

Deployment of Infrared Inspection Technologies at Sandia National Laboratories

**Experimental Mechanics/NDE & Model Validation –
Non Destructive Test Laboratory
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Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

Outline

- About Sandia National Laboratories
- Infrared Basics
- IR Capabilities at Sandia National Laboratories
- Thermal Wave Inspection Set-up and Applications
- Infrared Capabilities and Limitations
- Conclusions

Sandia's Sites

**Albuquerque,
New Mexico**



**Livermore,
California**



Tonopah, Nevada



**Waste Isolation Pilot Plant,
Carlsbad, New Mexico**

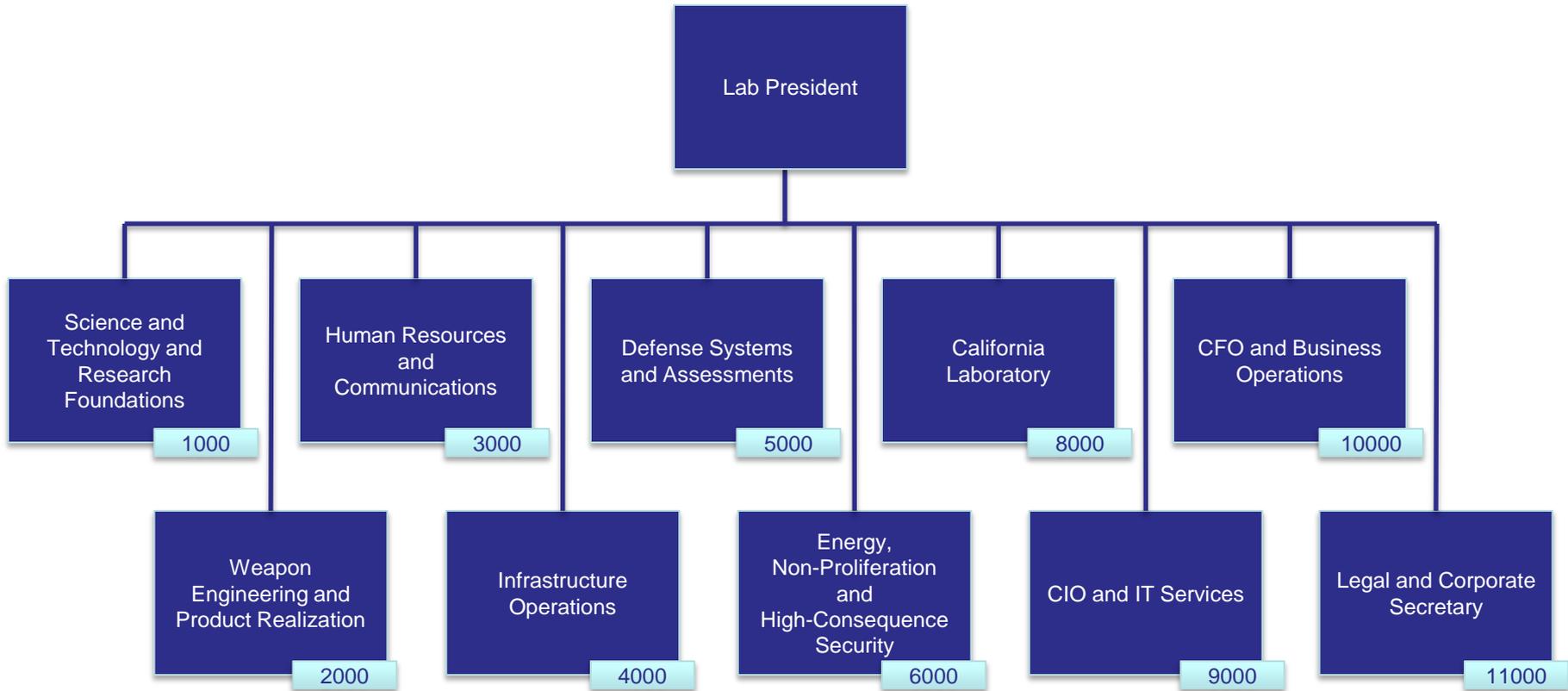


Pantex, Texas



Sandia's Structure

<http://dx.doi.org/10.2361/qirt.2012.300>



- Division 1000 : Science and Technology and Research Foundations
 - Center 1500 : Engineering Sciences
 - 1520 : Solid Mechanics and Structural Dynamics
 - Organization 1522 : Experimental Mechanics, NDE, and Model Validation

