

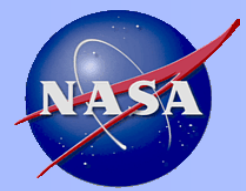
Nondestructive Evaluation Sciences Branch

Advanced Thermal Inspection with Pulsed Light Emitting Diodes (PLED) Technology

Joseph N. Zalameda

NASA Langley Research Center

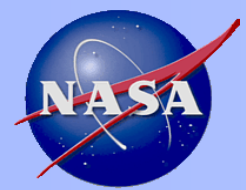
LAR-TOPS-392 Webinar June 18, 2025



Acknowledgements

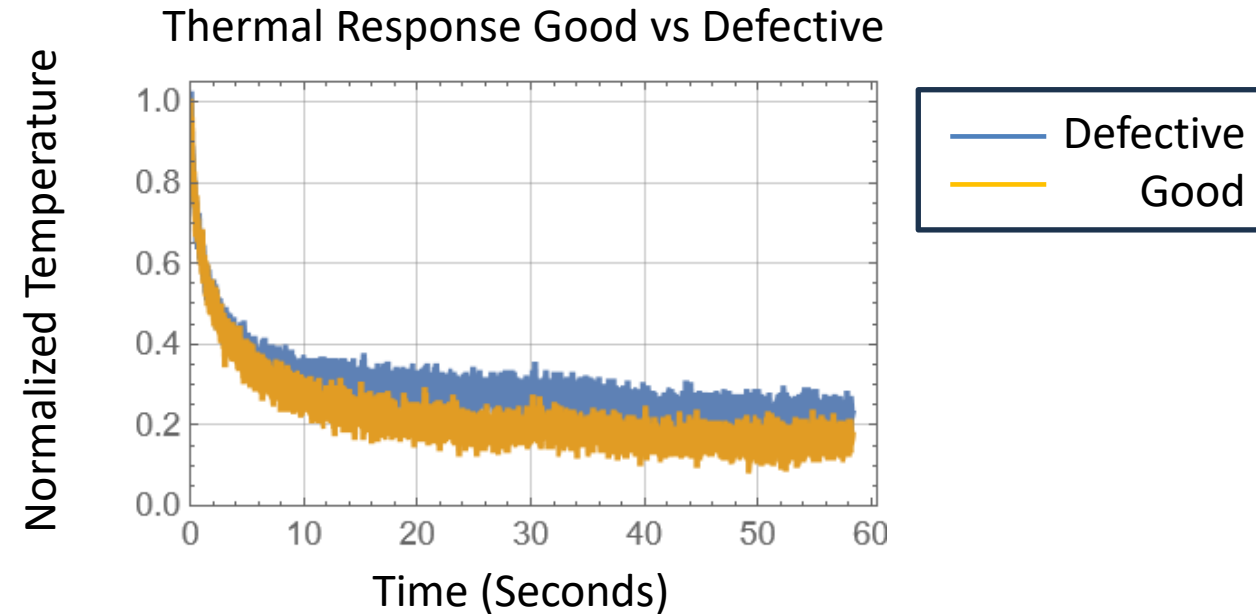
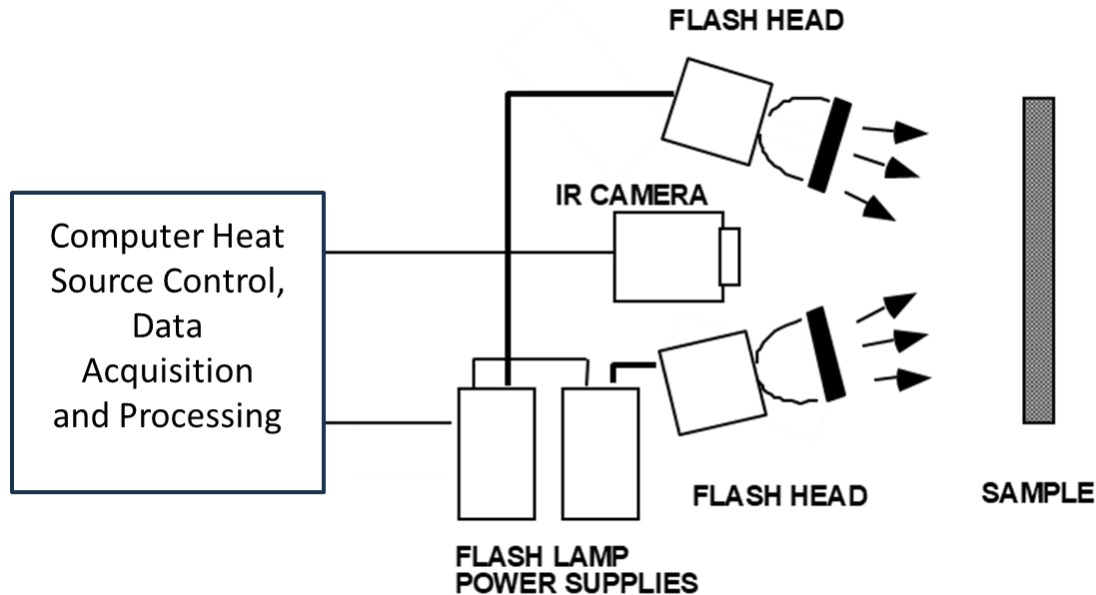
Nondestructive Evaluation Sciences Branch

- Peter Spaeth and William P. Sommers of the Nondestructive Evaluation Sciences Branch (NESB) for the X-ray CT analysis and measurements
- Josh L. Brown and William B. Bretton (NESB) for sample and 2nd generation PLED heat source fabrication and James B. Bly (NESB) for 1st generation PLED fabrication
- NASA Transformational Tools and Technologies Project and the Transformative Aeronautics Concepts Program for support of this work

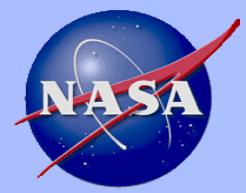


What is Flash Thermography?

Nondestructive Evaluation Sciences Branch



- Advantages of flash thermography: Noncontact, large area inspection, and safe.
- Heat sources such as flash bulb or quartz lamps stay hot after lights are turned off, leads to false defect indications and inaccurate quantitative measurements of material properties.
- Reflective surfaces with low emissivity, such as metal surfaces or unpainted fiberglass composites, typically will need to be painted with high emissivity paint.



