Large-Standoff, Large-Area Thermography (LASLAT)

Nondestructive Inspection of Composite Structures

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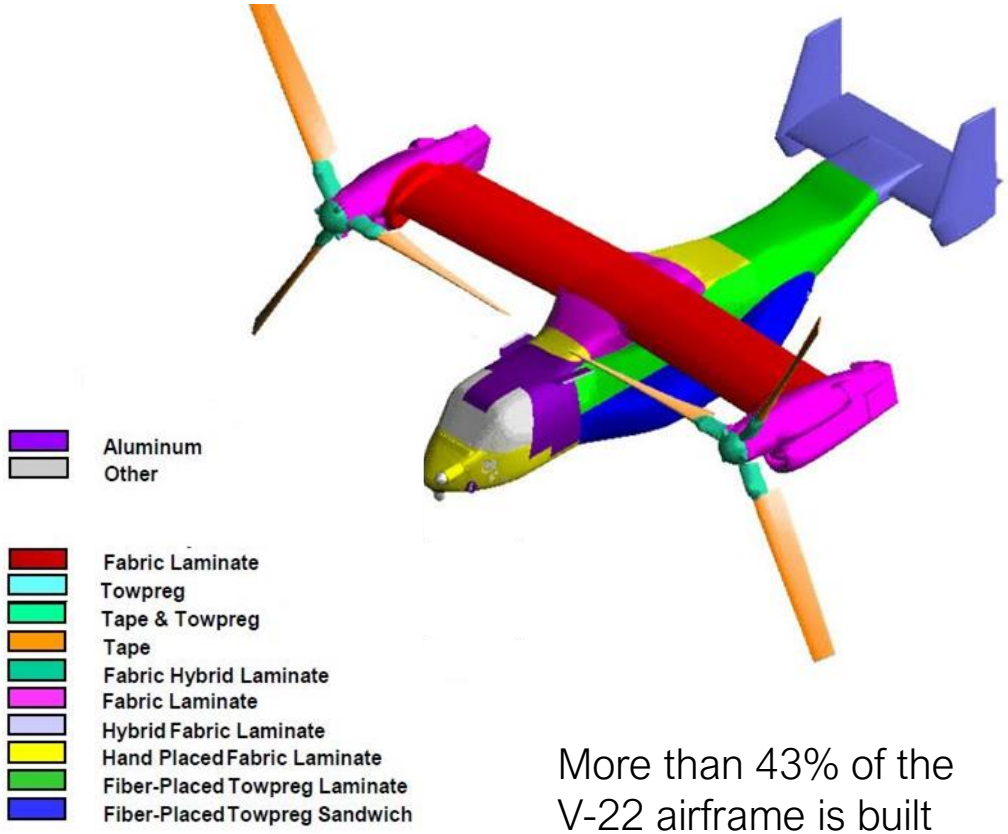
Thermal Wave Imaging

Overview

- NDI of Large-Scale Composite Structures
- Thermographic NDI
- Large-Standoff, Large-Area Thermography (LASLAT)
- LASLAT Developments
  - LASLAT Gen 2
  - ProjectIR
  - EagleIR
- Demos & Applications

NDI of Large Scale Composite Structures

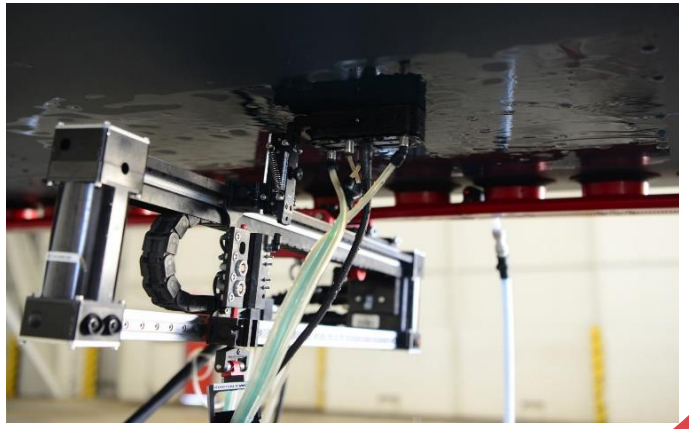
- Aggressive Non-Destructive Inspection (NDI) is integral to maintaining warfighter readiness
- NDI of composite aircraft can be challenging
  - No visual indications of damage
  - Large areas must be inspected
- Effective NDI should detect the earliest indication of defects
  - Components can be repaired or replaced before the structural integrity or performance of the aircraft is compromised



More than 43% of the V-22 airframe is built with composite materials

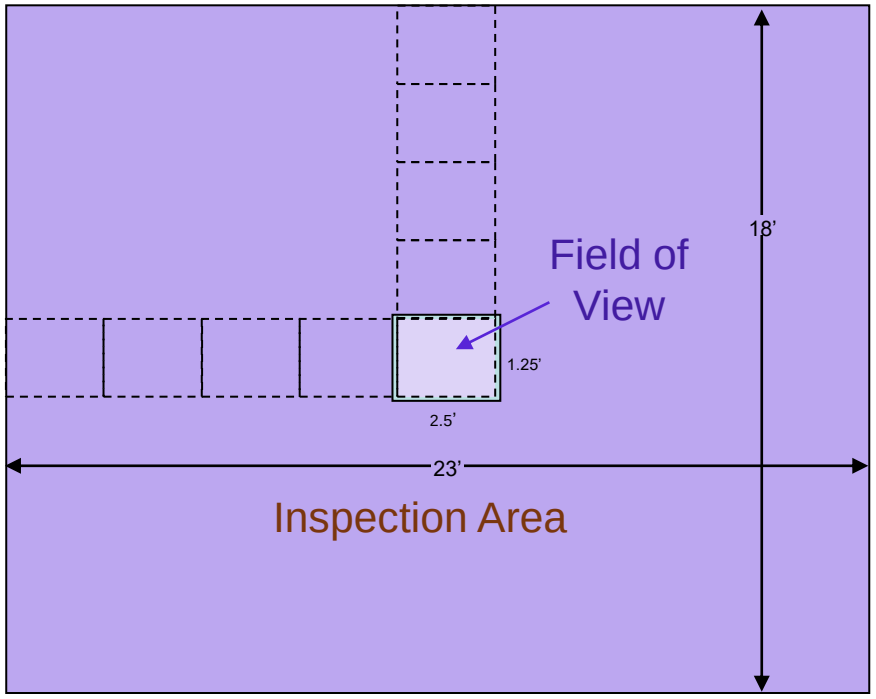
Composite NDI Approaches

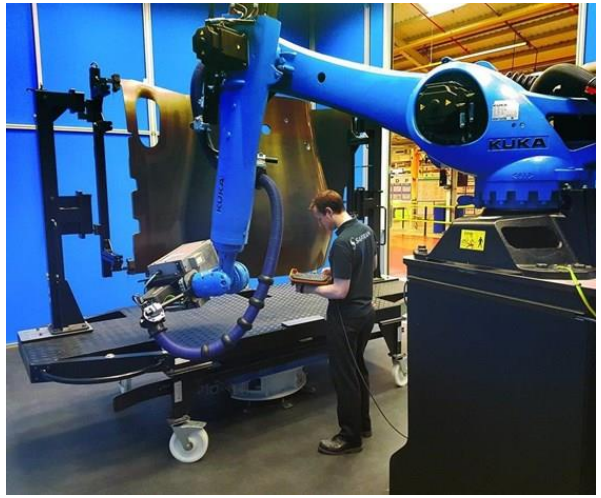
Method	Advantages	Issues
Coin tap	-Low cost	-Point inspection -Large, near surface features only -Imprecise defect localization -Maintenance hangars are loud
Ultrasound A-Scan (current baseline)	-Excellent depth penetration	-Point inspection or scanning required -Very time consuming(~2 ft^2/hr) [1] -Insensitive to fluid intrusion
MAUS Ultrasound	-Area inspection (~10 ft^2) -Moderate inspection rate (~22 ft^2/hr)[1] -Excellent depth penetration	-Contact/couplant required -Insensitive to fluid intrusion
Flash Thermography	-Area inspection -Moderate inspection rate (~8 ft^2/hr)[1] -Detects a wide range of composite defects	-Tradeoff between sensitivity and area coverage



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

Conventional Approaches to Large Area NDI



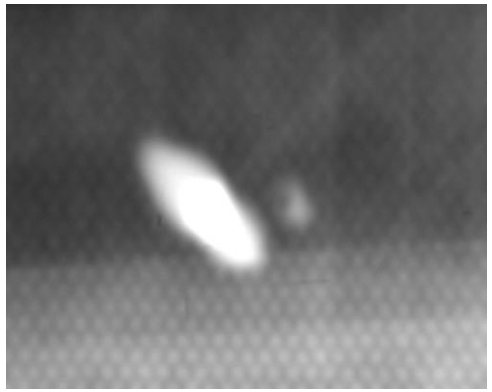


- Manual
- Fixed gantry
- Robotic system
- Creeper/ scanner
- Drones

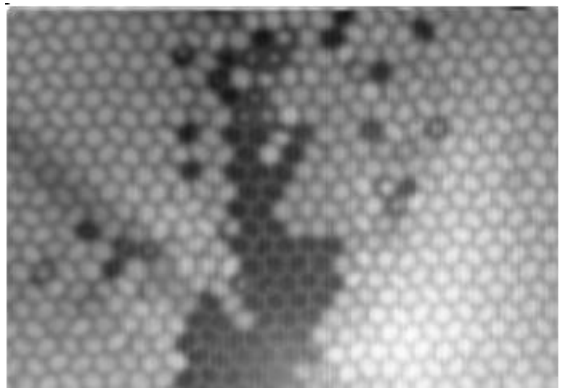
Thermographic NDI

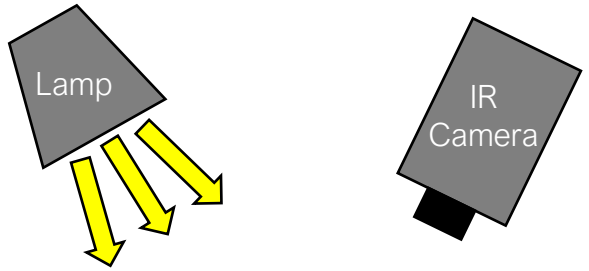
- Target surface is heated and monitored using an IR camera as heat is conducted into the part
- Internal discontinuities modify the cooling behavior at the surface
- Signal processing can be used to enhance sensitivity and for quantitative measurements (e.g. thickness, thermal properties)

