Progress in Autonomous Inspections using Collaborative Robots

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Overview

- Composite Usage
- NASA's Interest in Composites
- Background on Collaborative Robots
- Experimental Approach
- Inspection Results
- Conclusions

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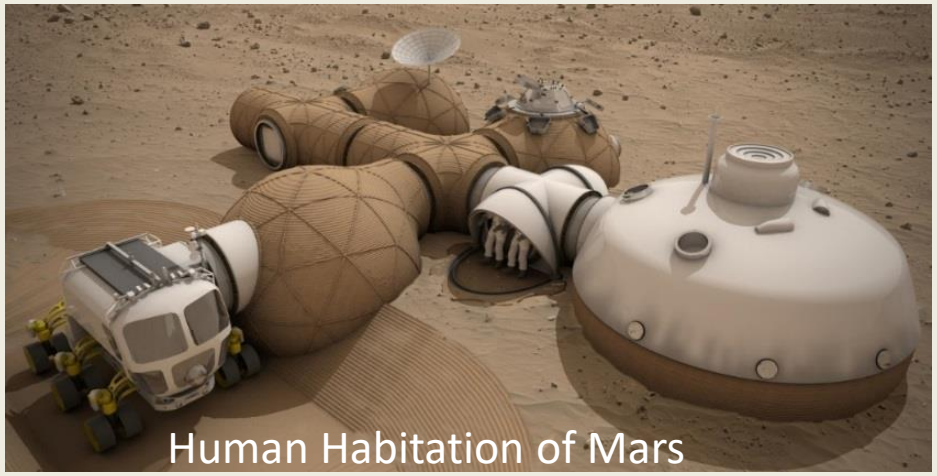

Human Habitation of Mars

Composite Usage in Aircraft

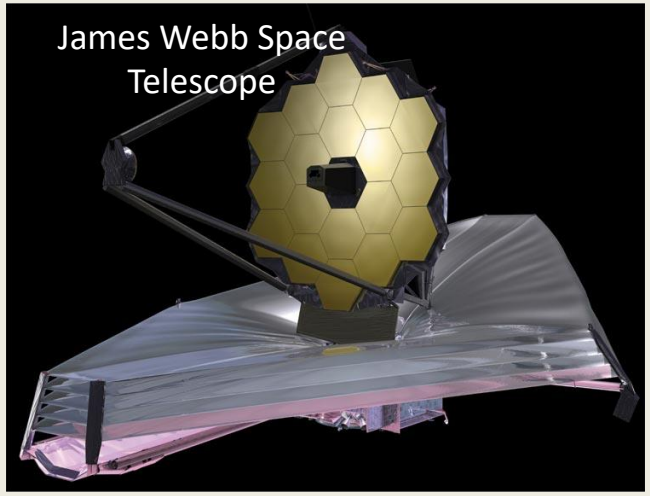
~50% by Weight
~80% by Volume

- Composites enable lighter weight, lower cost structure with fewer parts
- Larger composite structures require more efficient inspections
  - Results in larger amounts of data
  - Requires more effective interpretation and disposition approaches
- More sophisticated in-service inspections and/or monitoring required for sustainment

Composite Usage in Spacecraft

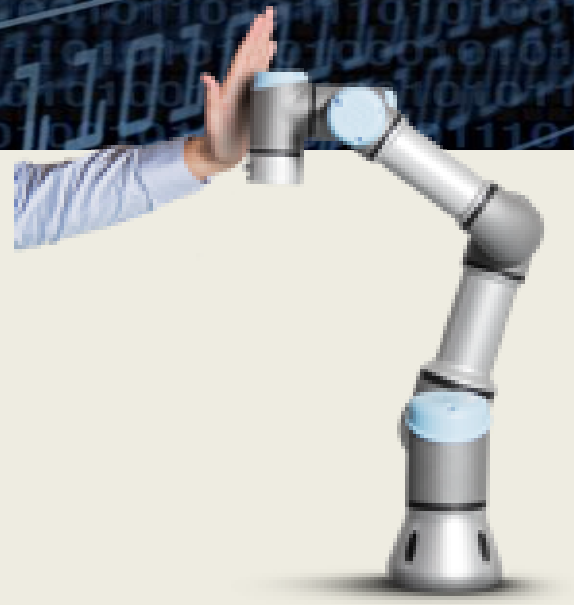
- NASA has investigated the use of composites as a means of saving weight and increasing payload capacity
- SLS system trade studies show that an all composite structure could decrease the mass by 40% and increase the payload to LEO by 25 metric tons