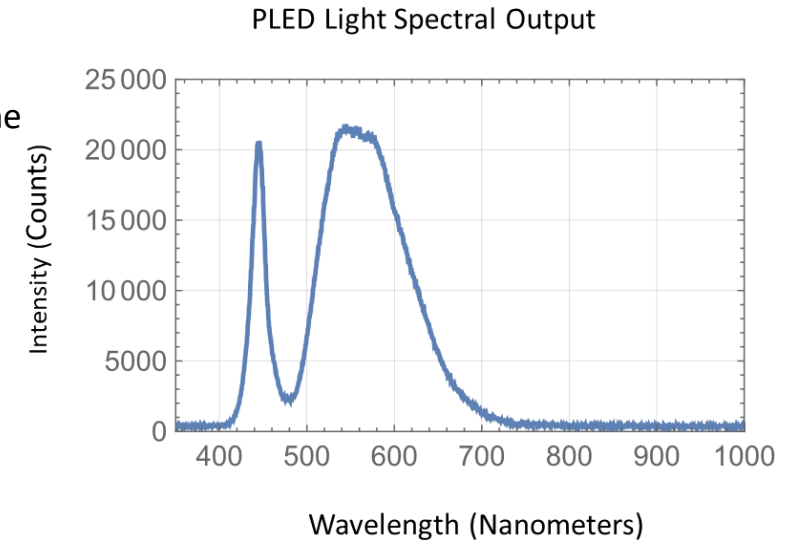
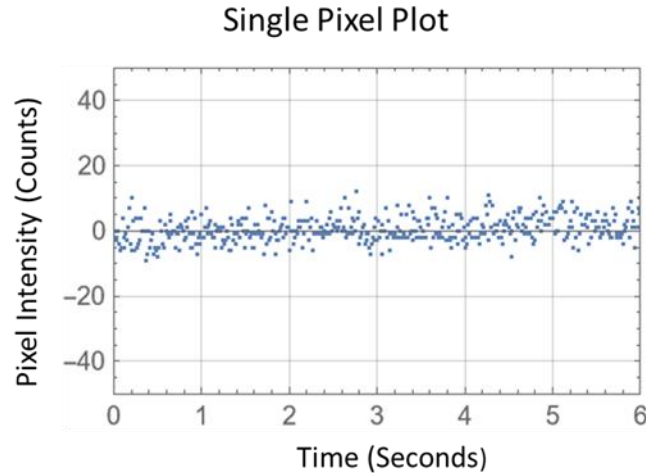
Advantages of Light Emitting Diode (LED) Thermal Inspection

Nondestructive Evaluation Sciences Branch

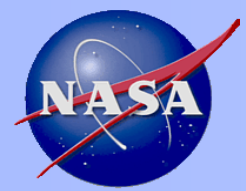
Direct View of Heat Source



Direct View of Heat Source Reveals No Detection of the Light Source



- Heat source light is not detectable by infrared camera and therefore camera is not blinded by the heat source from reflections.
- The surface's temperature response is more accurately measured since the afterglow of flash lamps and quartz lamps are not superimposed on the surface temperature so reduced false defect indications.
- Improve model based quantitative single side thermal inspection.
- Pulsed light is more safe than intense flash.
- No flash power supplies so reduced costs.
- Pulsed light can deliver more heat vs. flash.

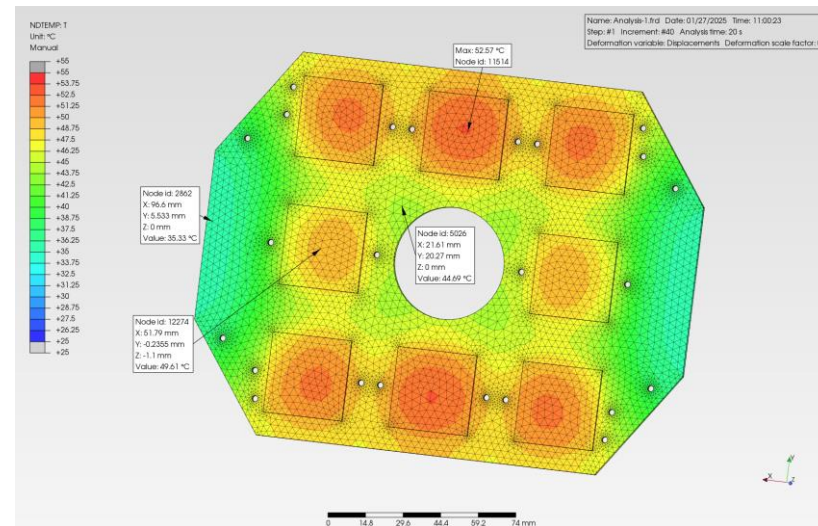


Pulsed LED Heat Source and Prototype System

Nondestructive Evaluation Sciences Branch

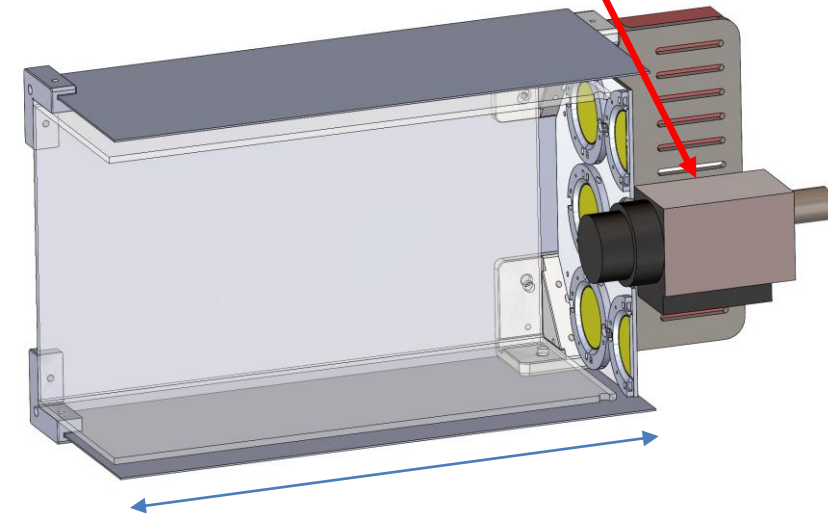


Array of LED Chips



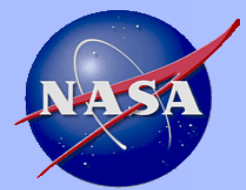
Thermal Management Design for Heat Sinking, Flash bulbs and quartz heat lamps cannot be mounted onto a heat sink!