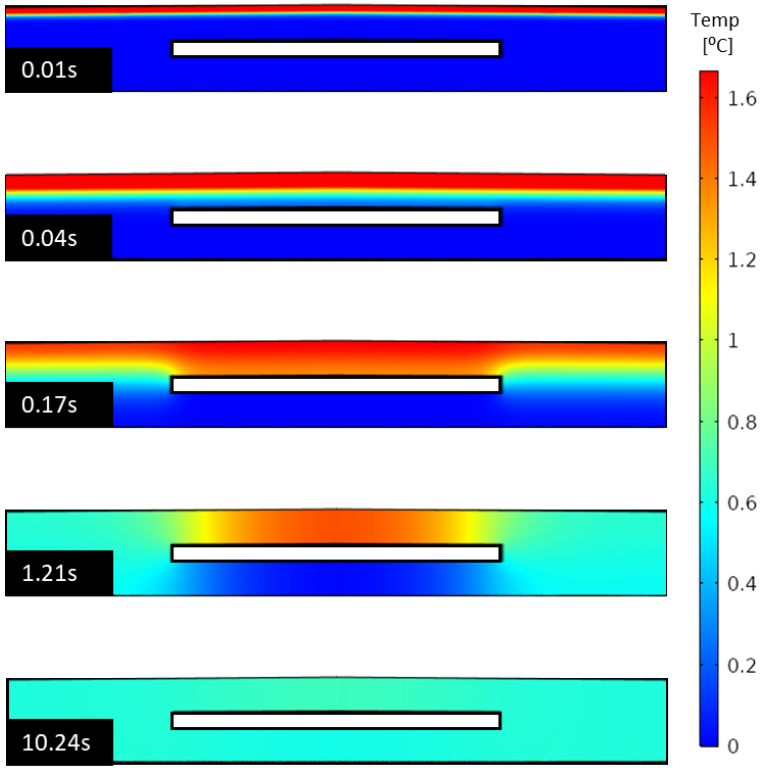
Impact damage produces hot spot



Water intrusion produces cold spot



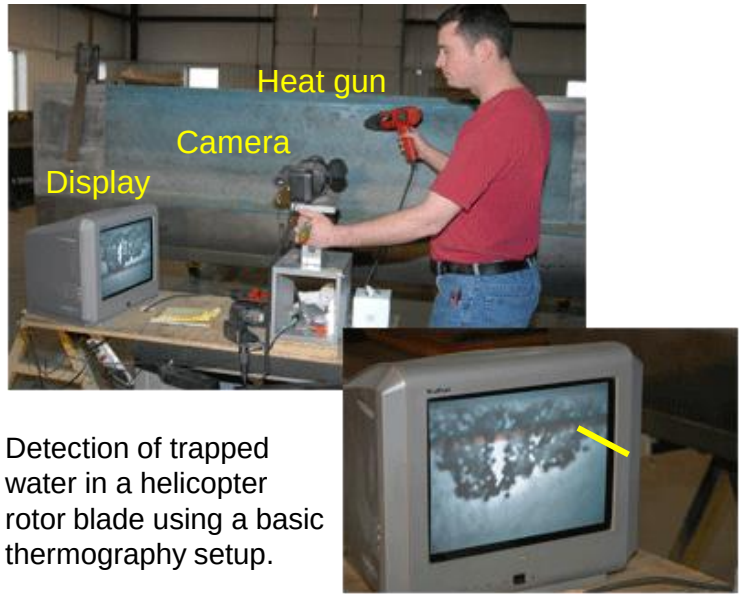




Finite difference model of a 1" diameter void placed 0.1" deep (AR = 10) in a 0.25" thick steel slab

Thermographic NDI

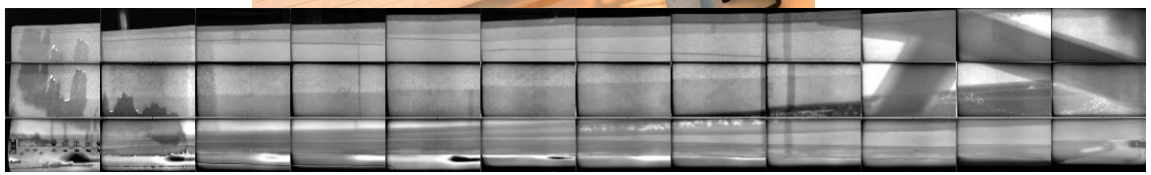
CH-47 Main Rotor Blade Inspection



Detection of trapped water in a helicopter rotor blade using a basic thermography setup.

Inspection Standoff: 1 ft
Inspection Area: 8 x 10”
Heat Source: Heat Gun
Heating Duration: 2-10 s

V-22 Proprotor Blade Inspection



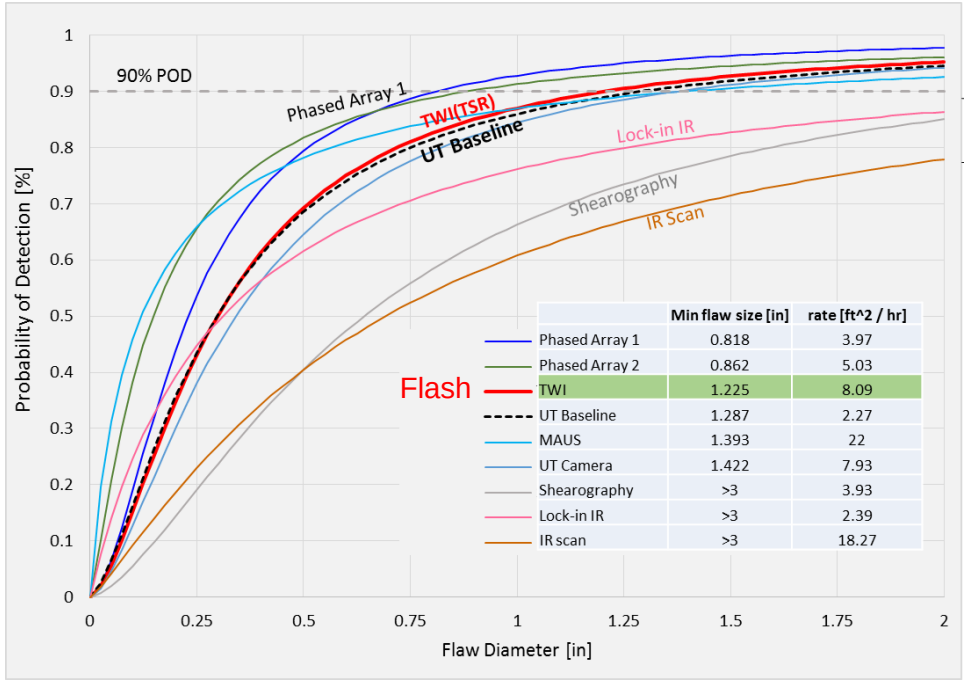
Stitched image of V-22 proprotor combines 36 shots after TSR processing

Inspection Standoff: 1 ft
Inspection Area: 8 x 10”
Heat Source: Flash Lamp Array
Heating Duration: <10 ms

Thermographic Signal Reconstruction (TSR)

- Physics-based processing improves sensitivity
- Developed by TWI under NAVAIR SBIRs
- 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

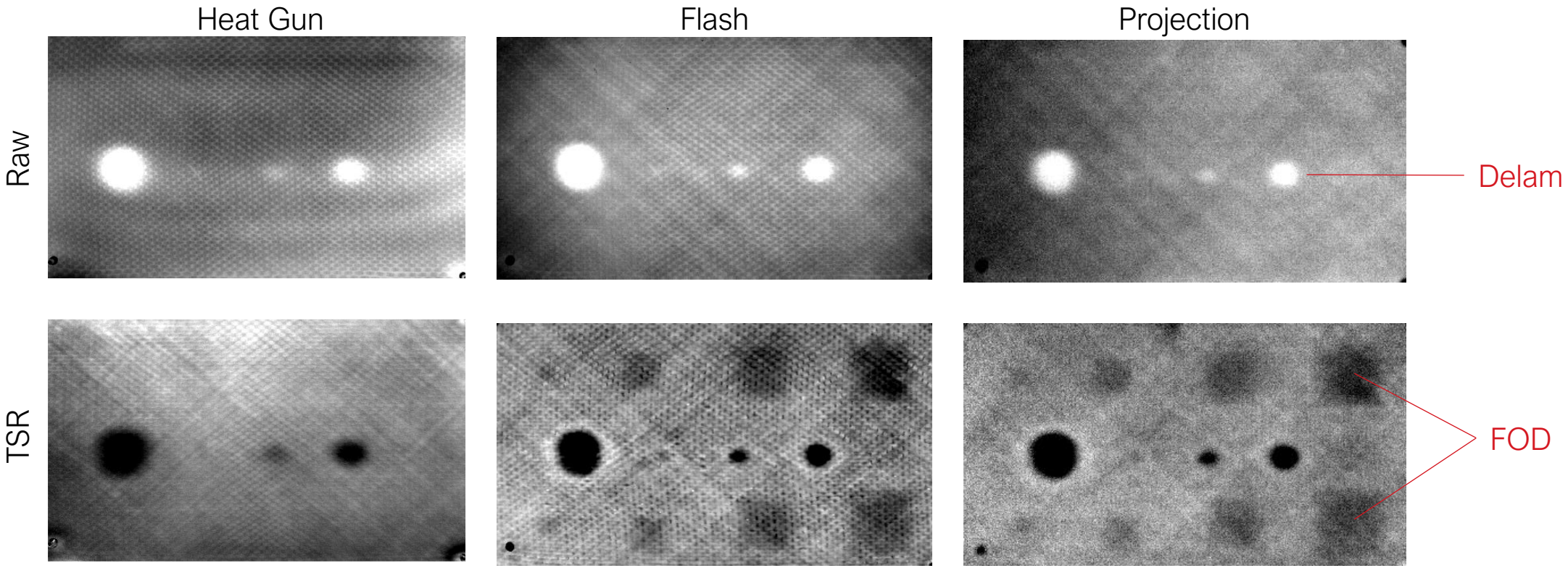
POD: Constant thickness and complex geometry flaws, 12-20 Plies