SLS

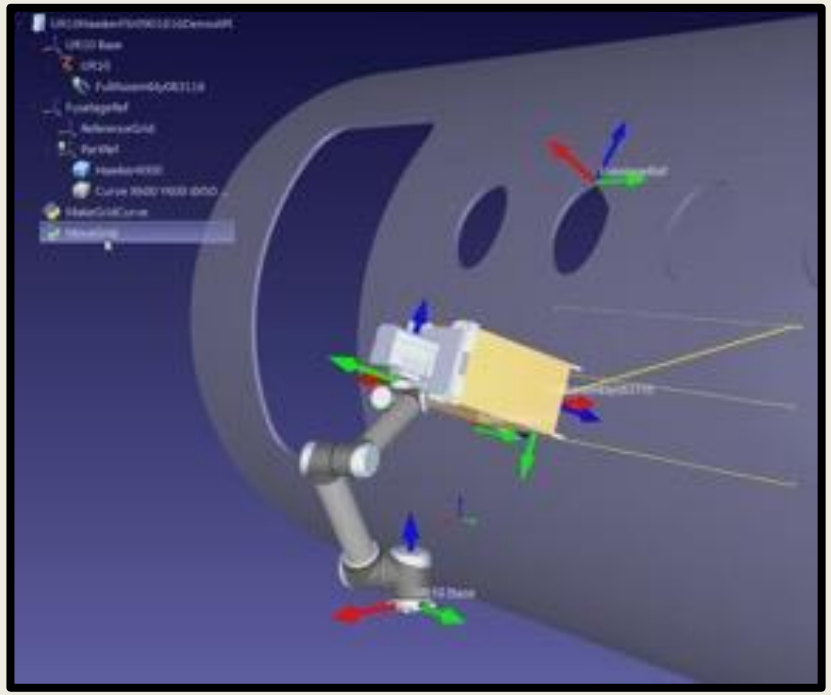


Composite cryogenic fuel tanks

Collaborative Robots

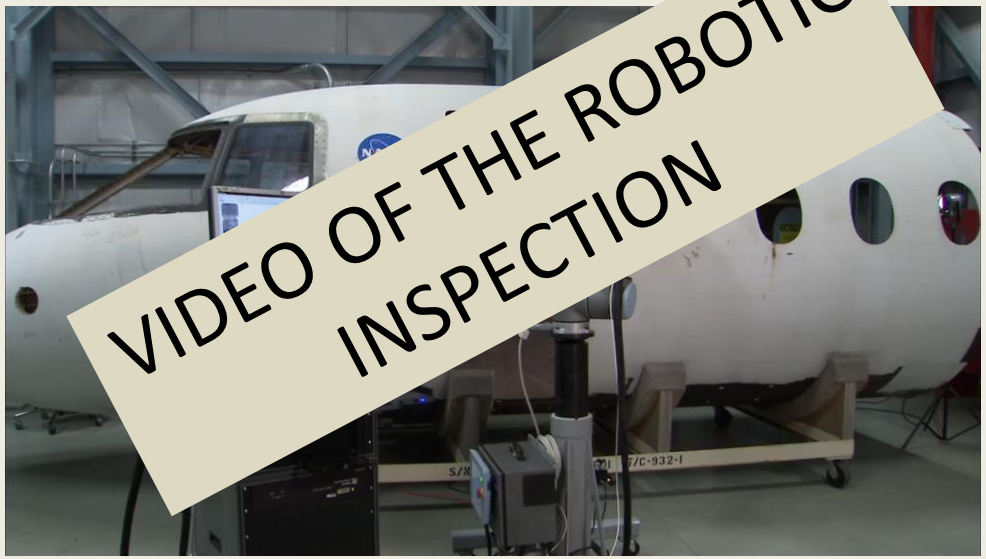


- Collaborative robots are typically lower cost, can work alongside humans and do not require separate safety zone.
- Reduce lengthy, costly, manual inspection of large composite structure that can not be inspected by gantry systems.
- NDE Inspections rarely have exclusive access to large structures making the use of robotics challenging.
- Easily reconfigurable for different geometries and inspections.
- Initial demonstration of operational capability using thermography inspection type.
- Inspection system and robot integrated into one system.
- Highly automated: limited operator input required.