Infrared Camera
Side View Cutout



10.5 inches

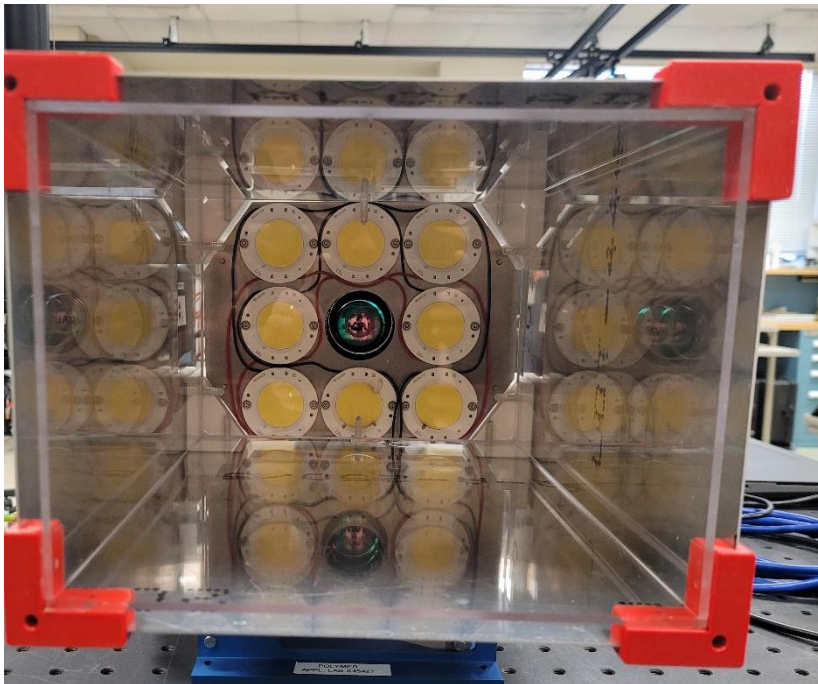
Prototype Concept



Pulsed LED Laboratory Inspection Setup

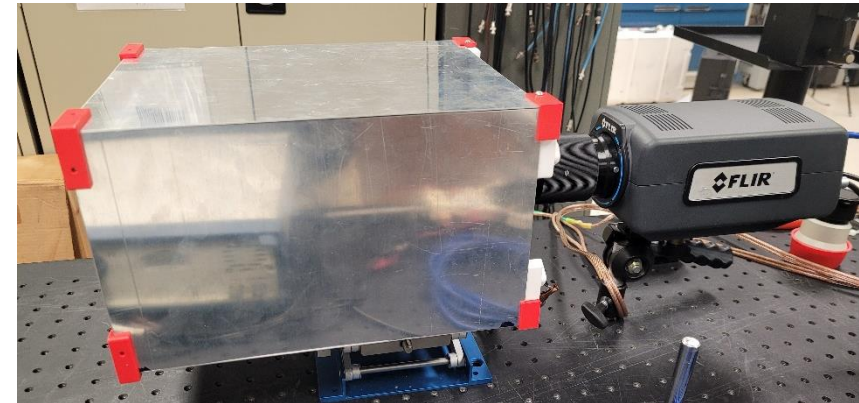
Nondestructive Evaluation Sciences Branch

Front View of Hood

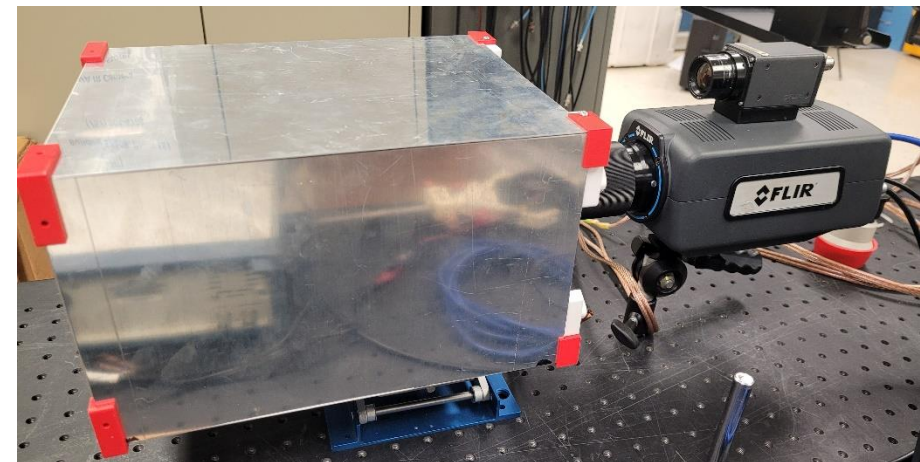


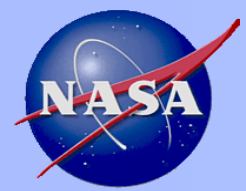
Inspection Area of Hood is approximately 5.75 x 7.75 inches

Side View of Hood with Infrared Camera



Side View of Hood with Camera and Proposed Smaller Infrared Camera

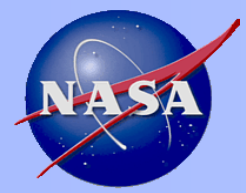




Emissivity Measurement of Inspected Samples

Nondestructive Evaluation Sciences Branch

Sample	Measured Emissivity
Unpainted Aluminum Sample with Material Loss	0.35 +/- 0.020
Unpainted Aluminum Sample with Circular Material Loss	0.21 +/- 0.012
Polished Additive Manufactured Ti-6Al-4V Disk	0.39 +/- 0.017
Painted Aluminum Sample	0.90 +/- 0.008