	Min flaw size [in]	rate [ft^2 / hr]
Phased Array 1	0.818	3.97
Phased Array 2	0.862	5.03
TWI	1.225	8.09
UT Baseline	1.287	2.27
MAUS	1.393	22
UT Camera	1.422	7.93
Shearography	>3	3.93
Lock-in IR	>3	2.39
IR scan	>3	18.27

Ref: DOT/FAA/TC-15/63 Dec 2016

Thermographic Signal Reconstruction (TSR)

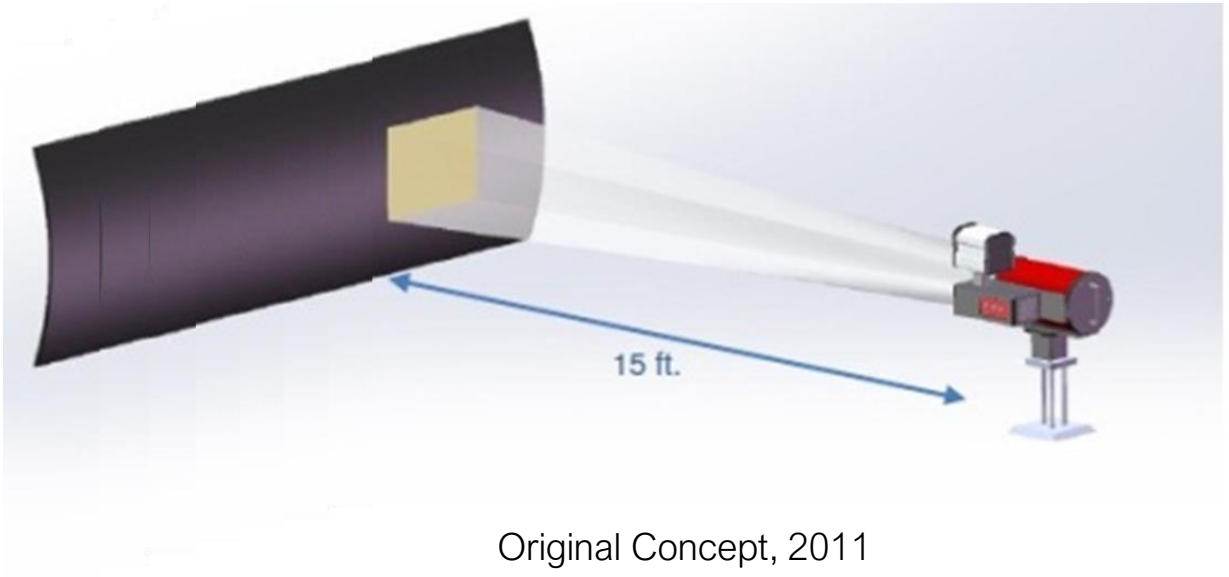


12 ply CFRP with simulated delaminations and FOD at mid-depth

Large-Scale, Large-Area Thermography (LASLAT)

Large area inspection from a fixed position

- Automated area scan
  - Produces single image of entire area
- No gantry, creeper or track
- Operate in open hanger
- Flat or curved surfaces
- Easily configured for new inspection



Original Concept, 2011

Developed under NAVAIR SBIR N092-097

Large-Scale, Large-Area Thermography (LASLAT)

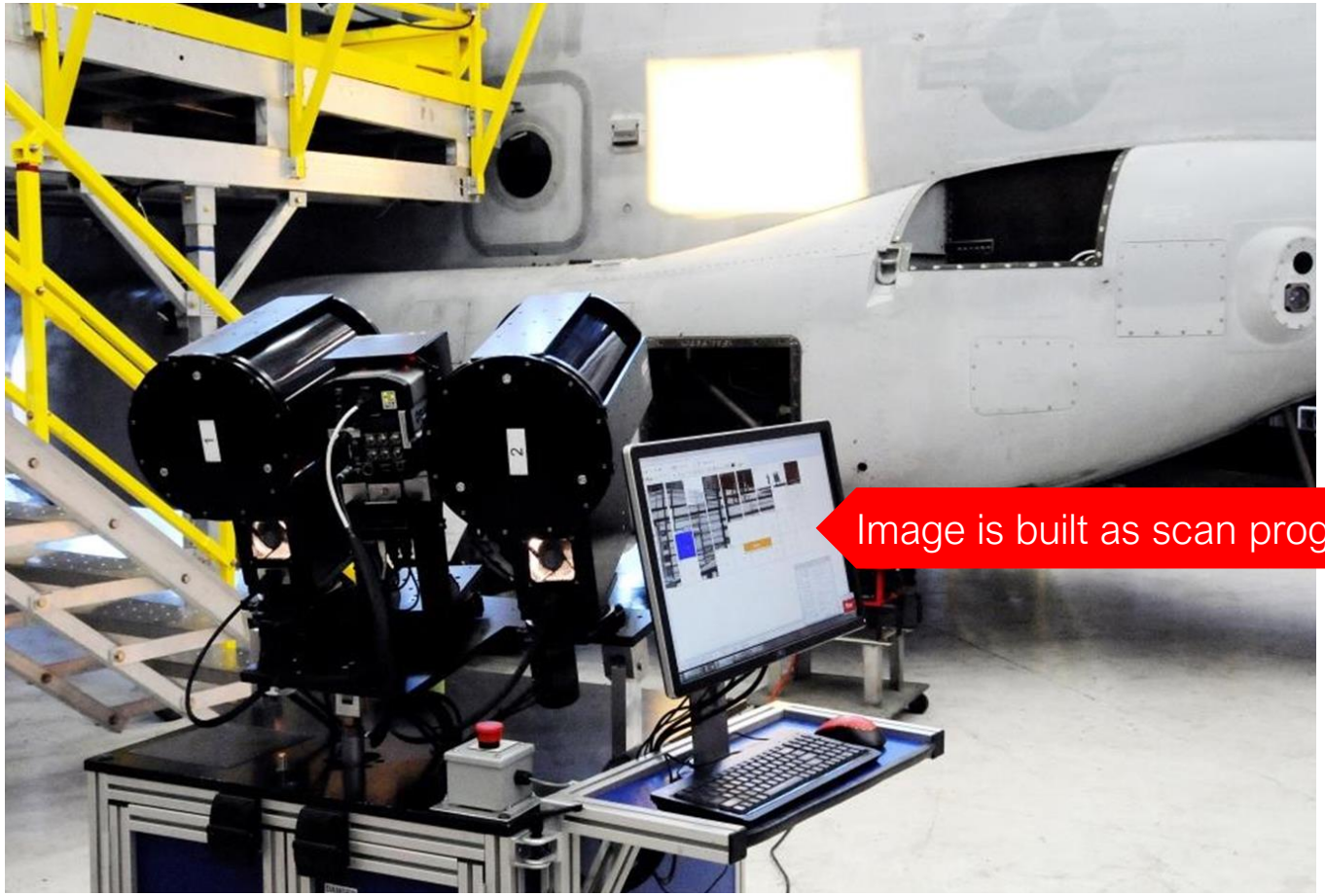
- Working Distance: 10 – 15 ft.
- Coverage Area: 17 ft x 15 ft @ 15 ft standoff
- Inspection Rate: 4.4 ft^2/min or 260 ft^2/hr
- Advanced signal processing provides simplified interpretation / analysis
- Provides significant labor reduction
- Winner of 2016 DOD Maintenance Innovation Competition
- Winner of 2017 CTMA Technology Competition