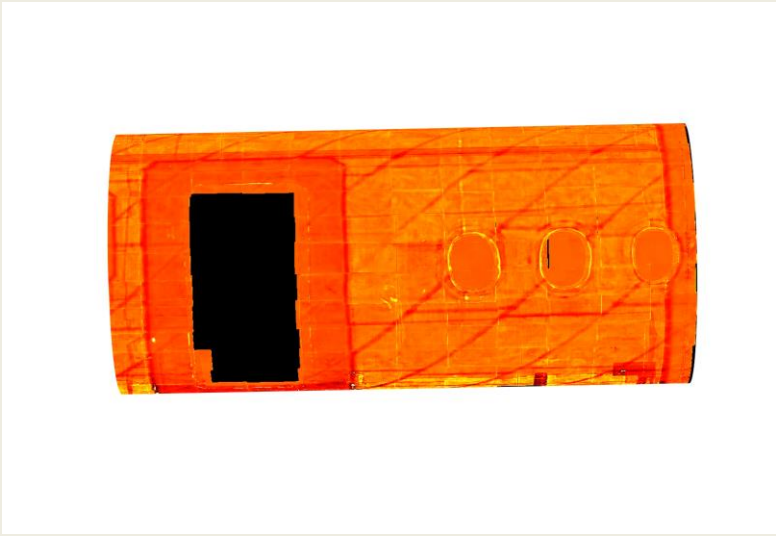


Conventional Robotic Implementation

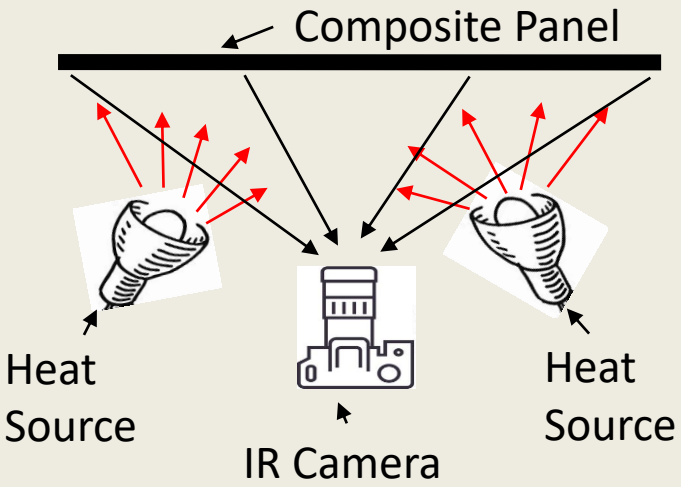
- Challenges to large area complex geometry inspection:
  - Manpower intense data collection
  - Processing of large data sets
  - Registration and mapping
- Robot technology can be adapted to address many of these challenges