Inspection of Aluminum Sample with Material Loss

Nondestructive Evaluation Sciences Branch

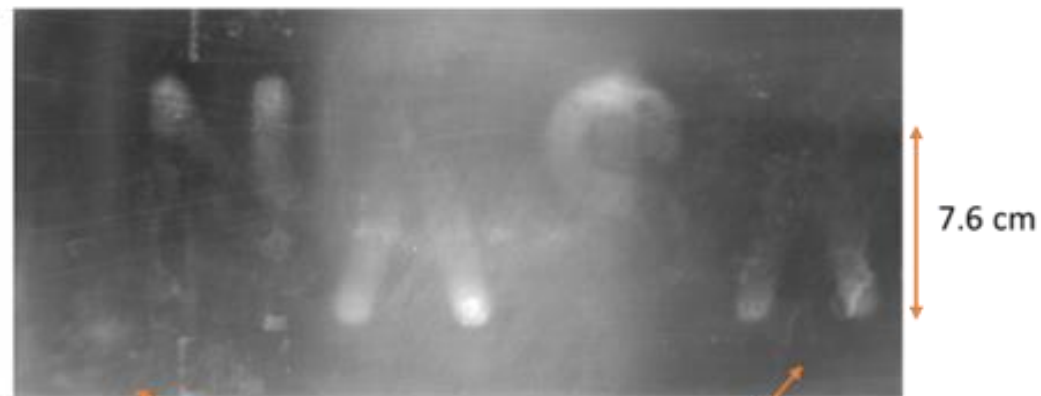
Picture Front



Picture Back



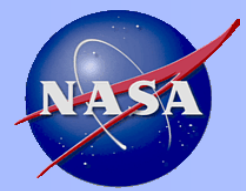
Flash Thermal Inspection



PLED Thermal Inspection



Flash Lamp Reflections



Inspection of Aluminum Sample with Circular Material Loss

Nondestructive Evaluation Sciences Branch

Picture Front

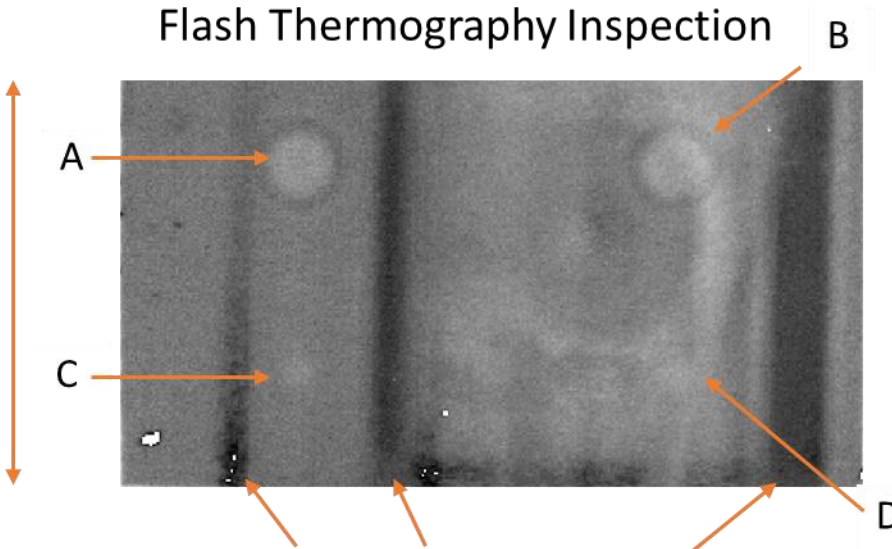


Picture Back



8.9 cm

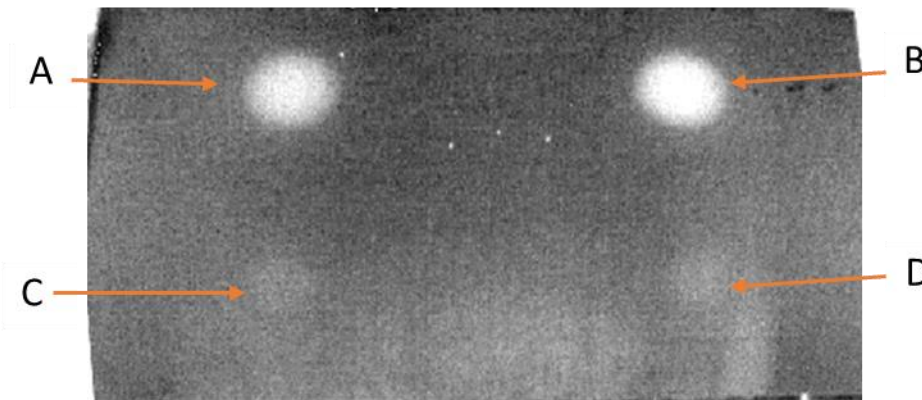
Flash Thermography Inspection

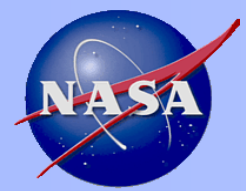


8.9 cm

Flash Lamp Inspection Reflections

PLED Thermography Inspection





Inspection of Unpainted Polished Ti-6Al-4V Additively Manufactured Disk

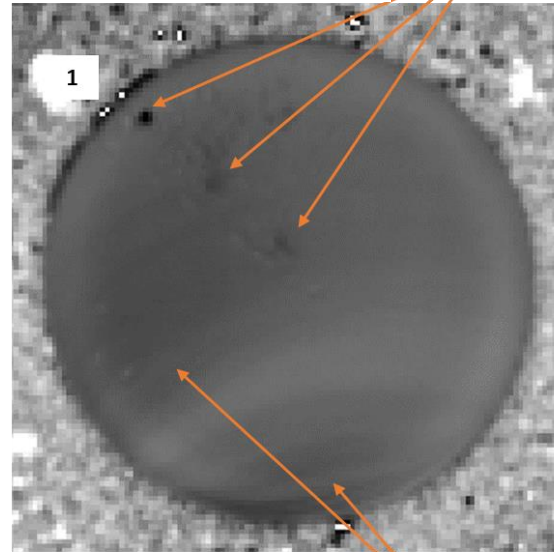
Nondestructive Evaluation Sciences Branch