Developed under NAVAIR SBIR N092-097

V-22 Fuselage Inspection at FRC-E

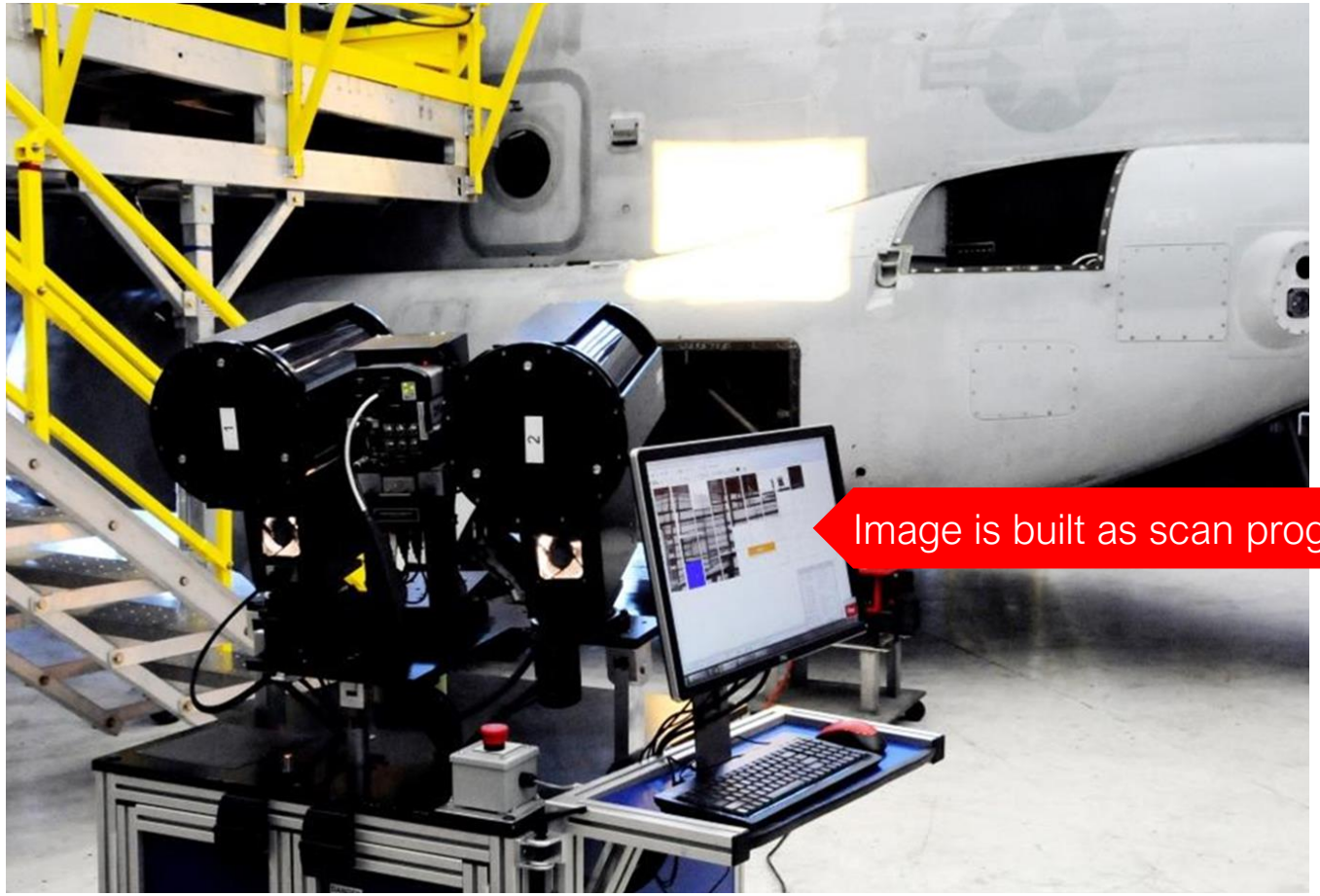
Automated scan of inspection area

V-22 Fuselage Inspection at FRC-E



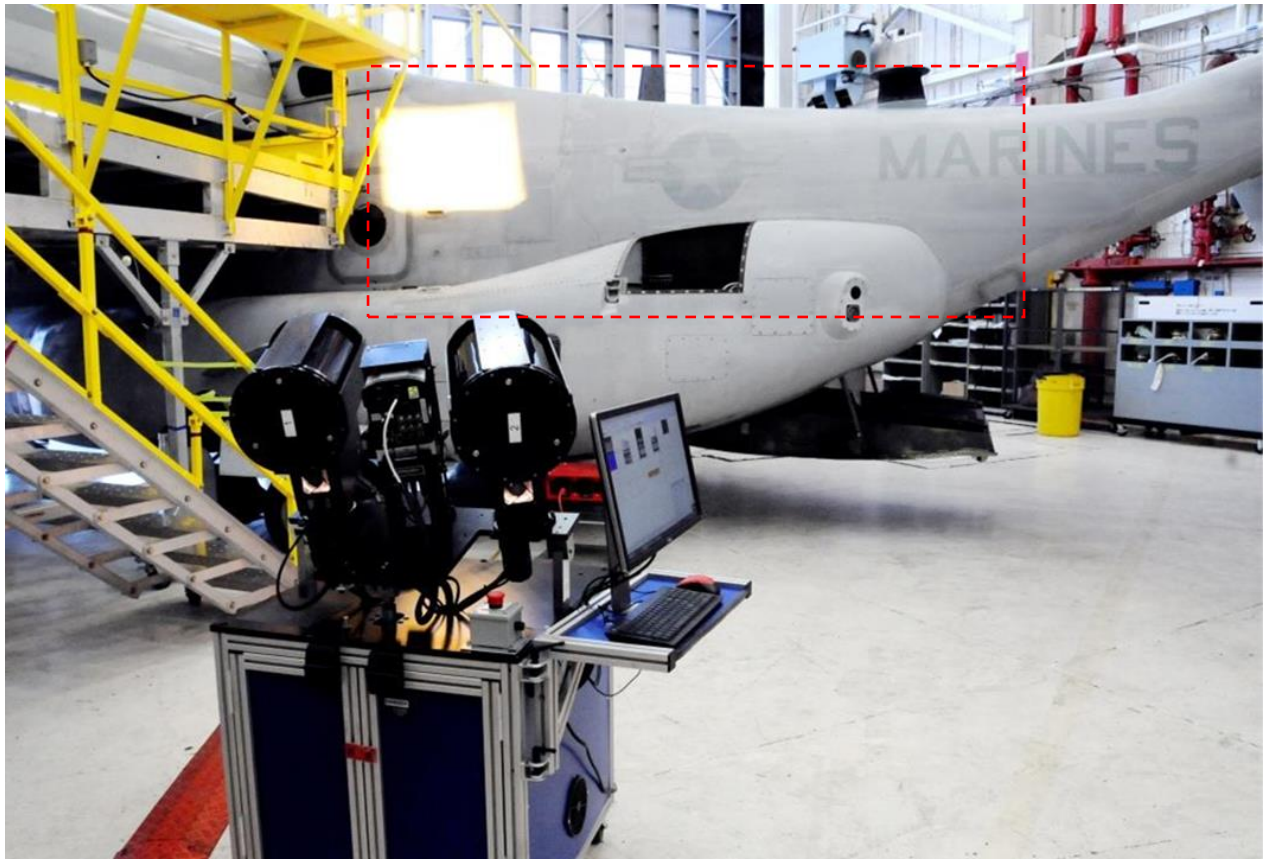
Automated scan of inspection area

V-22 Fuselage Inspection at FRC-E

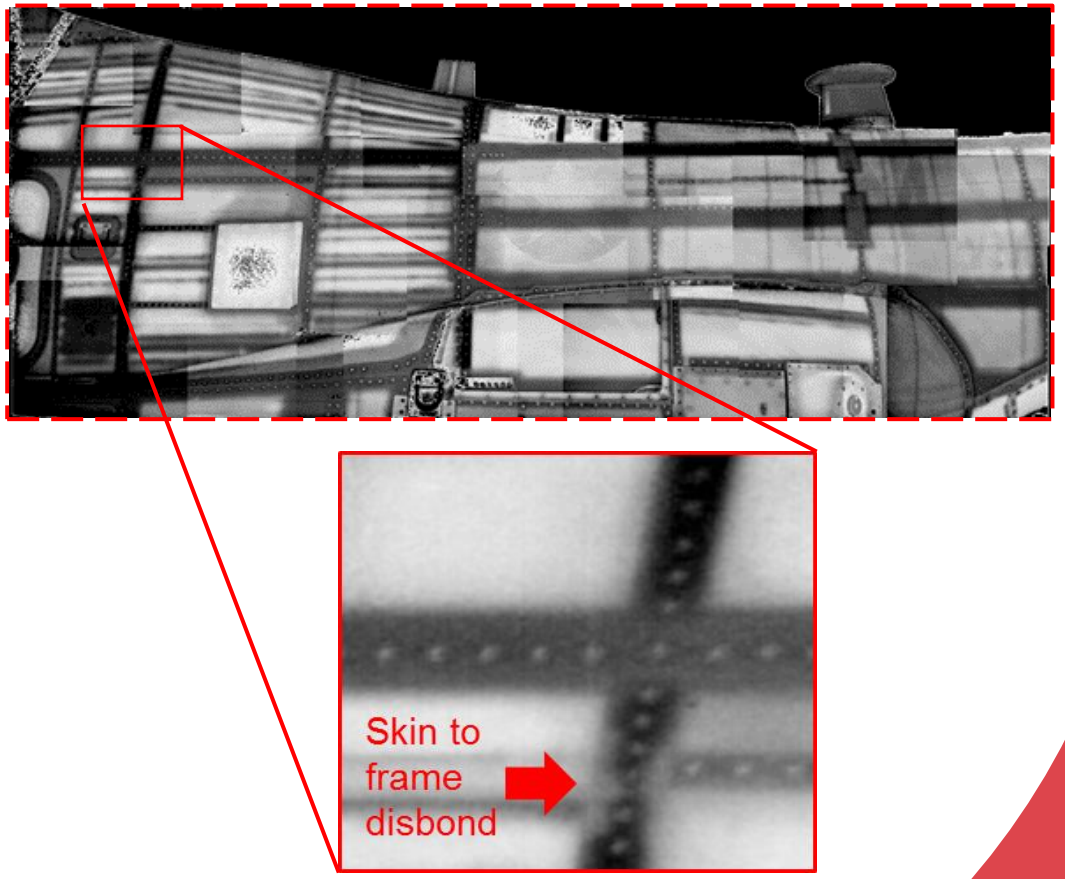


Automated scan of inspection area

V-22 Fuselage Inspection at FRC-E

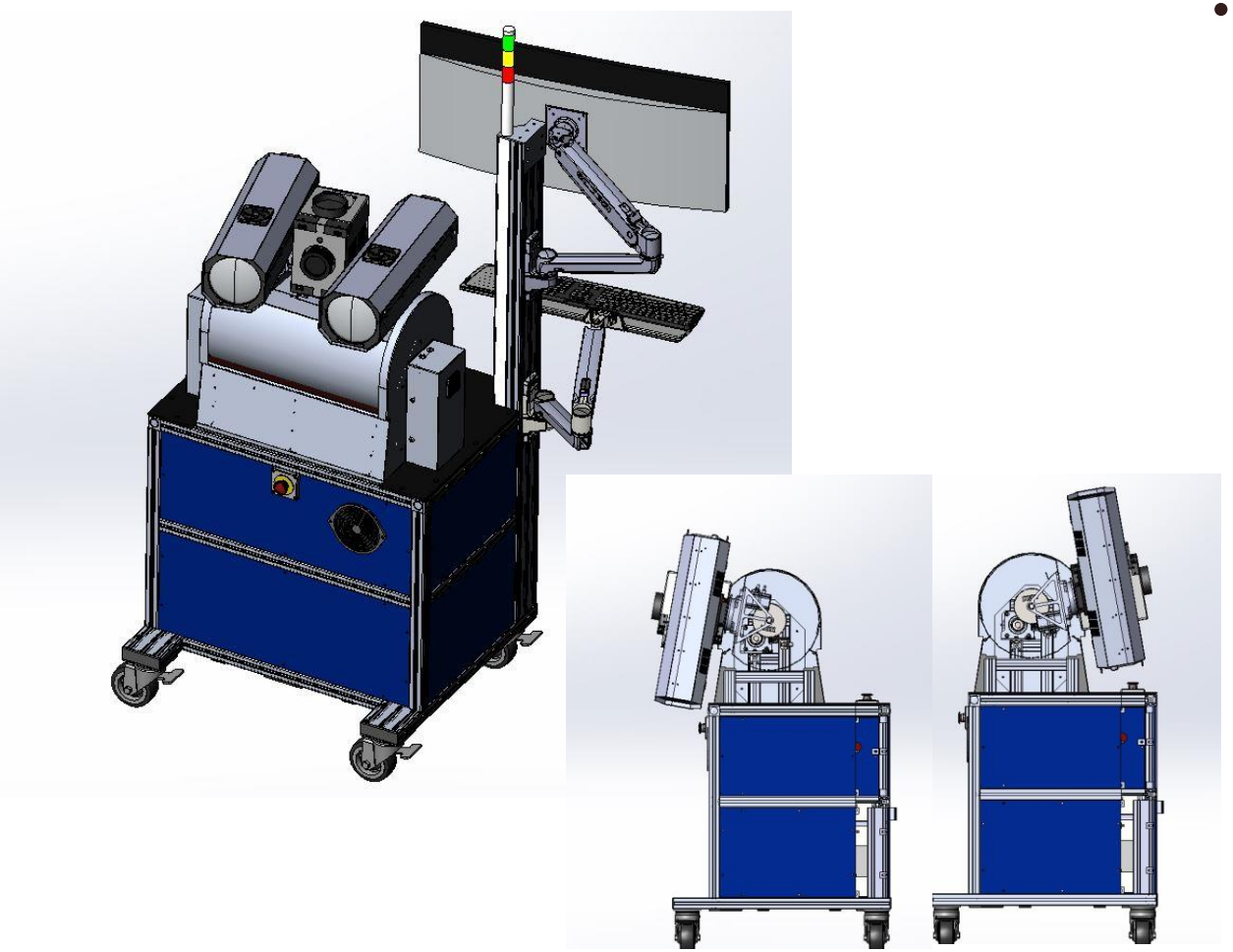


V-22 Fuselage
Standoff: 15’ | Inspection Area: 6’ x 15’ | Inspection Time: 13 min



Zoom view of inspection area in MOSAIQ

LASLAT Progress Update

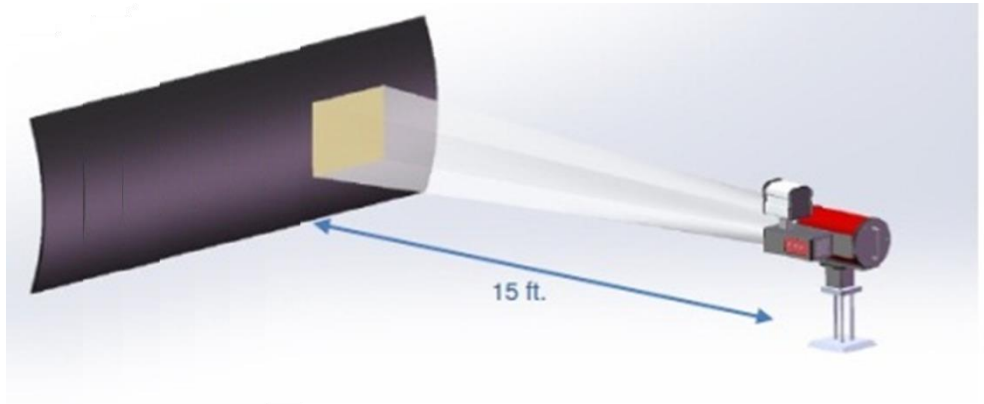


- Currently wrapping up a Phase II.5 SBIR with FRC-SW
  - Heat Projectors have been redesigned to decrease size, weight and cost
  - Motion system reaches +/- 70°, adequate for inspection of horizontal surfaces
  - Improved software controls