Robotic Inspection

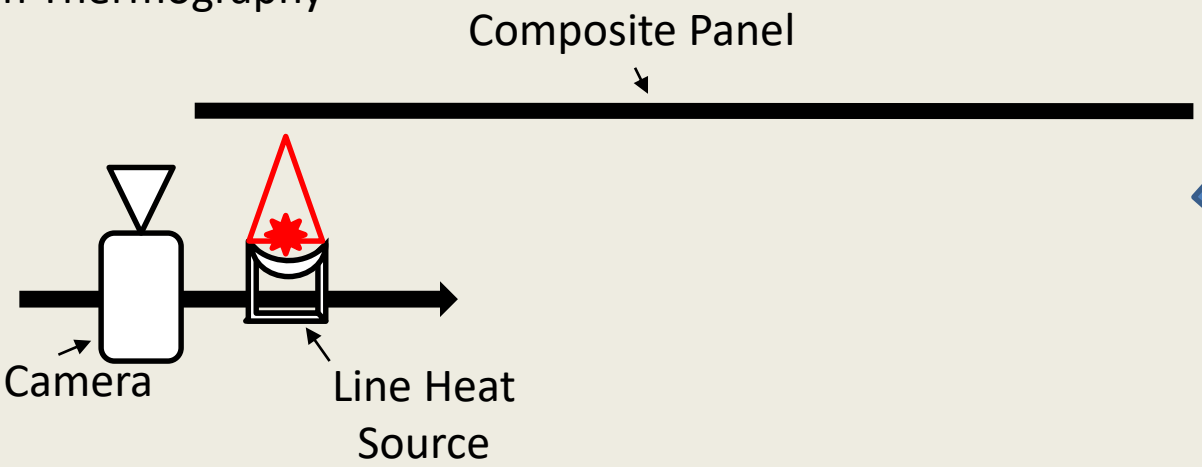


Robotic Inspection: Another Approach

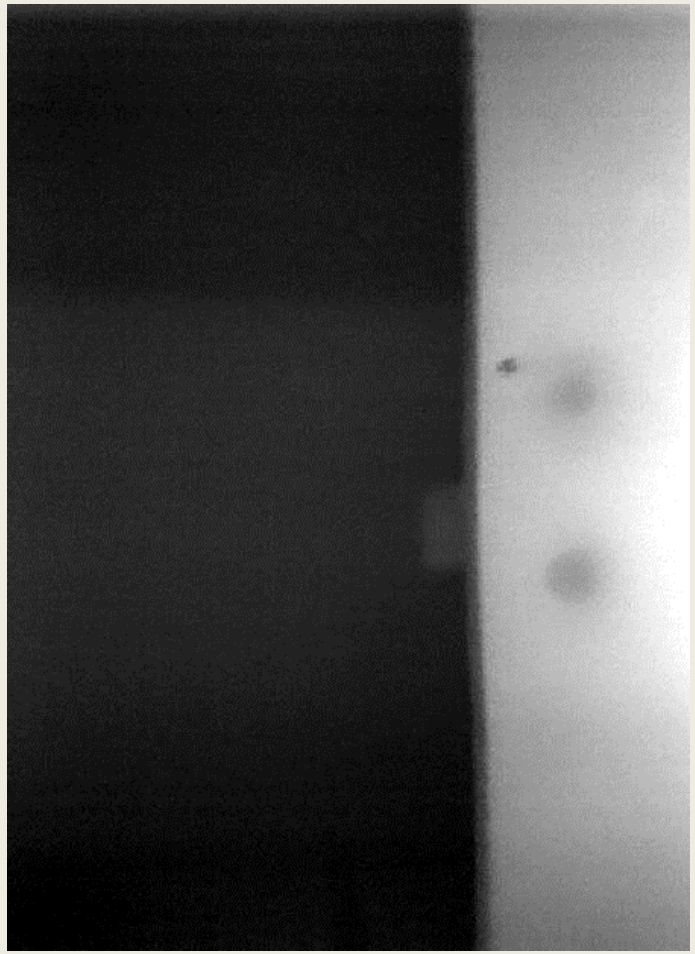


Conventional Flash Thermography

Line Scan Thermography

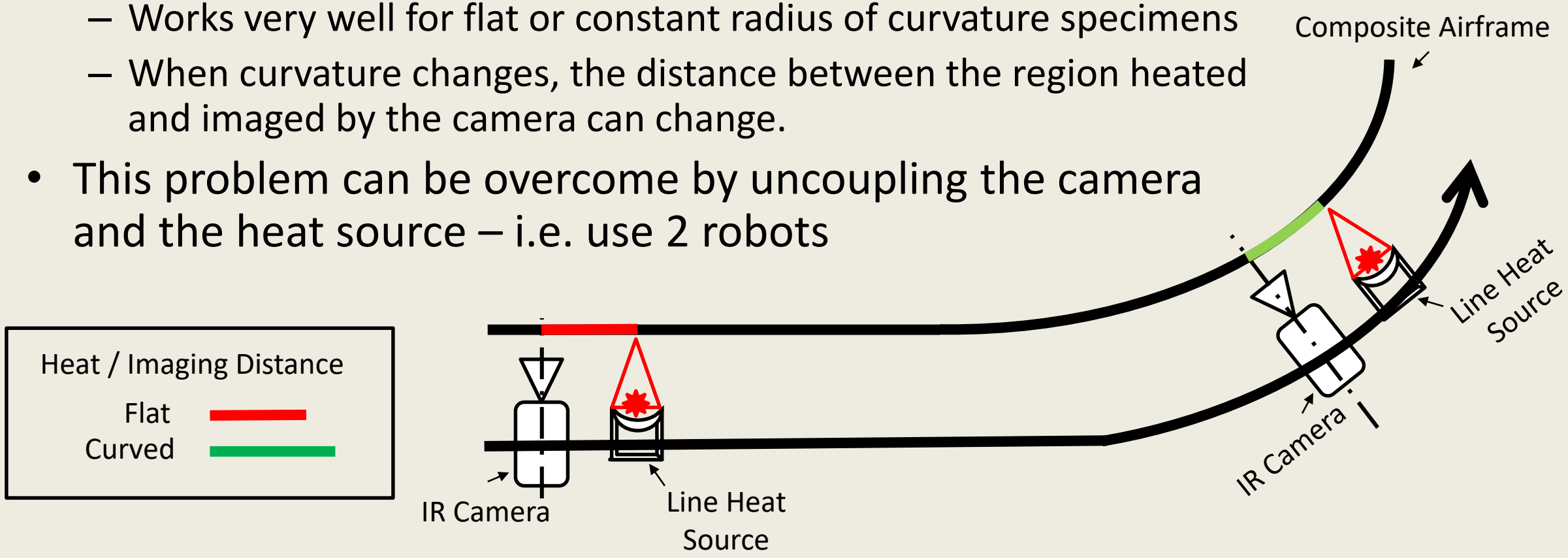


Speed advantage over conventional flash thermography grows as the inspection area increases