Non-Destructive Evaluation (NDE)

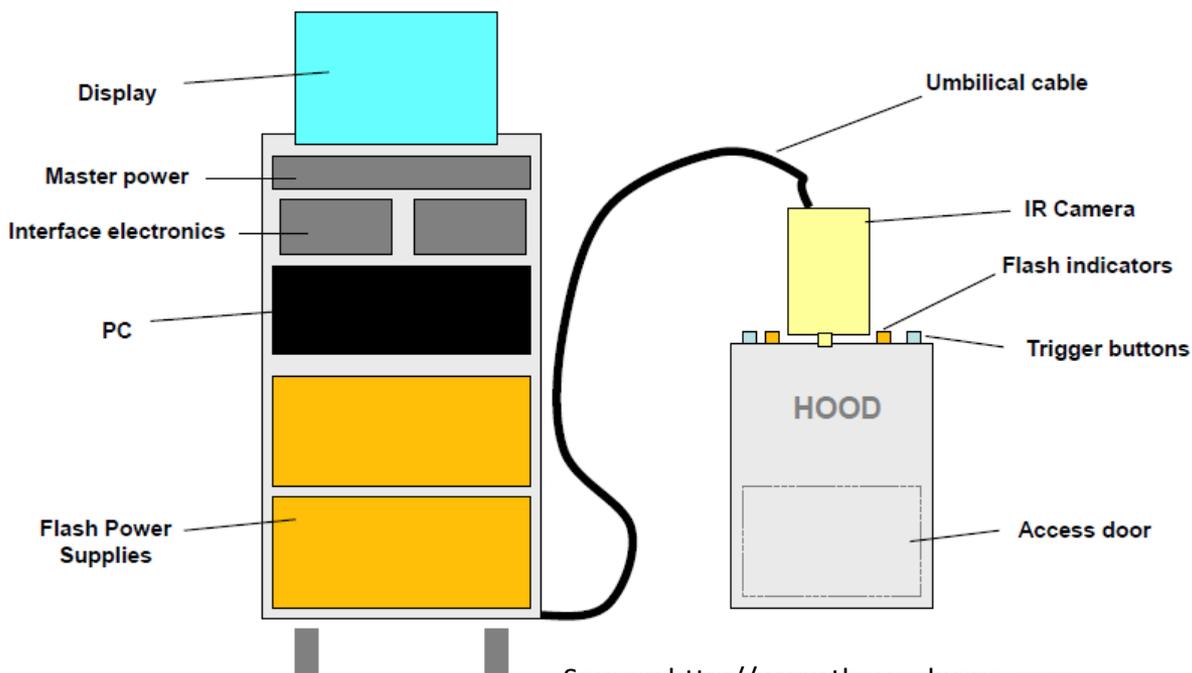
- NDE at Sandia Includes a suite of technologies
 - Radiography
 - Computed Tomography
 - Ultrasonic Diagnostics
 - Eddy Current Testing
 - **Infrared Imaging**
- Applications
 - Research and Development
 - Quality Control, Failure Analysis, & Testing Diagnostics

Infrared Basics

- Active Thermography (AT) is defined as a technique where a stimulus is applied to a target to cause the target to heat or cool in such a way as to allow characteristics of the target to be observed by infrared imaging.
- The difference between active from passive thermography is the intentional application of heating, cooling or other excitation method that results in a temperature rise or fall in a target, as compared to an otherwise in situ (passive) target.
- In active thermography, the thermal response of a target to a heating (or cooling) event is analyzed to determine the subsurface structure or material properties of the target. **The time at which temperature changes take place is often more important than the amplitude of the temperature change.**

EchoTherm Equipment

- EchoTherm Software processes thermographic signal reconstruction (TRS) and temperature-time profiles.
- Mosaiq software converts live images into data files single or multiple images.