  - Integration of NDI results with existing FRC-SW NDI data management software
  - Development of Temperature Controlled Thermography (TCT)

Developed under NAVAIR SBIR N68335-19-C-0667

ProjectIR

Current Status, 2020



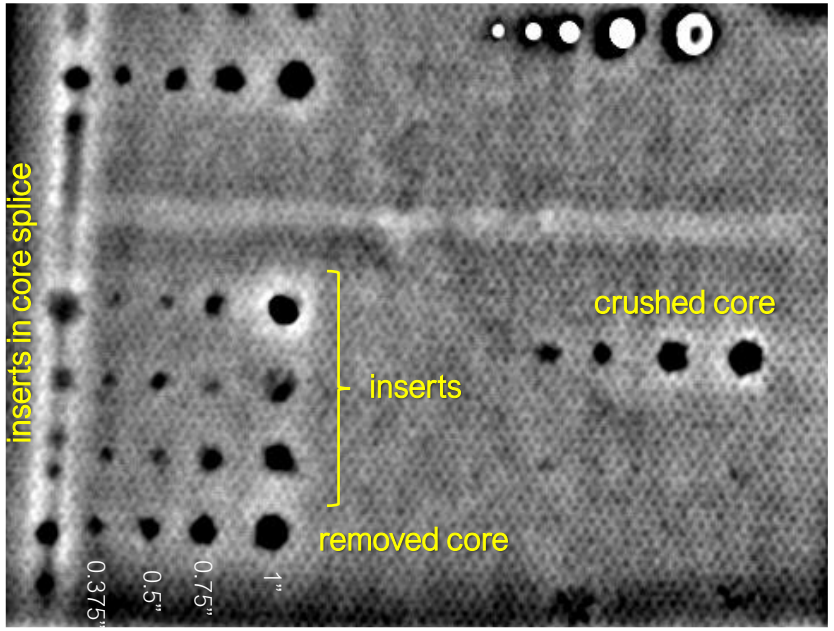
Original Concept, 2011

- Standoff: 4-7 ft.
- Single LASLAT Thermal Projector
- Manual Pan/Tilt Adjustment
- Many individual shots can be combined into a single composite image
- Replaces hand-held halogen step heating configurations
- Ideal for applications where full automation is not required

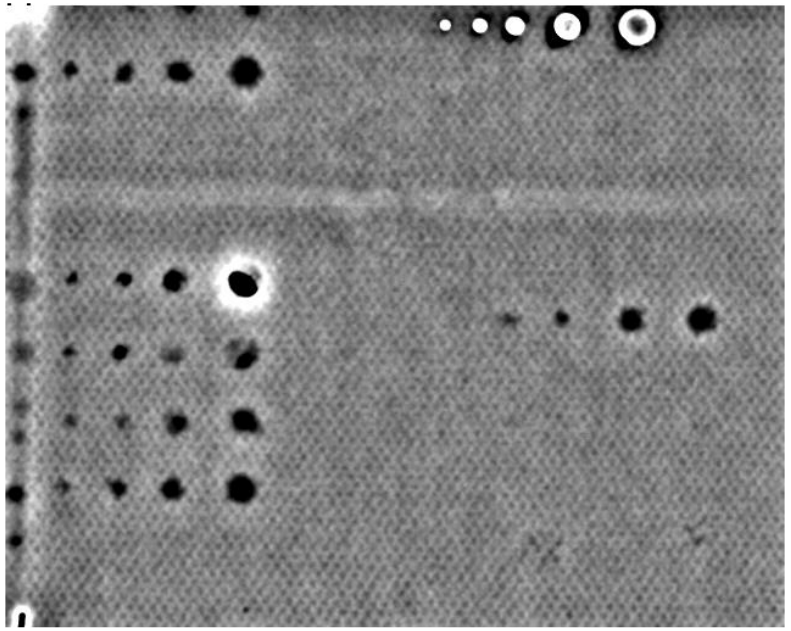
ProjectIR Defect Detectiom

7 Ply Sandwich Panel

Original LASLAT at 12’ standoff



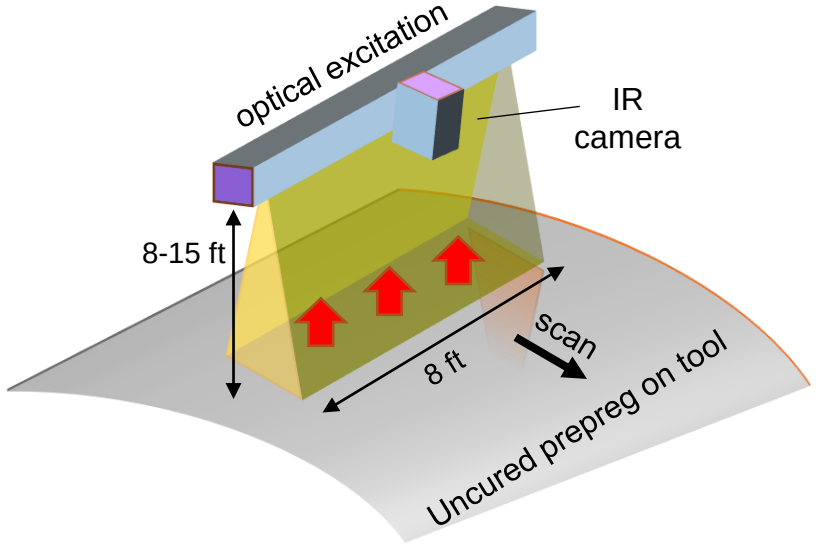
ProjectIR Lite at 12’ standoff



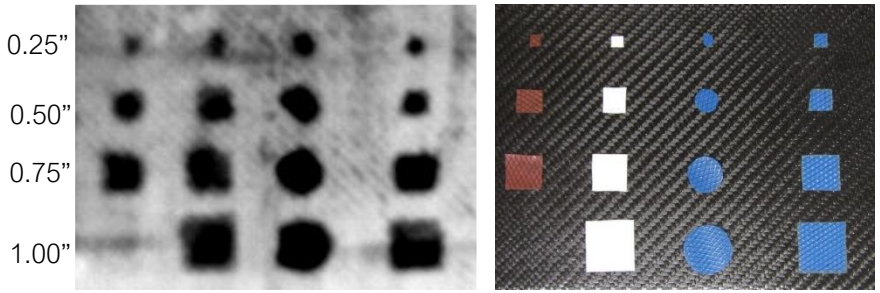
Both systems are able to detect a range of defects of varying size, depth, and composition.