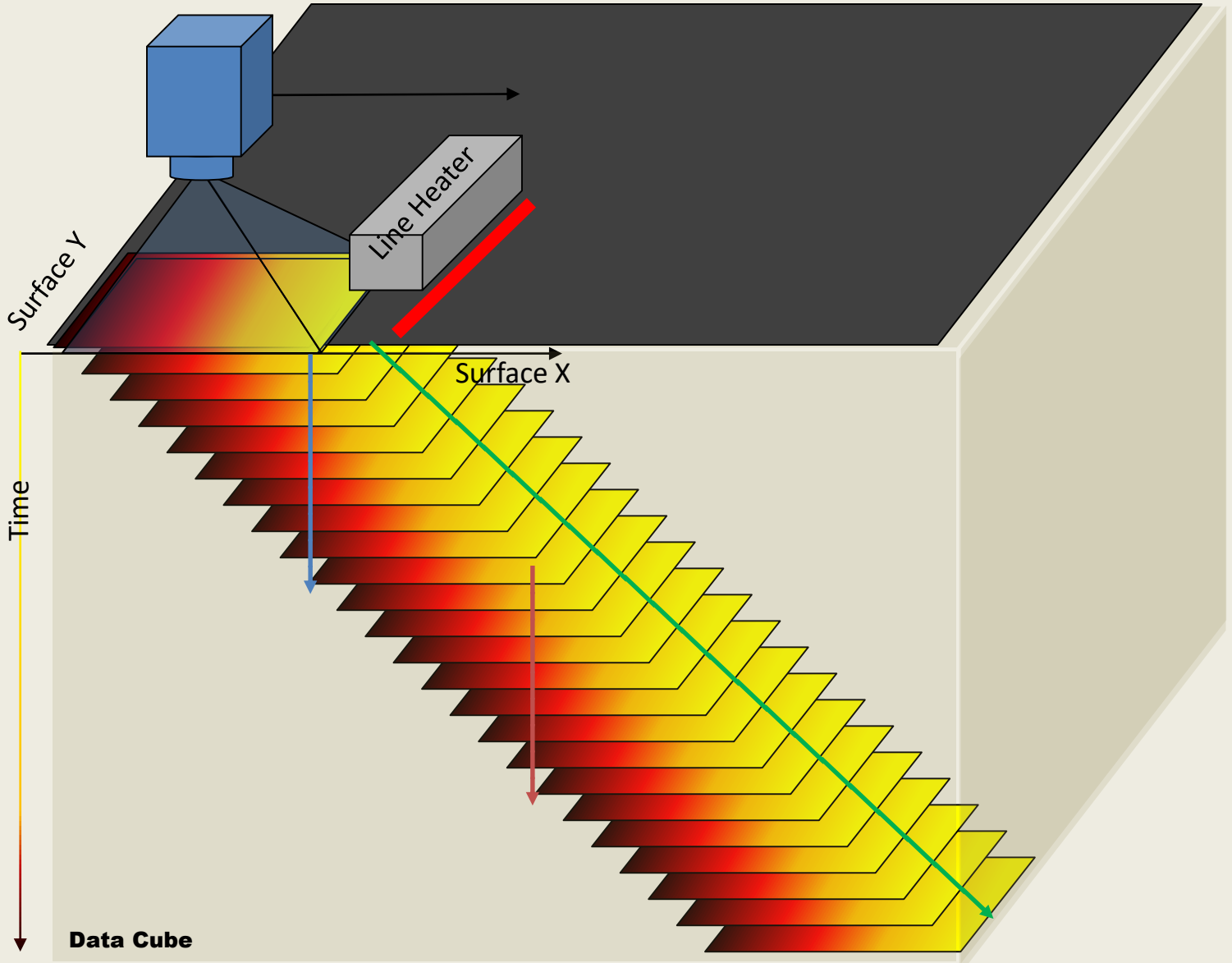


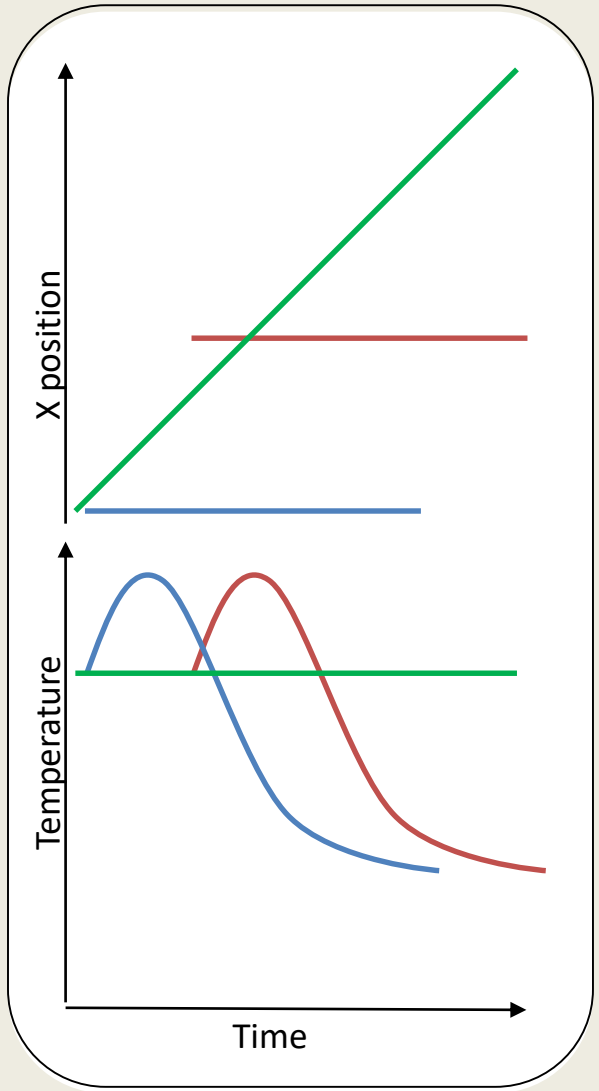
Why use Multiple Robots?