Source: <http://www.thermalwave.com>

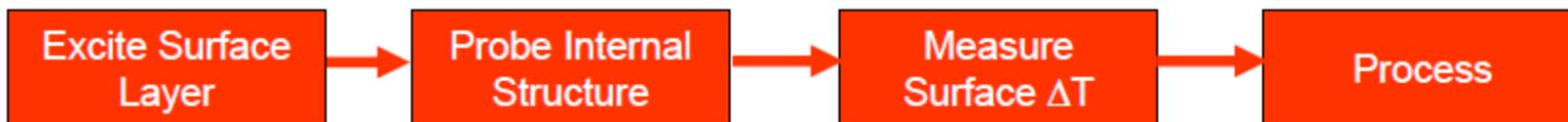
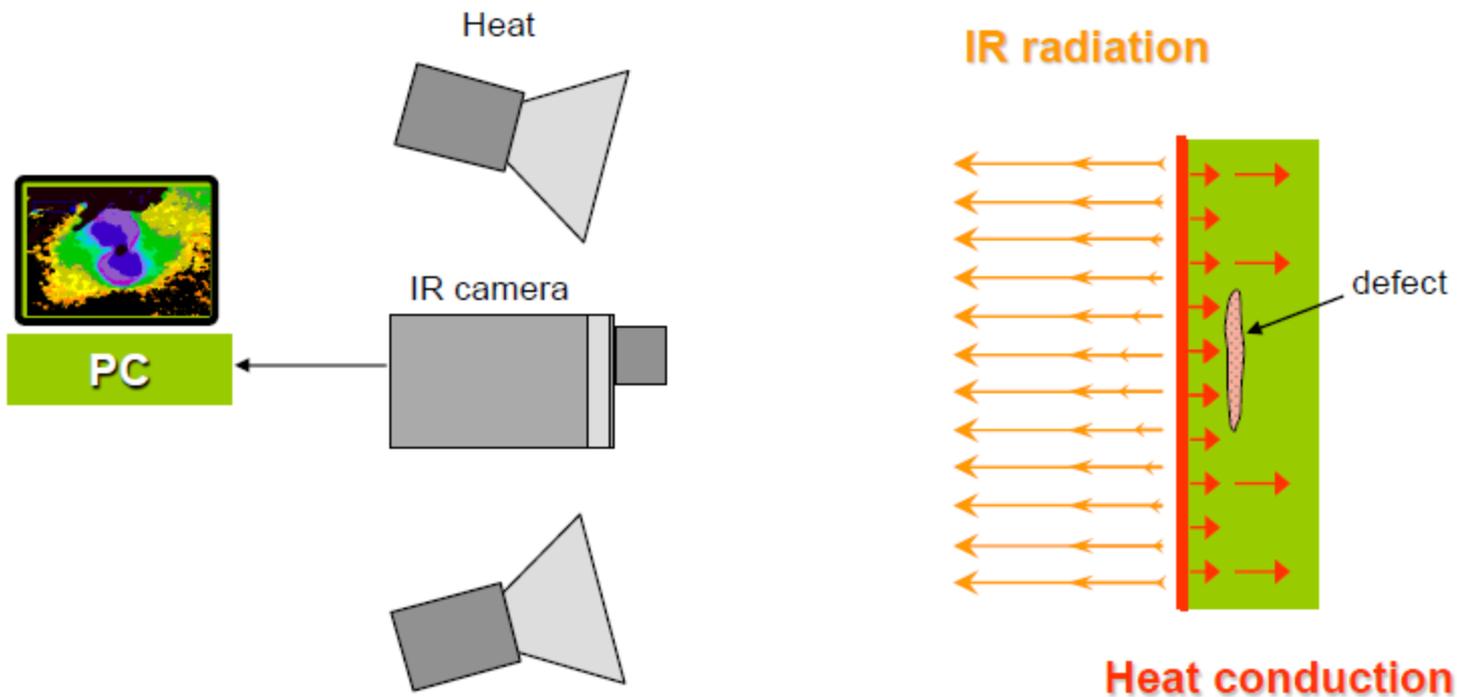
The hood contains two xenon flash lamps, parabolic reflectors and uses 5000 Joules per lamp.
FLIR 6106 camera (120 Hz @ 640 X 512 or 420 Hz @ 320 X 256 InSb) detector with 14 bit output.