EagleIR

- NDI of uncured composites (prepreg) is typically limited due to contamination issues
- LASLAT Technology provides non-contact NDI
  - Standoff Distance: 8-15 ft.
  - Stationary or scanning configurations (up to 120 in/s)
    - Inspect 110 ft in < 1 min
  - Inspect prepreg on tool during layup
    - Hand layup or ATL
  - Detect surface and subsurface FOD
- Real Time, Automated FOD Detection

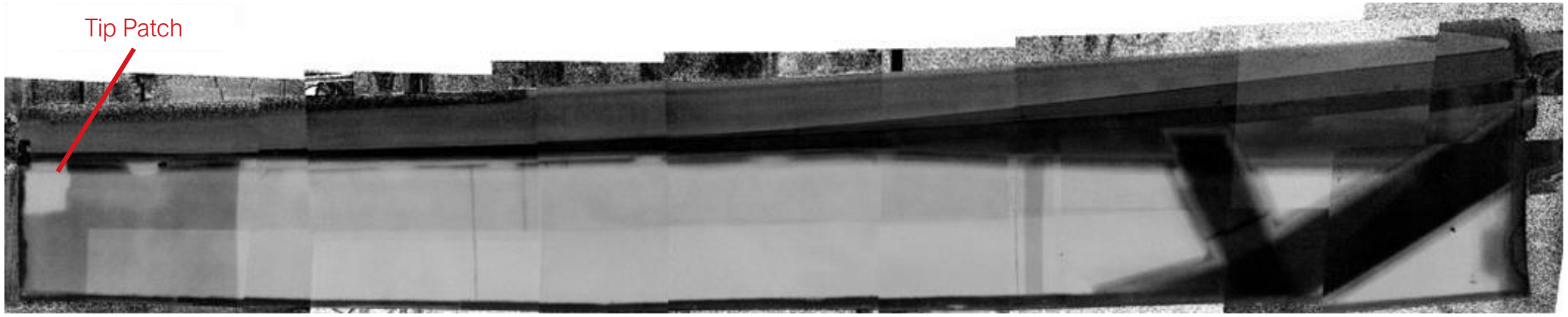


Subsurface FOD in prepreg on tool



Technology Deployment

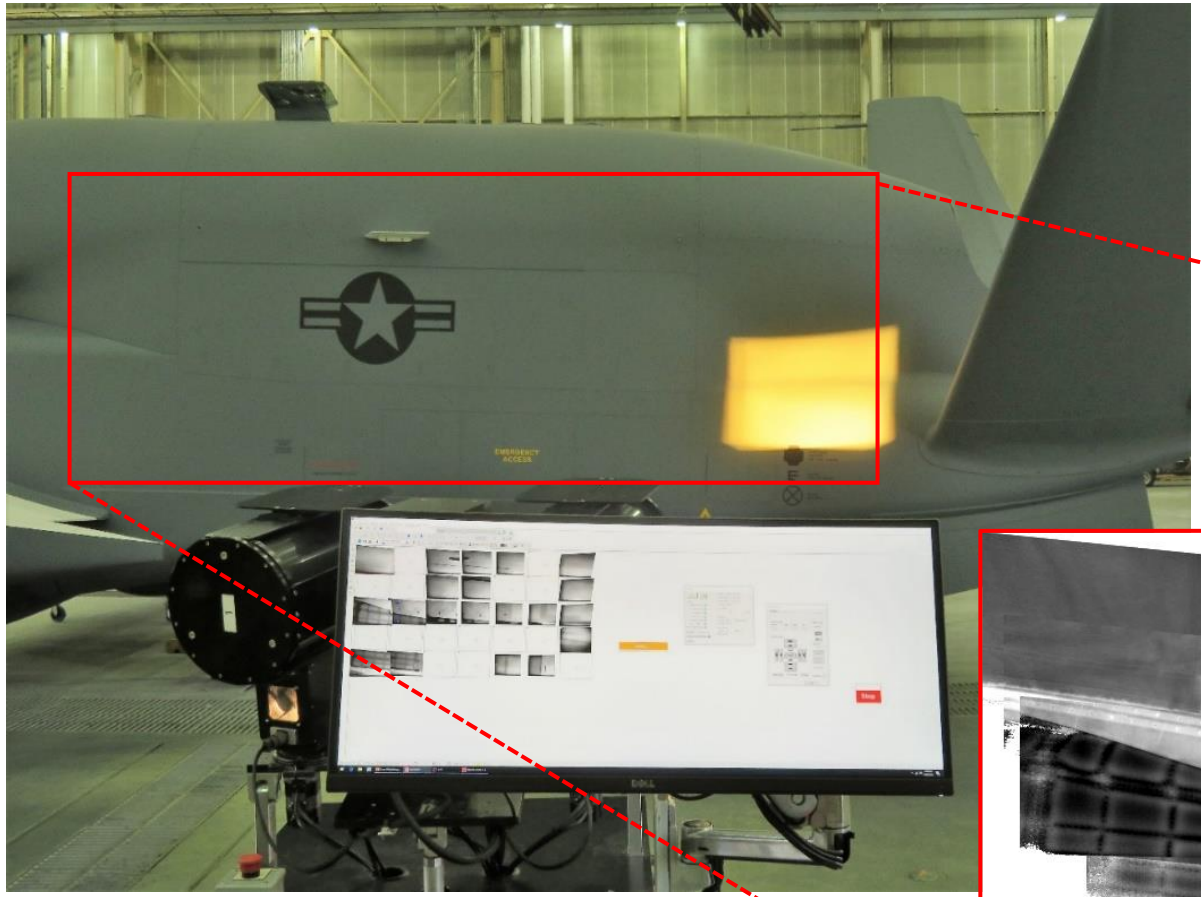
- TRL: 9
- First production system was delivered to NAVAIR FRC-E in December 2017
  - Currently used in V-22 and H-1 rotor blade inspections, reducing inspection times by 80%
- Current customers within DoD, primes and industry

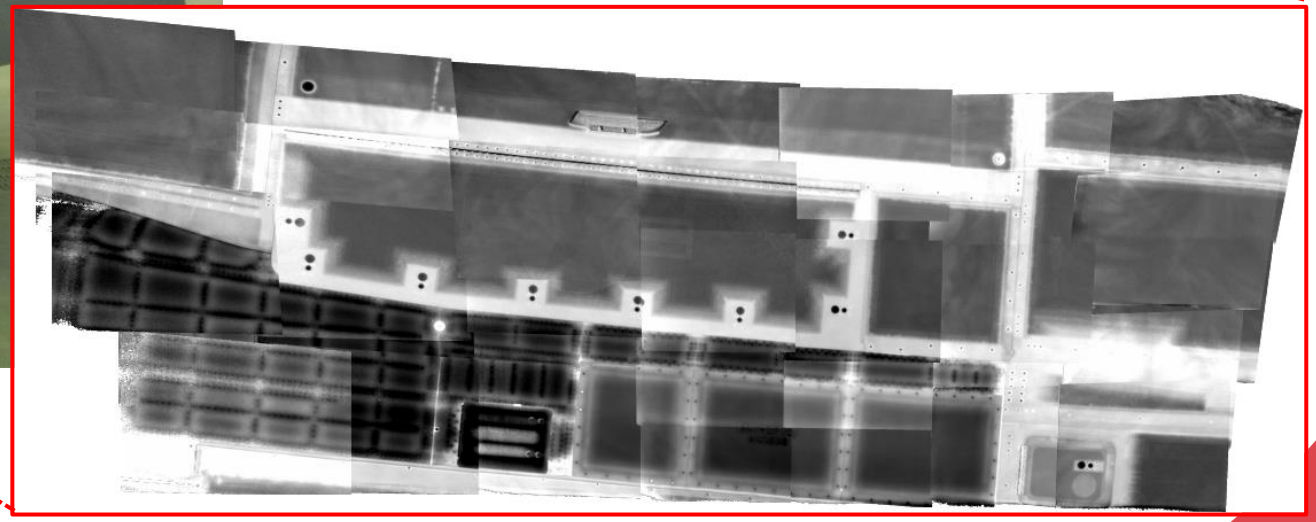


V-22 Rotor Blade: 3'x19' Inspection Area | 15' standoff | 9 min inspection

LASLAT Demo at Robins AFB

RQ-4 Global Hawk Demo: Fuselage Section





Standoff: 15 ft
Inspection Time: 8 min
Inspection Area: 16 ft x 4ft

Thermal Wave Imaging

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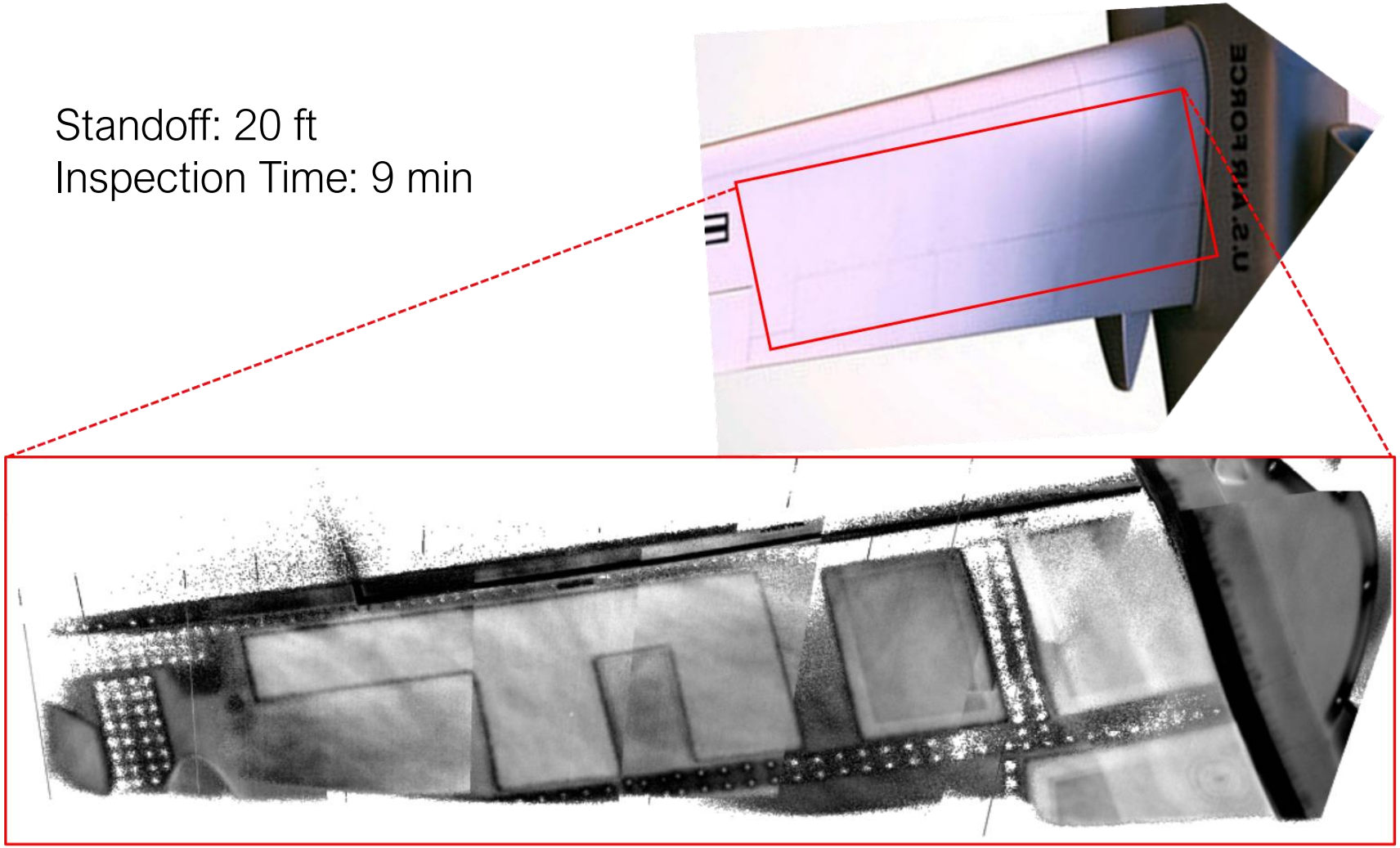
RQ-4 Global Hawk Demo: Wing Section