- Most implementations of Line Scan Thermography use a single robot and a fixed separation between the camera and the heater
  - Works very well for flat or constant radius of curvature specimens
  - When curvature changes, the distance between the region heated and imaged by the camera can change.
- This problem can be overcome by uncoupling the camera and the heat source – i.e. use 2 robots



Spatially Aligning the Data

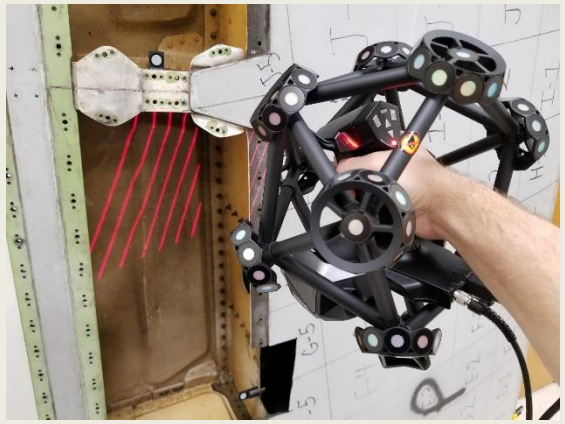


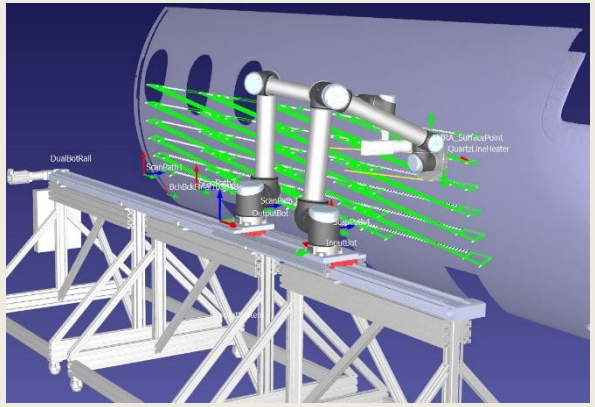


Experimental Implementation

- 3D scan side of fuselage for path projection
- Use the 3D scan and geometry of the robot to preplan the scan path
- Scan cylindrical acreage section (1m x 3m ~ 8.5min)
  - Scanning speed – 105 mm/s
  - Camera frame rate – 50 frames/s
- Acquire thermal data and map to surface geometry used for path planning