VoyageIR Equipment

- EchoTherm (TSR) and MOSAIQ software on a Toughbook laptop (Intel 2.26 GHz processor).
- The IR camera is a Microbolometer - 30 Hz @ 320 X 256 14 bit USB.
- Heat gun with trigger control.
- Handheld color touchscreen (live or saved images available).



Equipment Set-up



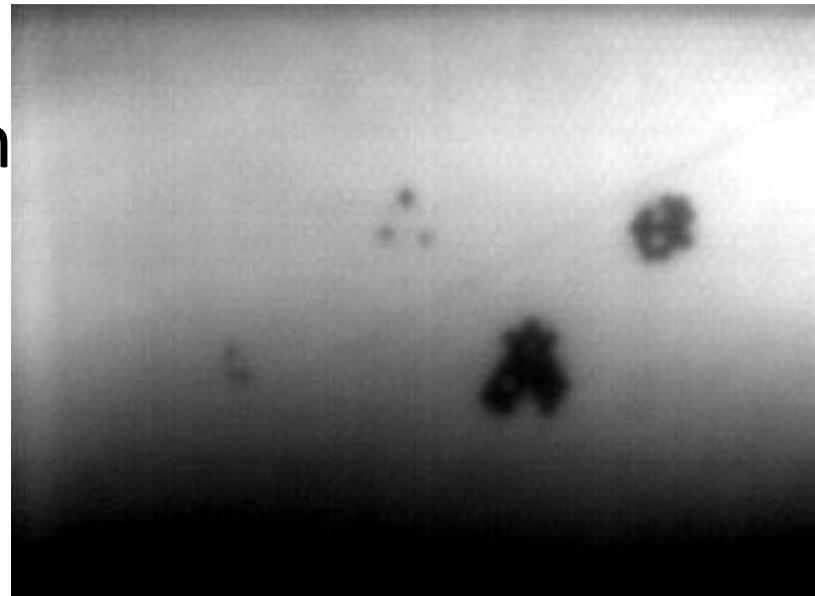
Source: <http://www.thermalwave.com>

Inspection Set-up and Applications

Most composite parts are very complex. One current project is determining if IR inspection can detect for water ingress into composite honeycomb structures.

Below is an IR image with embedded water.