Polished Disk



21.0 mm

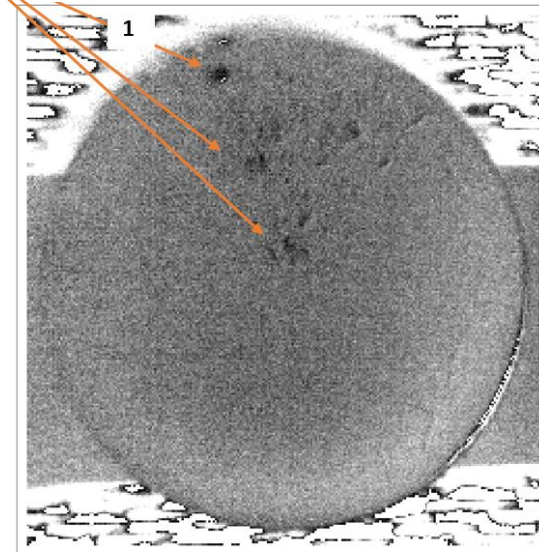
Flash Inspection



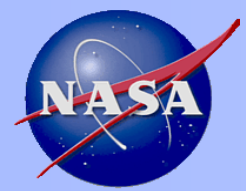
Porosity Indications

Flash Inspection Reflections

PLED Inspection

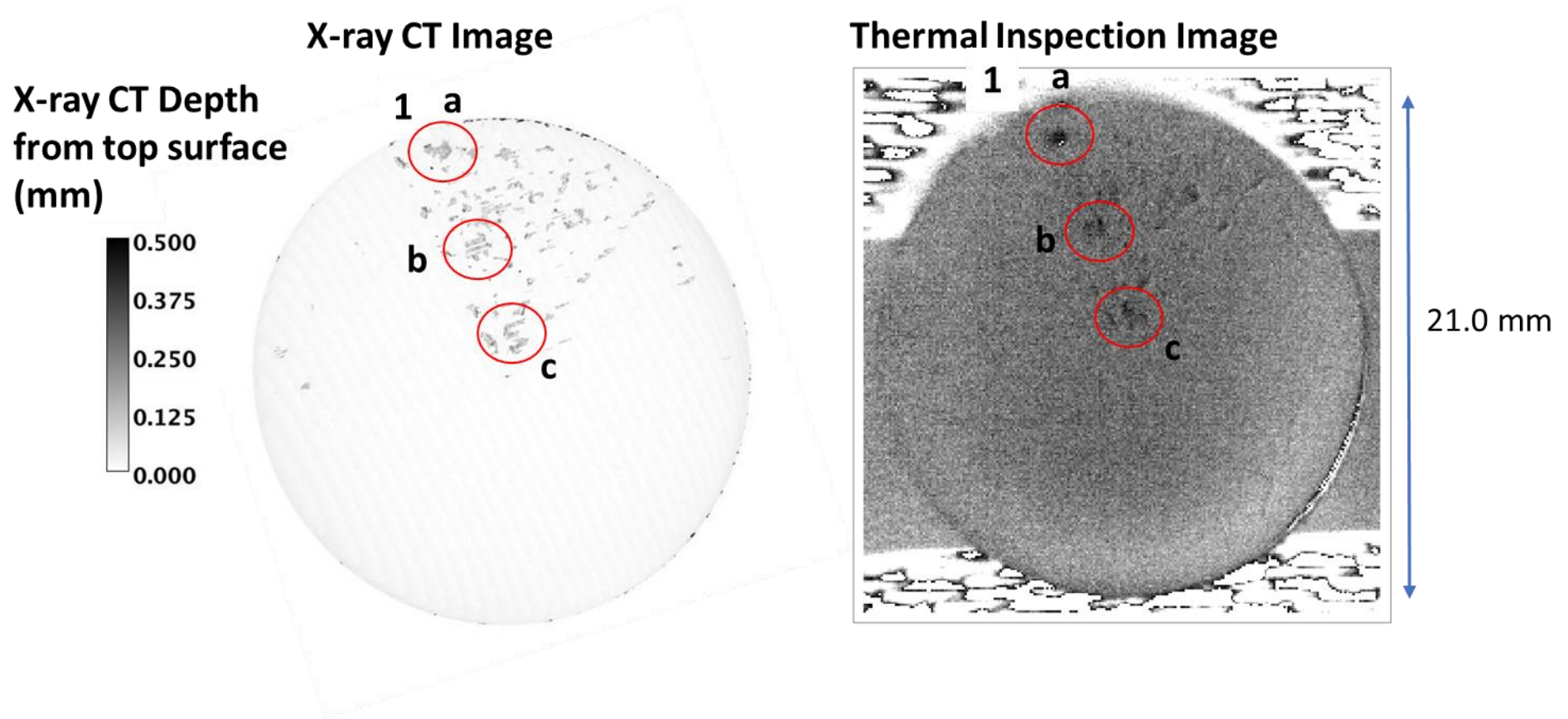


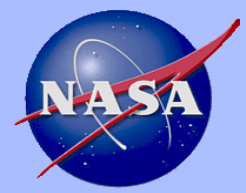
21.0 mm



PLED Thermography Comparison to X-ray CT of Ti-6Al-4V Disk

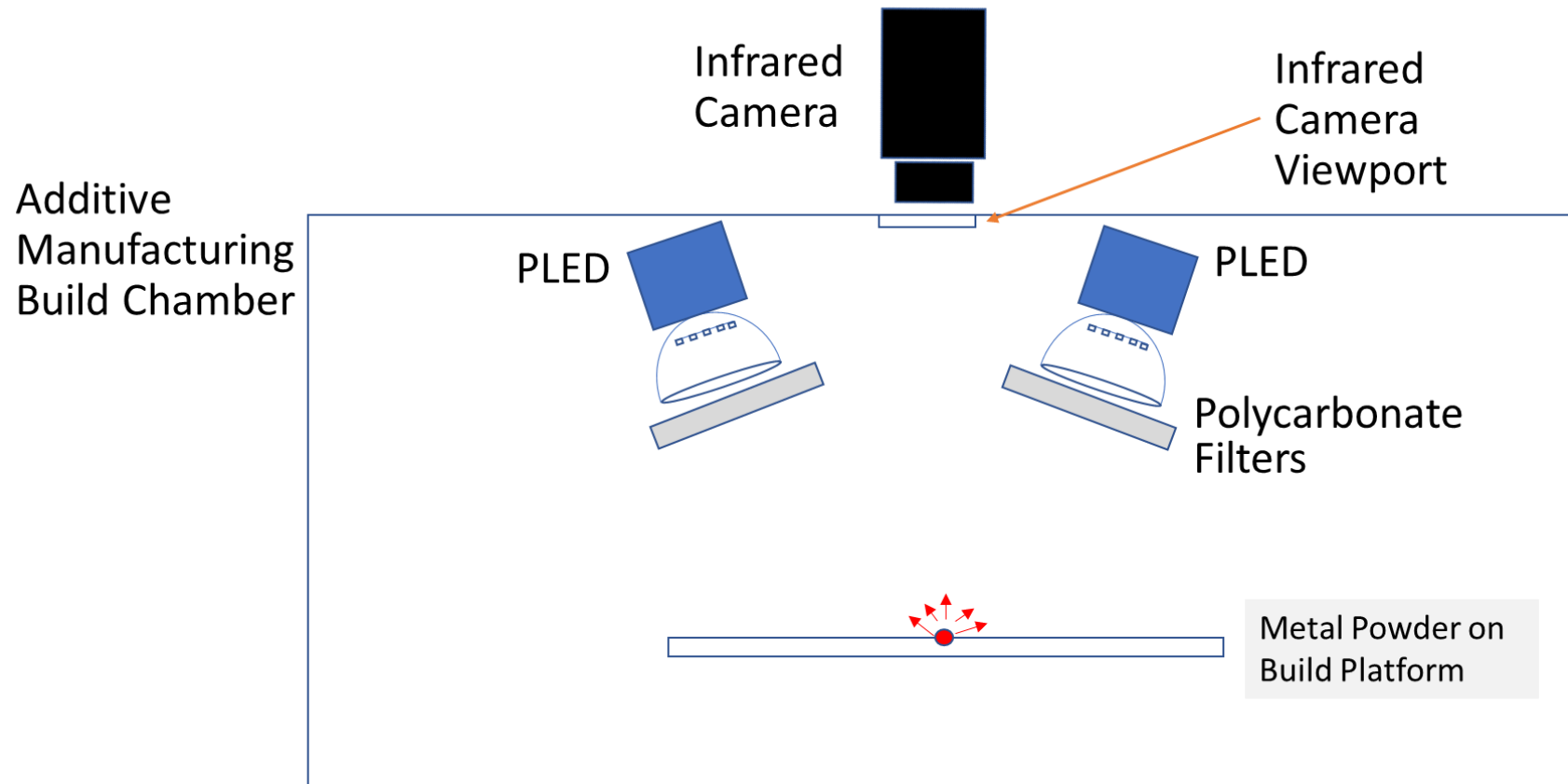
Nondestructive Evaluation Sciences Branch