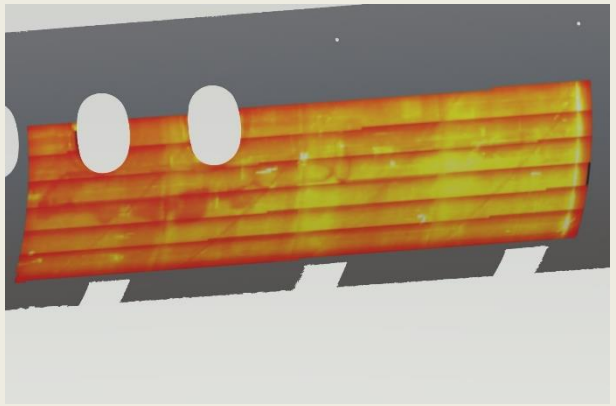
3D Scanner





Scan Path Planning

Data Acquisition



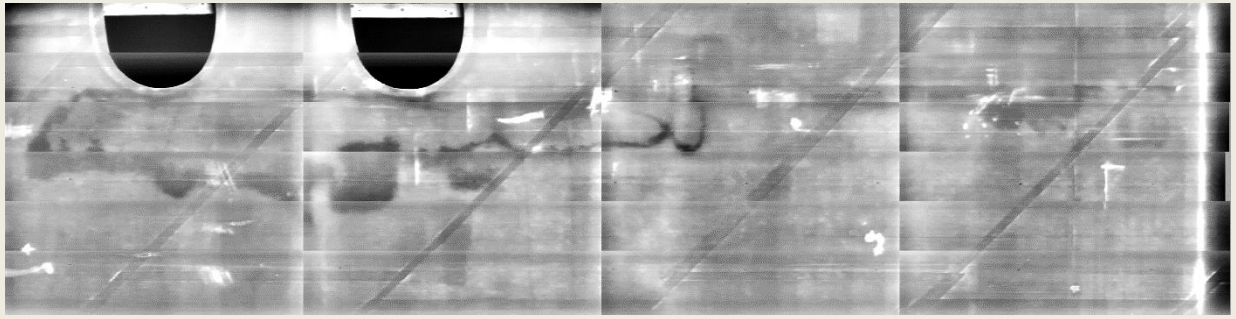
Data Analysis & Display

The Complete Process

Comparison with Flash Thermography

Flash Inspection (Full Temporal Processing)

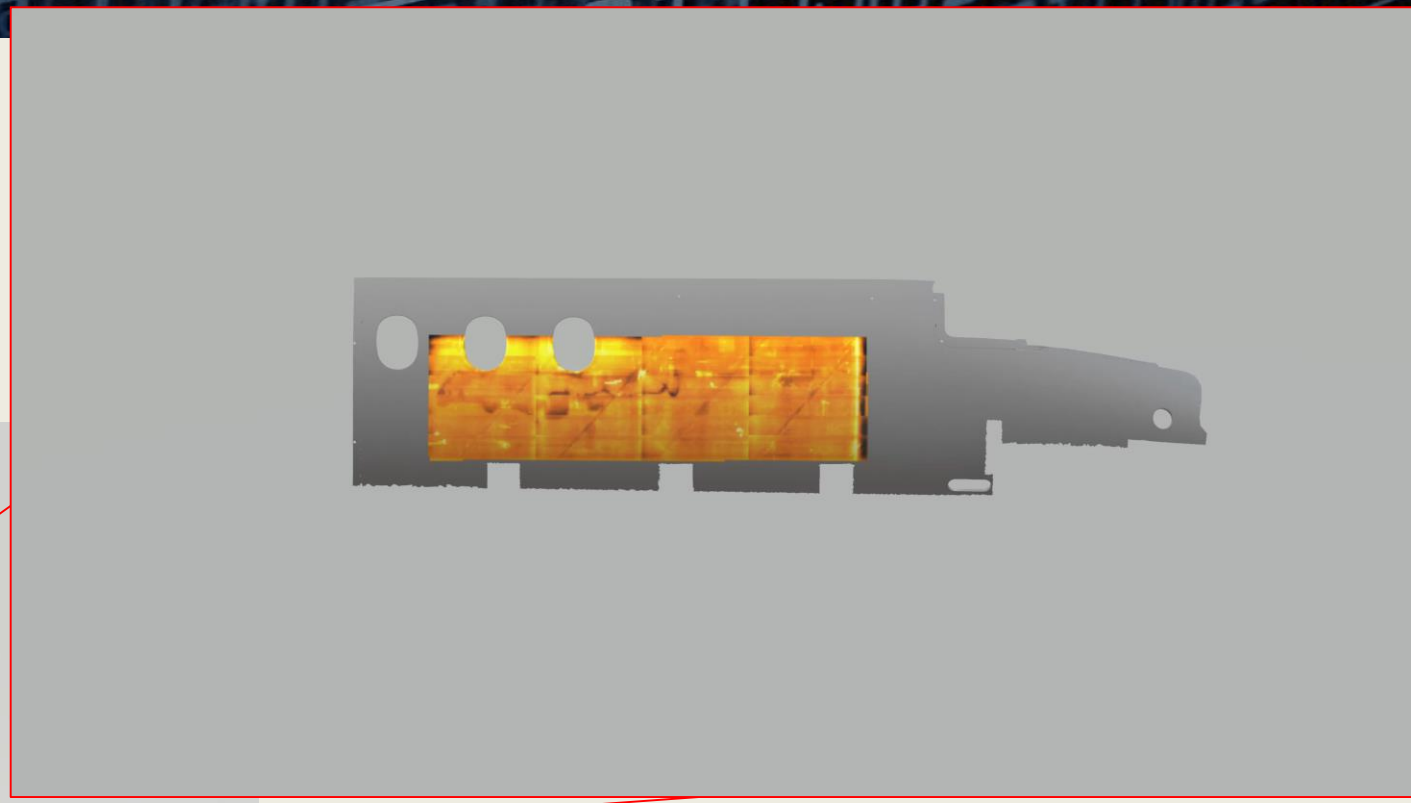
Collaborative Robotic Line Scan Thermography Inspection (Partial Processing)



