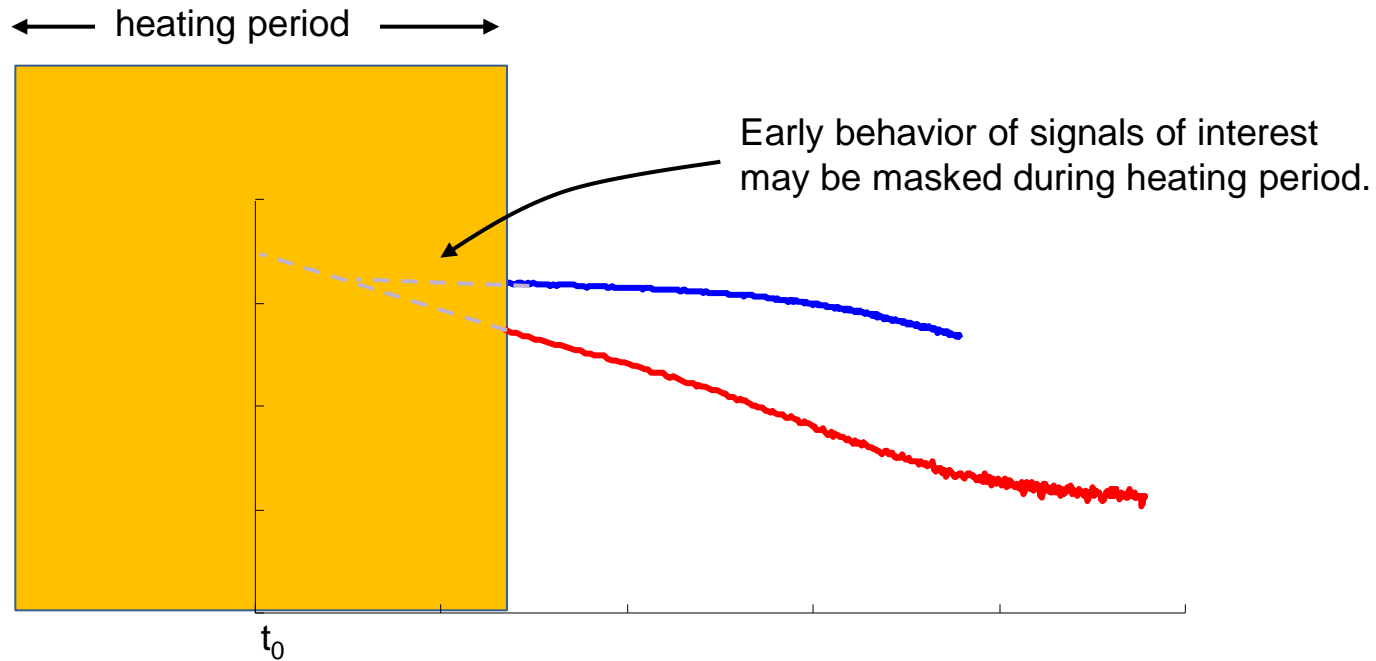


Disbond





# Extended Pulse Heating



Heating and cooling occur simultaneously during extended heating

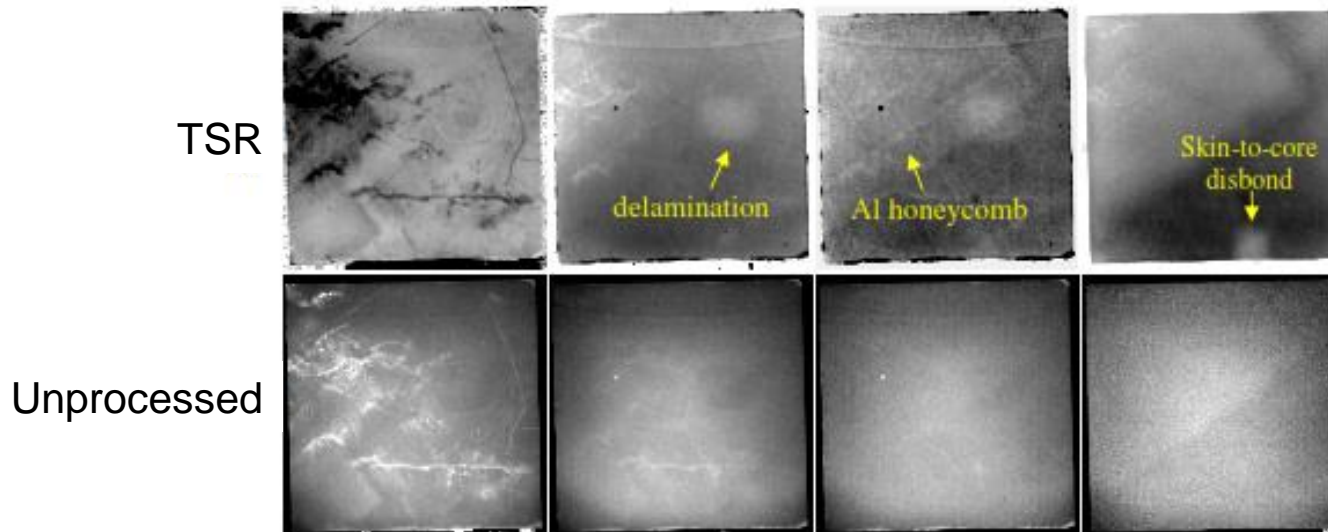
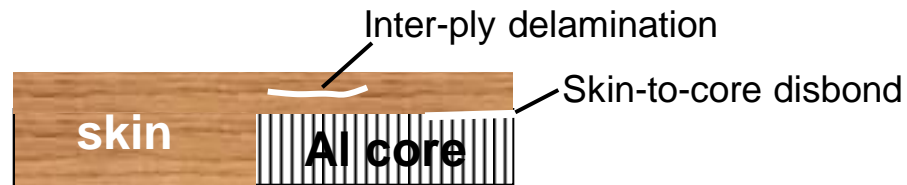