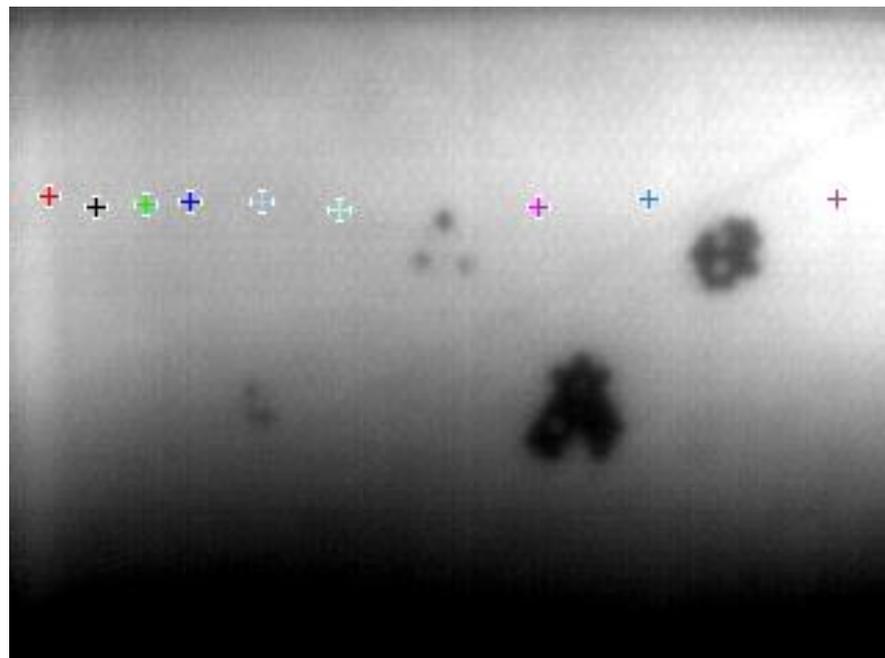
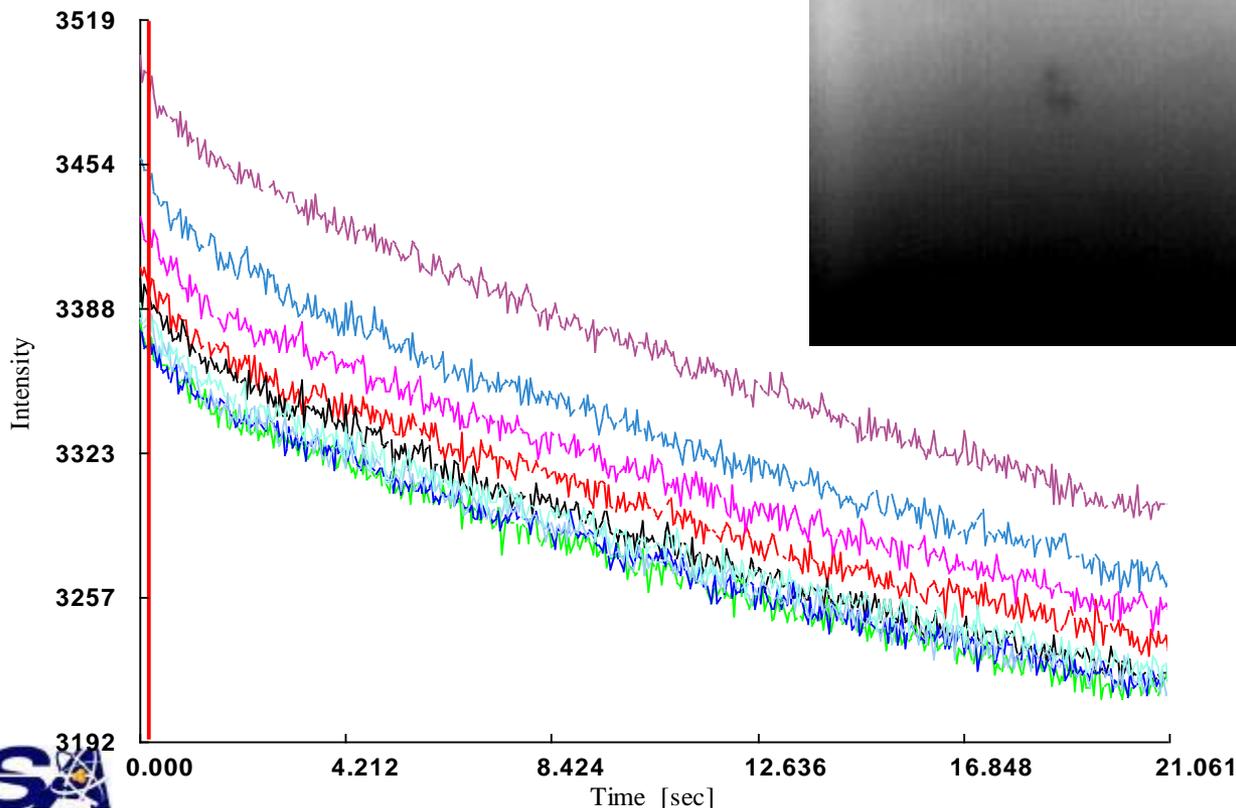
Both passive and active thermography
Can detect the water.