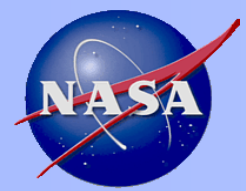




PLED Thermography for Additive Manufacturing In-situ Inspections during the Build Layer-by-Layer

Nondestructive Evaluation Sciences Branch





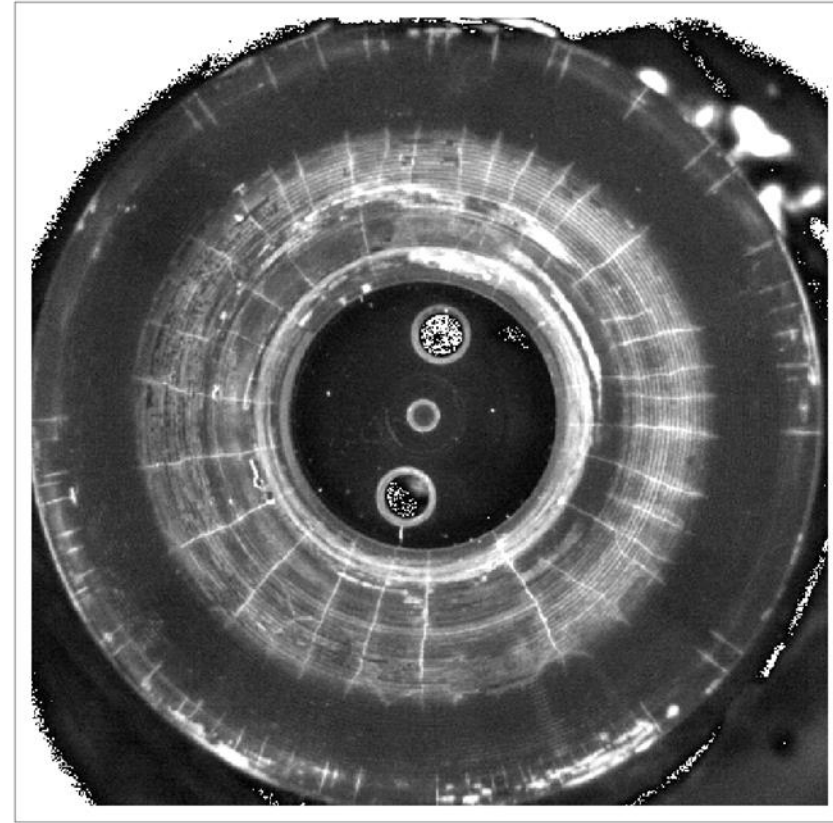
PLED Thermography for Crack Detection

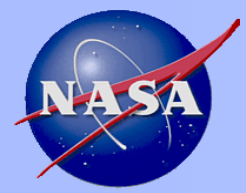
Nondestructive Evaluation Sciences Branch