Results similar to flash thermography with improved inspection speeds:
2X+ faster than robotic flash thermography
10X+ faster than manual flash thermography

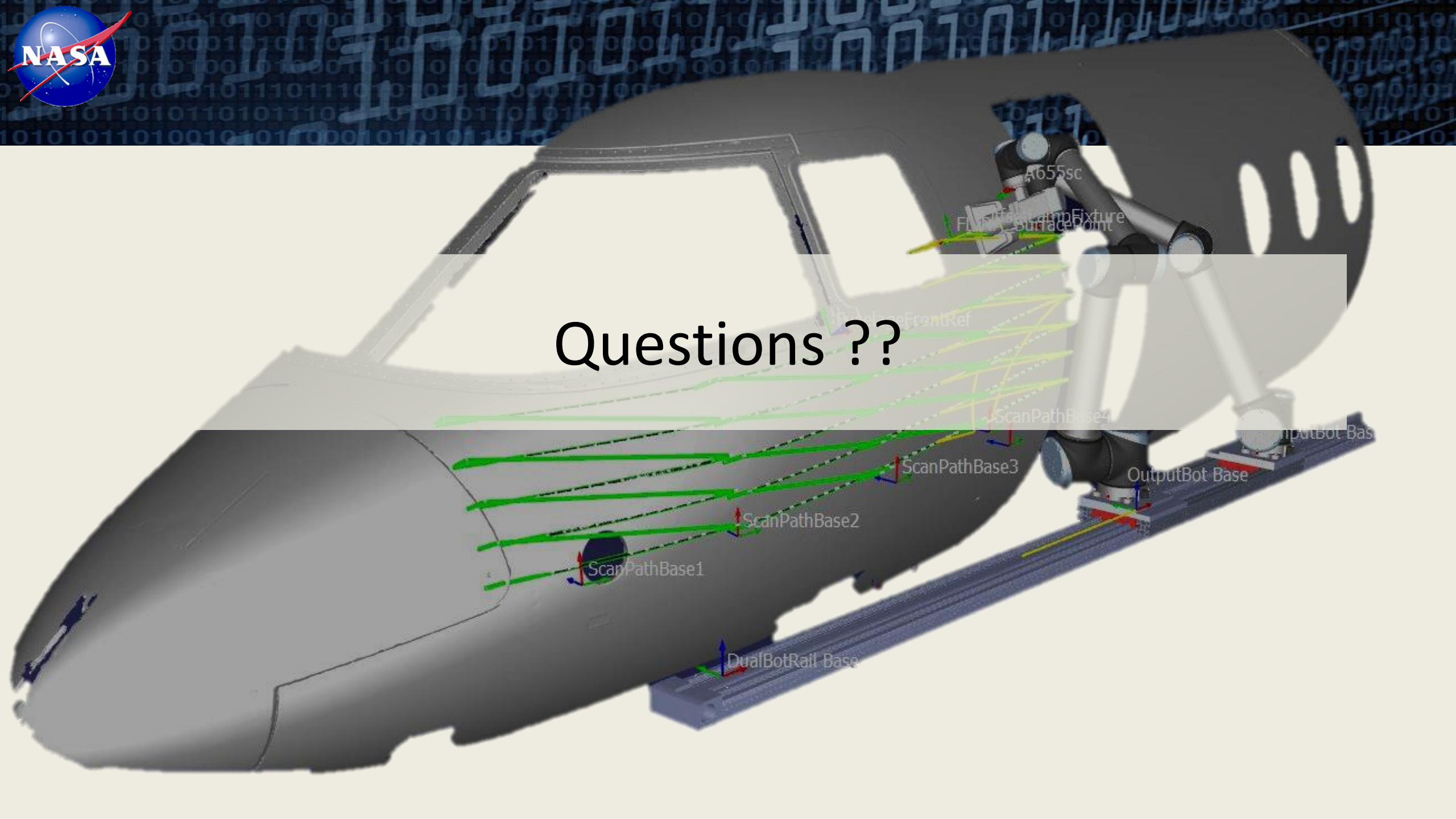
Results on Hawker 4000 Fuselage Section

Processed Data accurately registered to a model of the “as manufactured” structure



Conclusions

- We have demonstrated the use of multiple low-cost collaborative robots to perform rapid inspections on a composite aircraft fuselage.
- Scanned cylindrical acreage section (1x3m) in approx. 8.5 minutes - 10X+ faster than manual flash thermography.
- Line scan thermography data comparable to conventional flash thermography.
- Demonstrated the ability to map the thermography data directly to the “as manufactured” model of the structure.


A655sc
ScanPathBase4
ScanPathBase3
ScanPathBase2
ScanPathBase1
OutputBot Base
DualBotRail Base

Questions ??