Visually the honeycomb structure can be seen.
The dark pixels are cool spots where water is
within the cell structure.

Intensity Time Plot

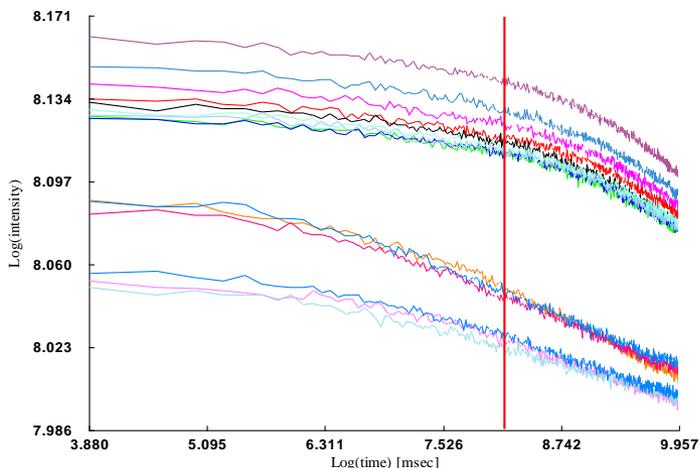
Cooling intensity is collected as a function of time. The event is analyzed to determine if there are changes in subsurface structure. Material thermal properties of the sample are used in baseline thermal measurements.



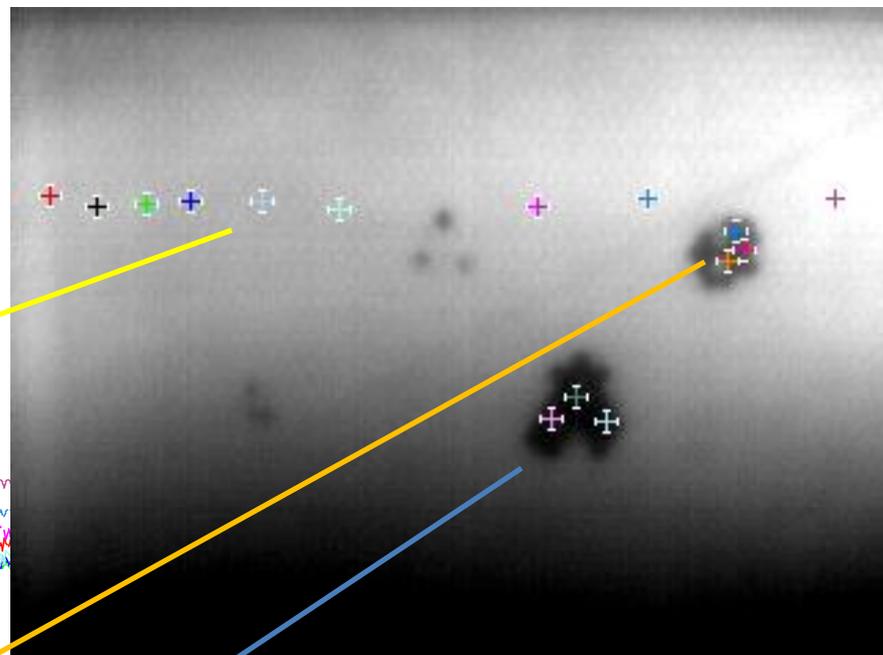
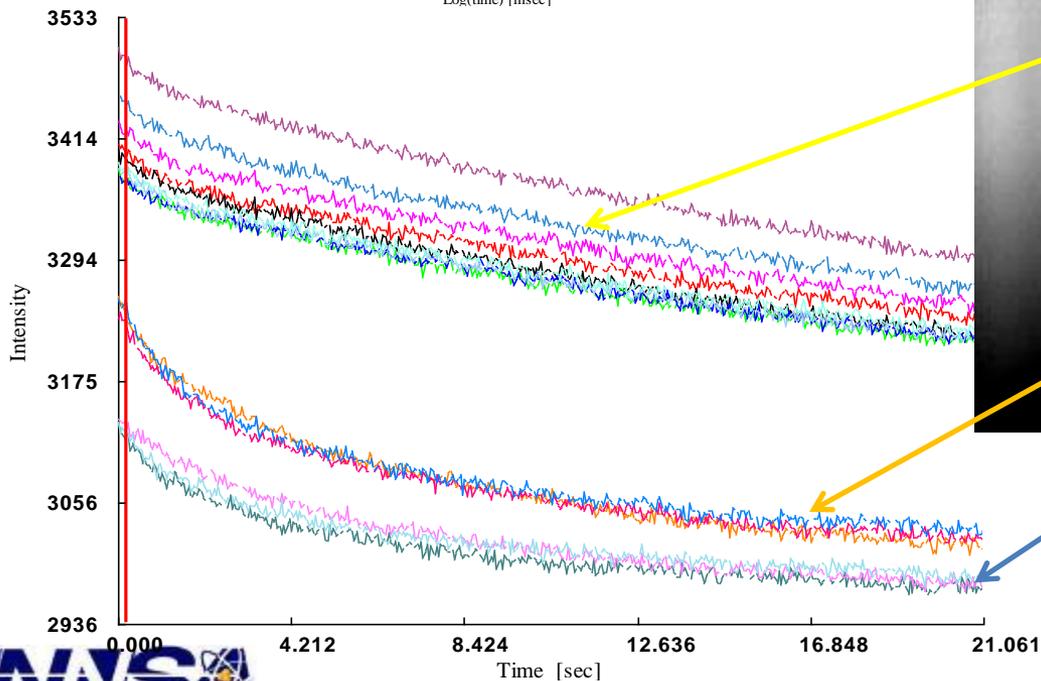
Each point above create a Intensity value per time step and the plotted.