# Performance



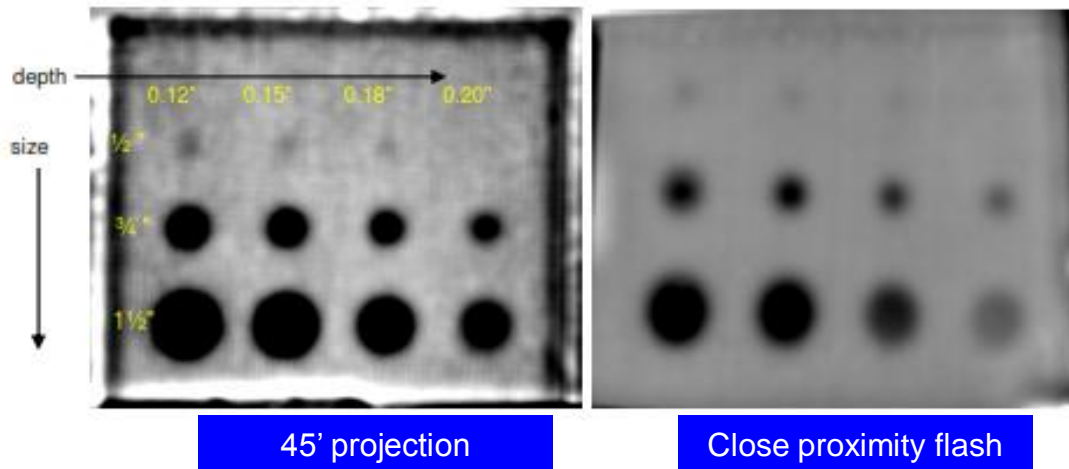
Features	Advantages	Benefits
Large standoff distance	Access to large structures without fixed installation	Reduced cost and adaptation to multiple inspections  Operation in fuel vapor areas
Large inspection area	No fixed scanning apparatus required	Reduced installation cost  Reduced inspection time
TSR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

# TSR Processing



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

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

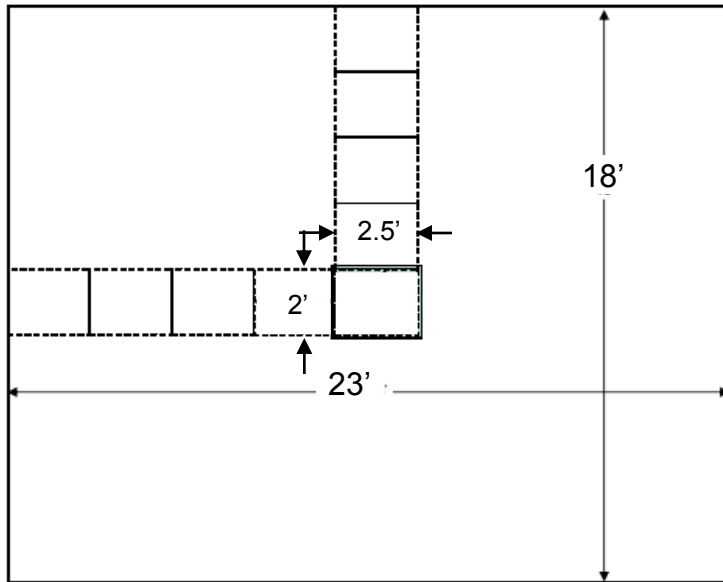


Comparison of projection system at 45' and close proximity commercial flash thermography system on a composite panel with hidden flaws.

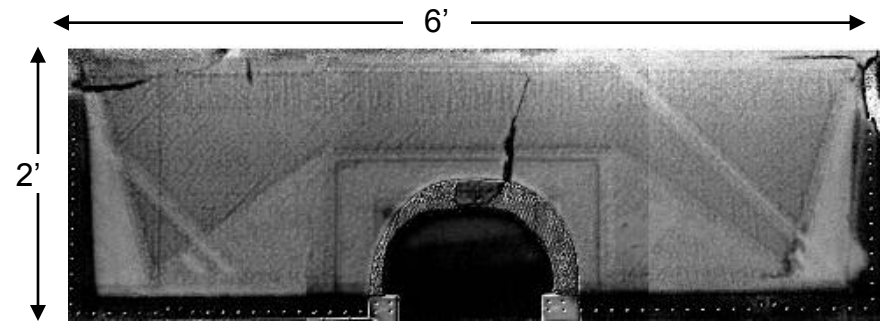
- Operating range 5-50 ft from inspection surface
- Instantaneous coverage area: ~2 ft<sup>2</sup>
- Total coverage area: ~ 400 ft<sup>2</sup>



# Large Area Inspection



System area coverage at 50 ft. stand-off



System software automatically combines far-field data into a single image.

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



# Current State of Development



Imaging  
and  
excitation

Signal  
processing

Software

Application  
specific  
hardware

- Current state: TRL 3-4
  - Working prototype in lab environment
- Field demo scheduled Q1 2013
  - Target state: TRL 5



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Questions?