Picture



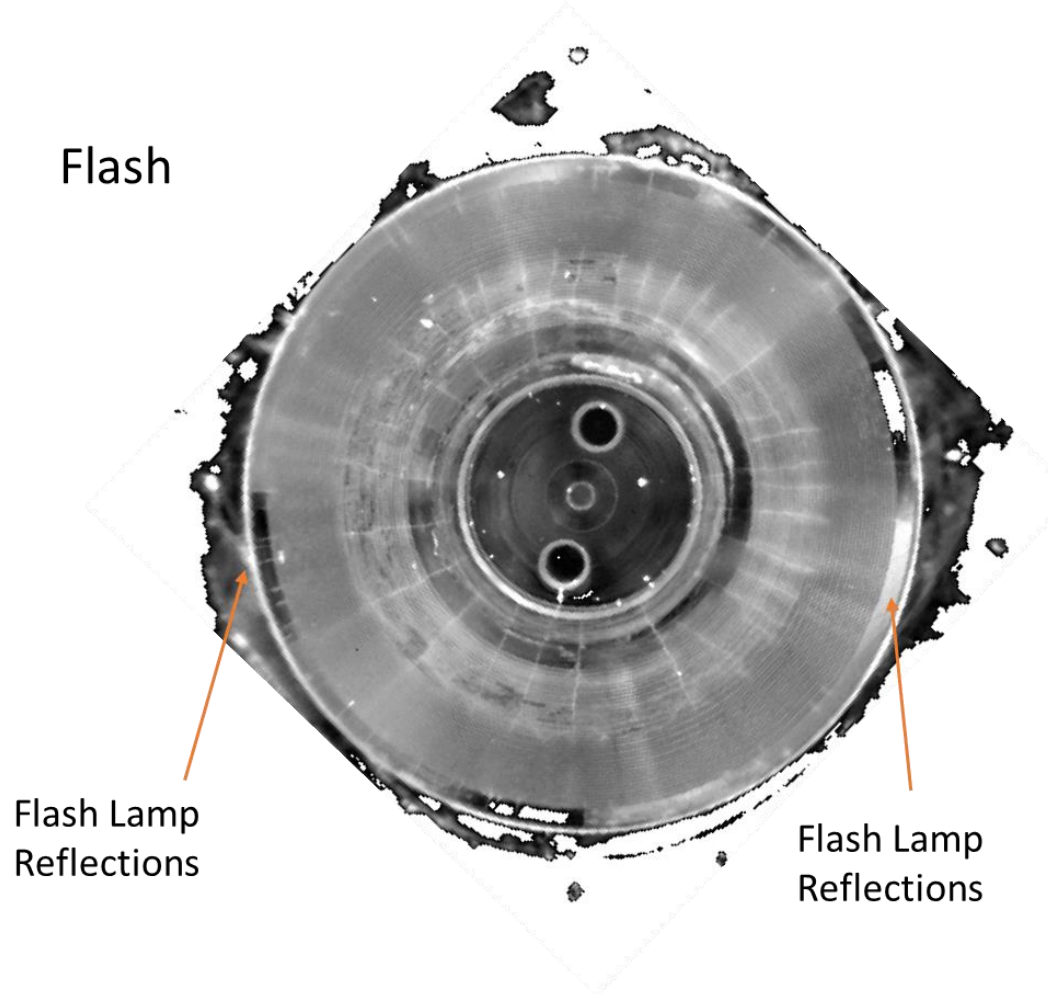
PLED



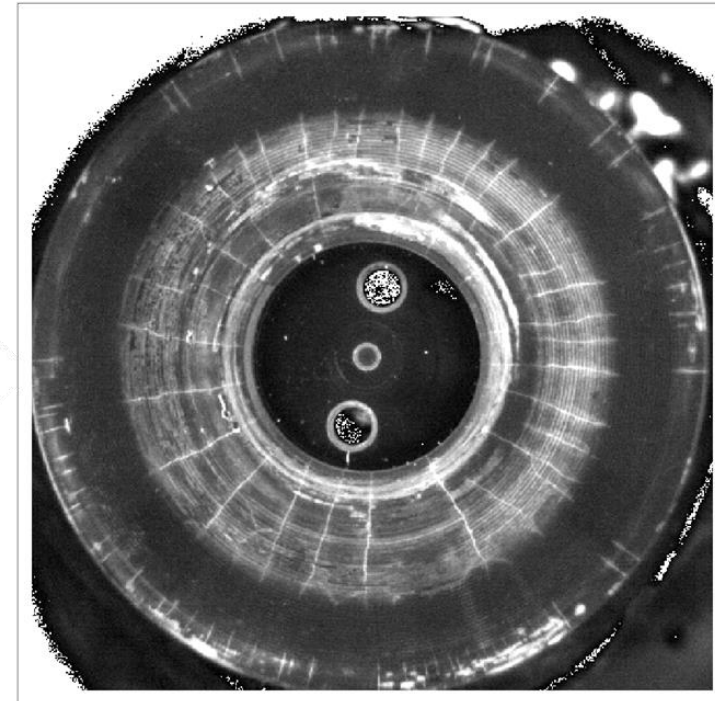


PLED Thermography Comparison to Conventional Flash Thermography

Flash



PLED



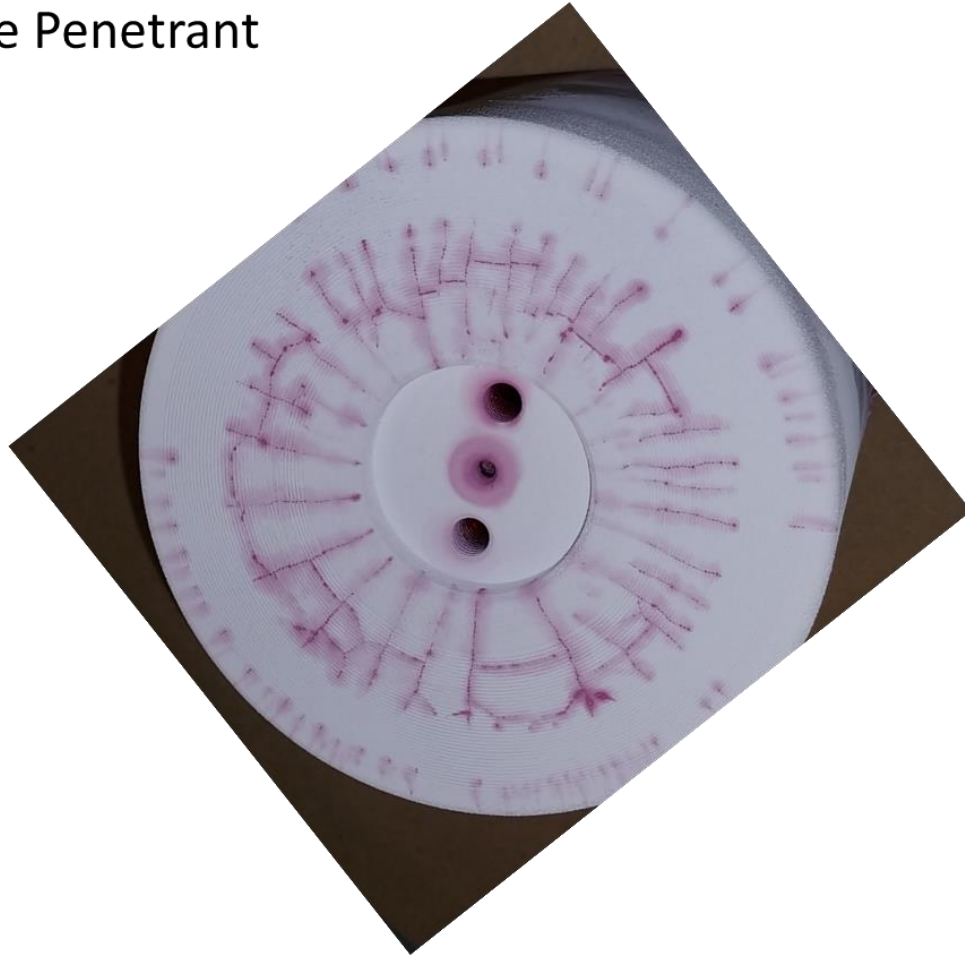
- Both flash and PLED thermal inspections takes less than a minute to perform



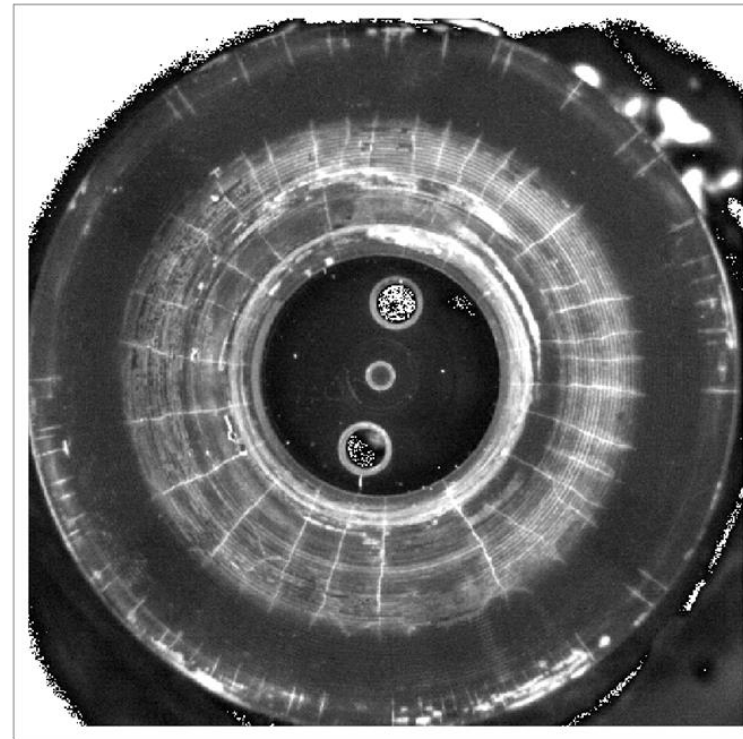
PLED Thermography for Crack Detection Comparison to Dye Penetrant