Standoff: 20 ft
Inspection Time: 9 min



Thermal Wave Imaging

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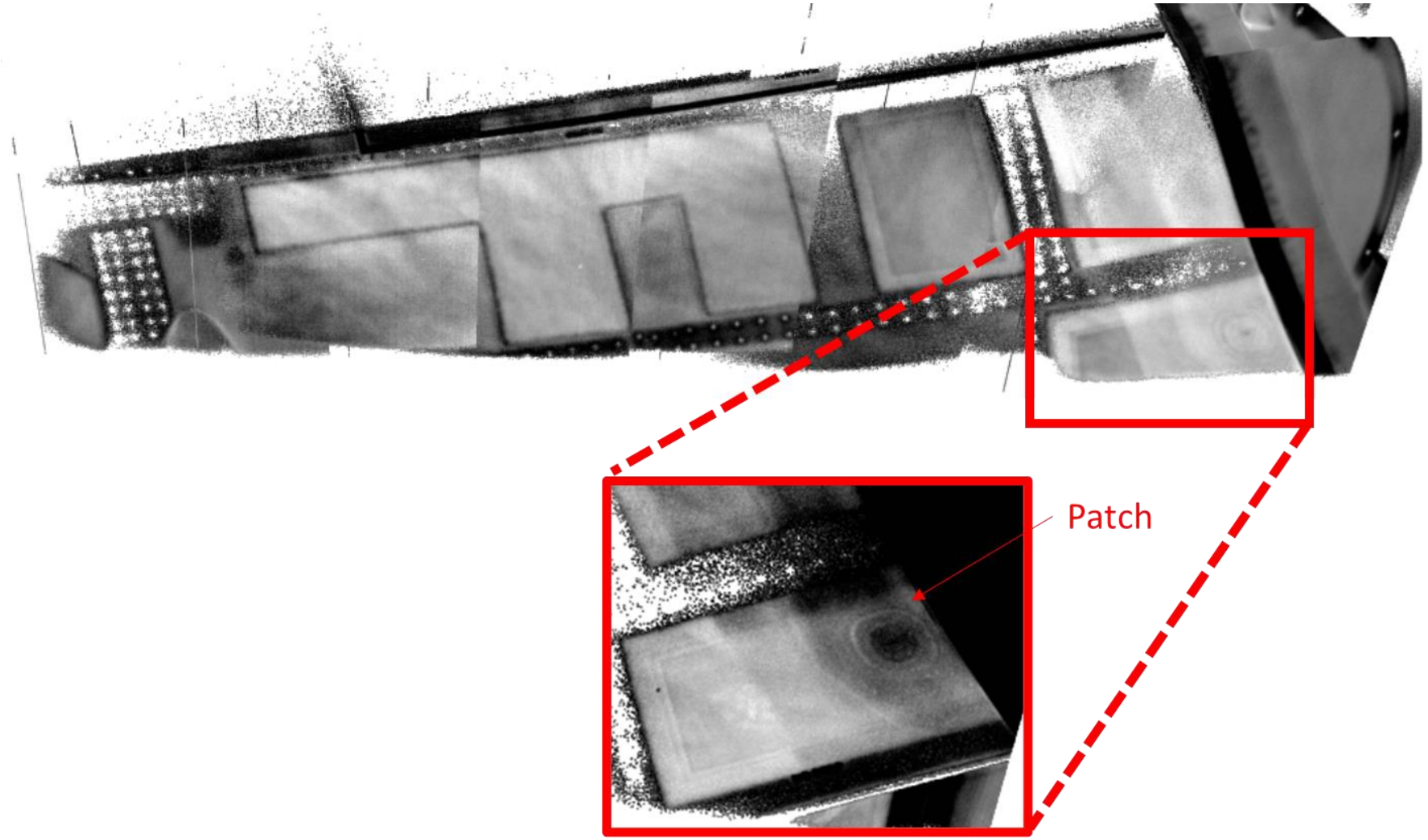
RQ-4 Global Hawk Demo: Patch Identification



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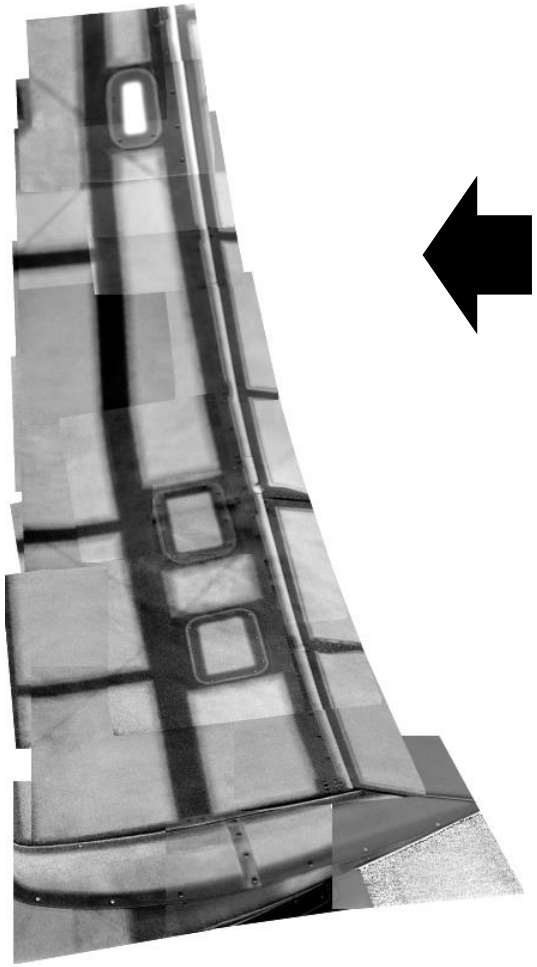
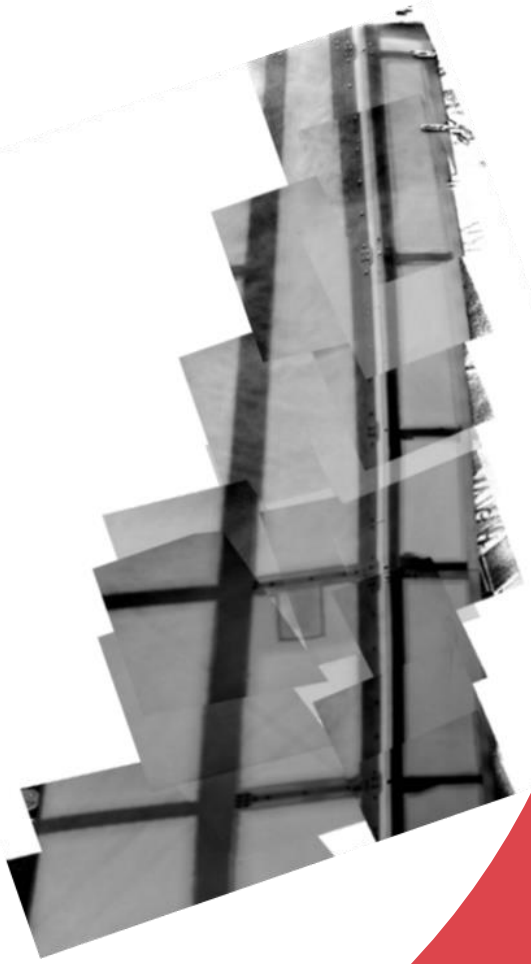
RQ-4 Global Hawk Demo: V-Tail