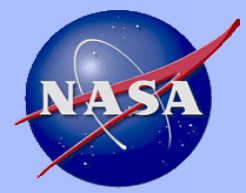
Nondestructive Evaluation Sciences Branch

Dye Penetrant



PLED

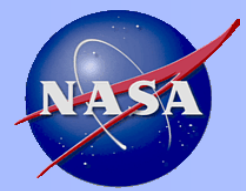




PLED Thermography for Fatigue Crack Detection

Nondestructive Evaluation Sciences Branch



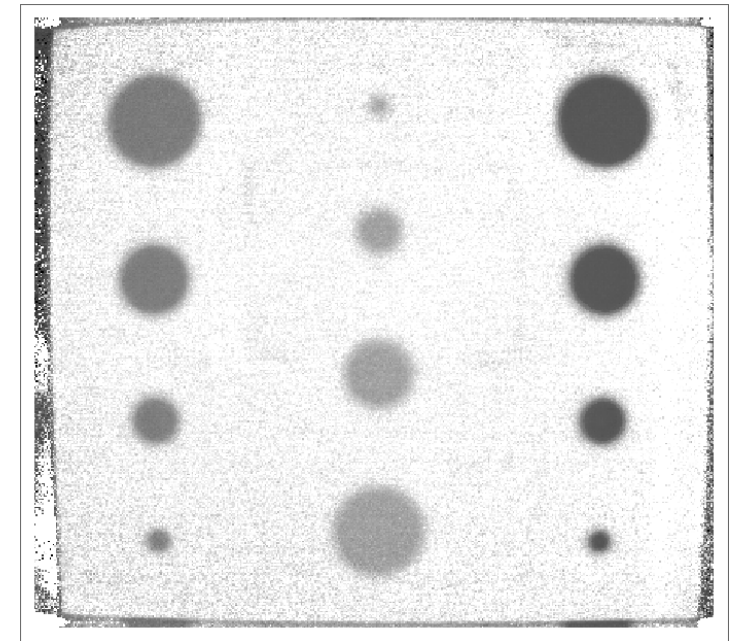


PLED Single Side Inspection with Model Fit

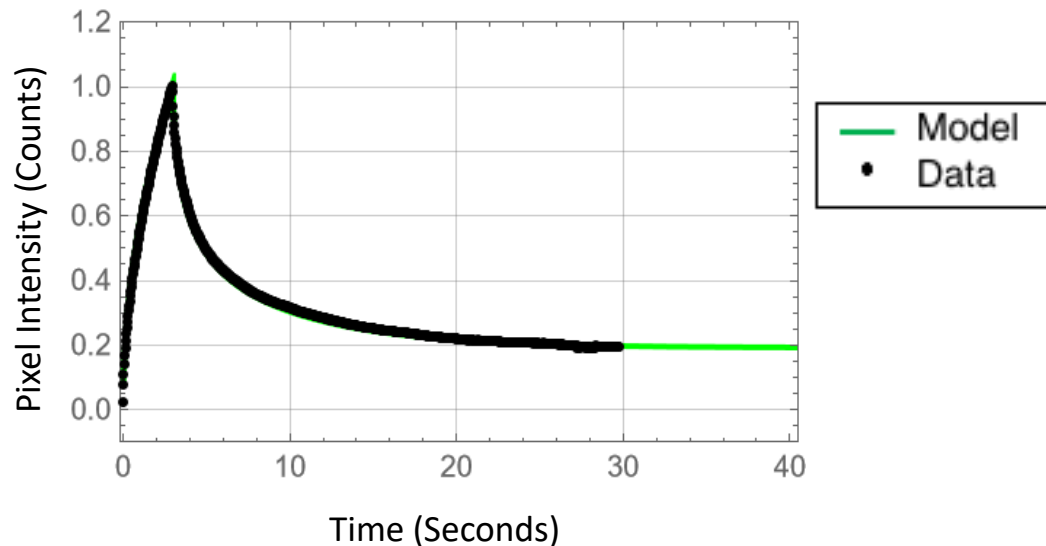
Nondestructive Evaluation Sciences Branch

$$T(t, l) = \frac{(F_0 t \alpha)}{K l} + \frac{F_0 l}{K} \left(\frac{1}{3} - \frac{2}{\pi^2} \left(\sum_{n=1}^{nmax} \frac{-1^{2n}}{n^2} e^{\frac{-\alpha n^2 \pi^2 t}{l^2}} \right) \right) - \left(\frac{(F_0 (t-t_0) \alpha)}{K l} + \frac{F_0 l}{K} \left(\frac{1}{3} - \frac{2}{\pi^2} \left(\sum_{n=1}^{nmax} \frac{-1^{2n}}{n^2} e^{\frac{-\alpha n^2 \pi^2 (t-t_0)}{l^2}} \right) \right) \right) U(t - t_0)$$

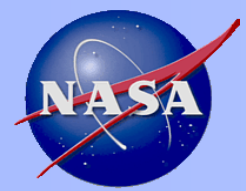
Sample with Material Loss Defects



Example Curve Fit to Model



- Quantitative Single Side Model-Based Thermal NDE is Possible with the PLED Heat Source and if diffusivity is known, then residual thickness can be measured noncontact.



Conclusions

Nondestructive Evaluation Sciences Branch

- The PLED heat source has been demonstrated as a viable heat source for thermal inspection of low emissivity surfaces such as metals for corrosion or crack detection.
- The PLED heat source advantage is the light is not observable with the mid-wave infrared camera.
- Single sided model fit revealed good agreement to the data and therefore quantitative single side model-based thermal NDE is possible with the PLED heat source (applicable to low or high emissivity materials).