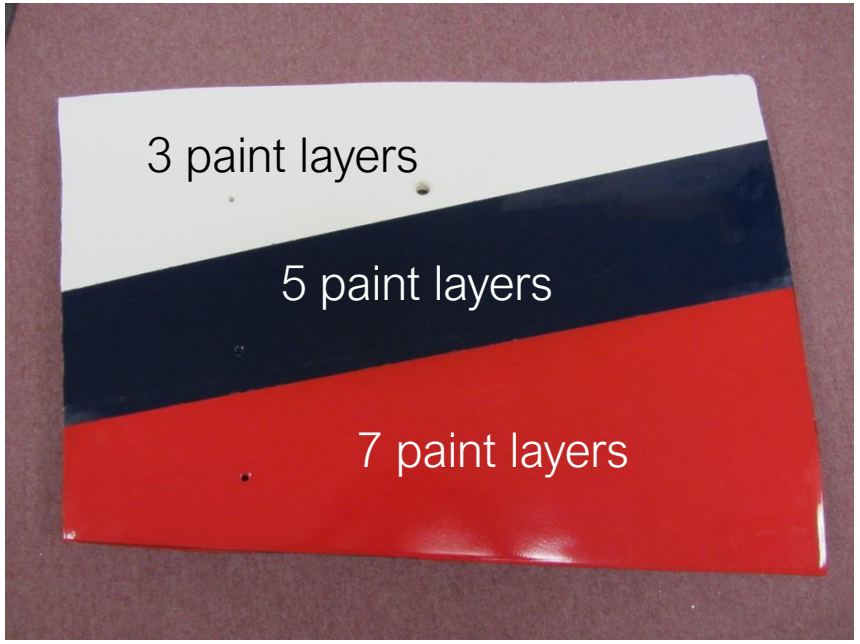


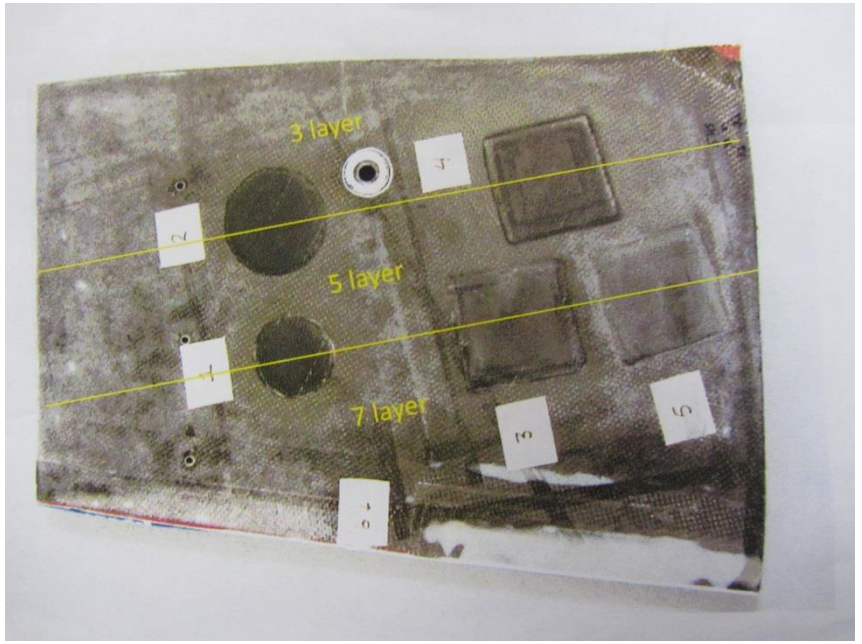
Outer Portion
- 15 ft standoff
- 29 shots
- 15 min fully-automated acquisition

Inner Portion
- 17 ft standoff
- 22 shots
- 10 min fully-automated acquisition



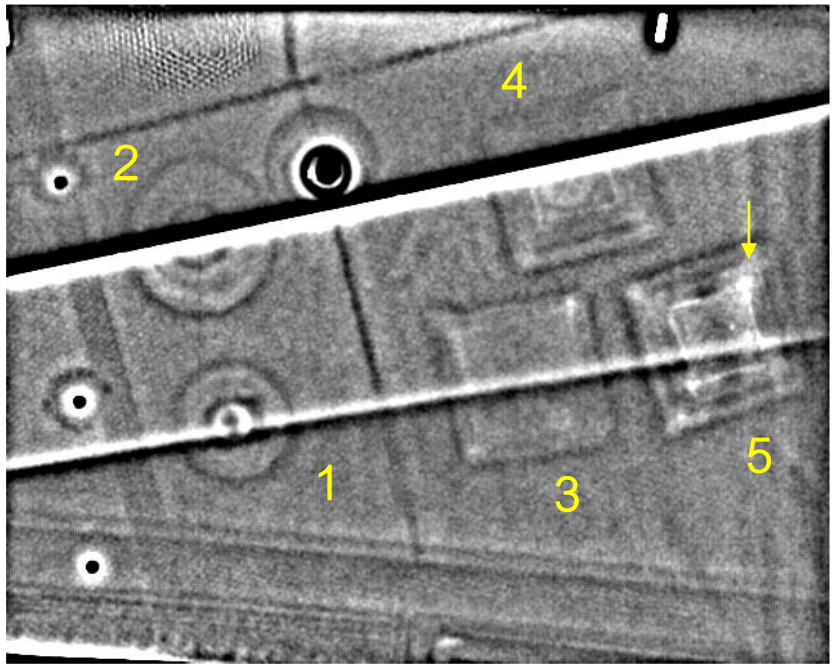
Application: A320 Rudder Repair Identification

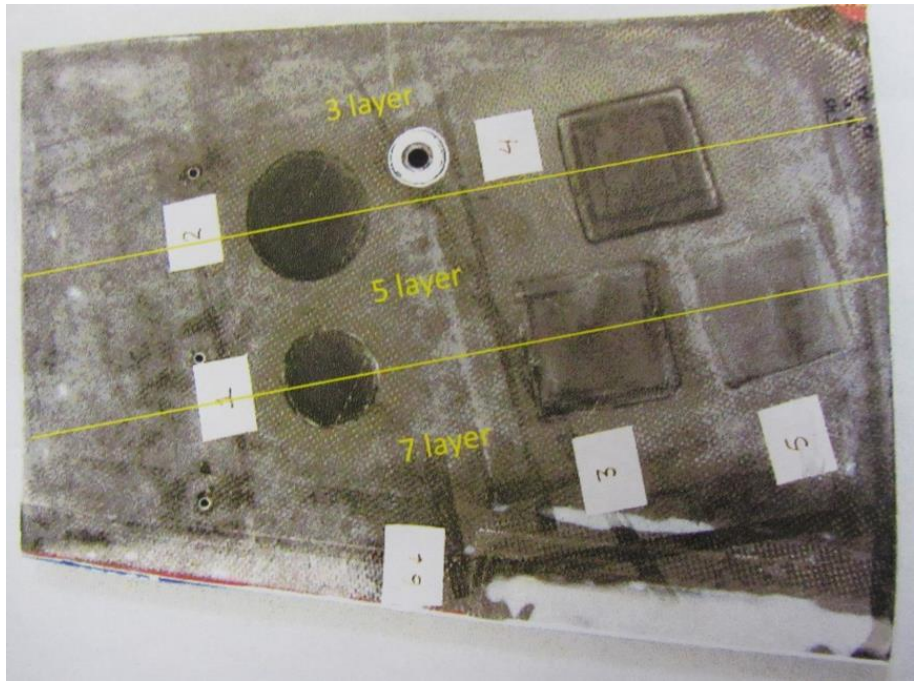




- 5 repairs
- 3 paint thicknesses (3,5,7 coats)

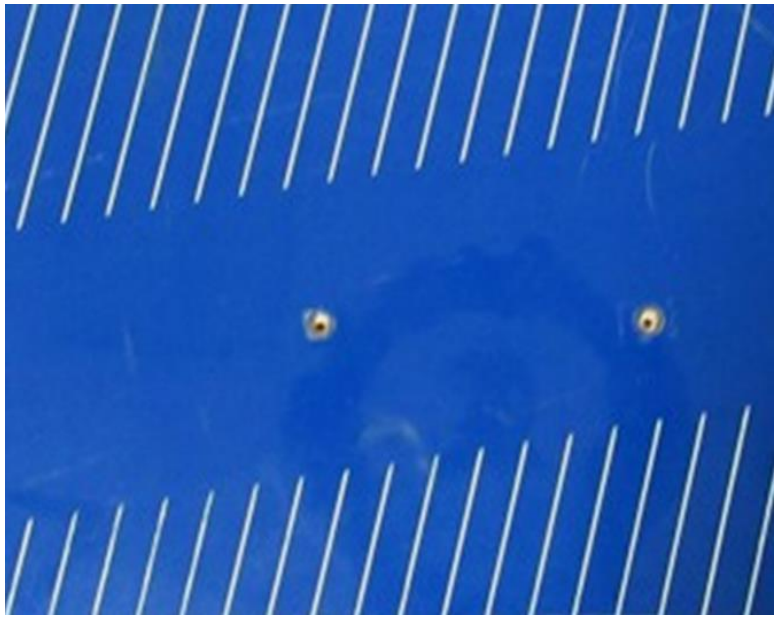
Application: A320 Rudder Repair Identification

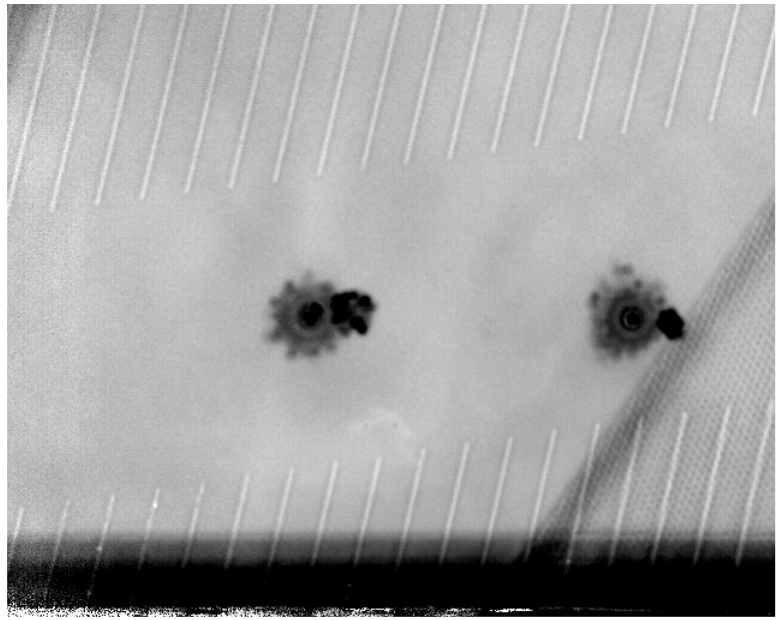




- Standoff: 12 ft.
- Inspection Time: 20 s
- No surface preparation
- Different paint colors and thicknesses do not interfere with detection
- Detects patch anomalies

Application: A320 Rudder Fluid Intrusion





- Standoff: 12 ft.
- Inspection Time: 15s
- Inspection Area: 16in x 24in
- No surface preparation
- Detects fluid intrusion

Questions?

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