Intensity Time Plot With Defects

Saturation

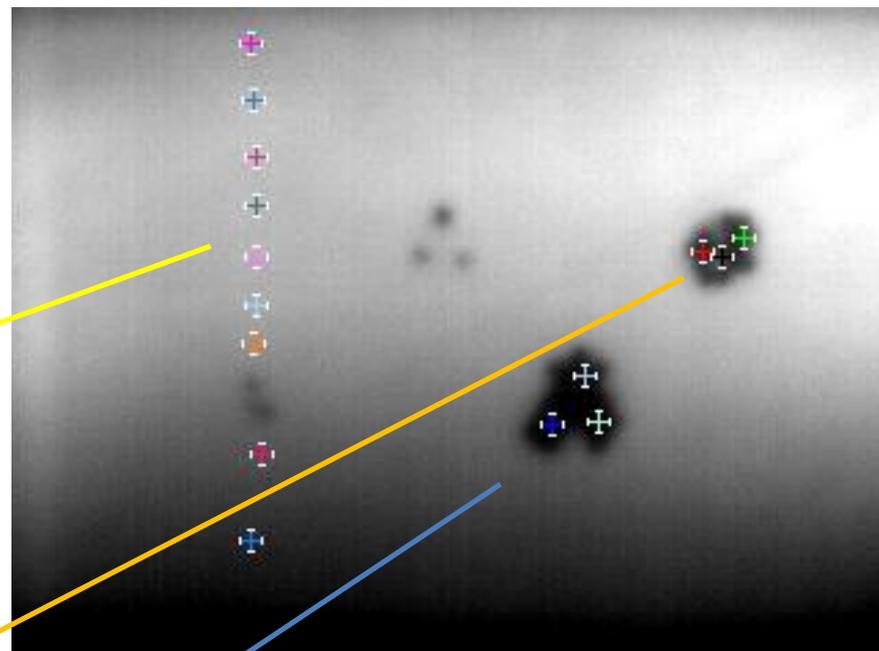
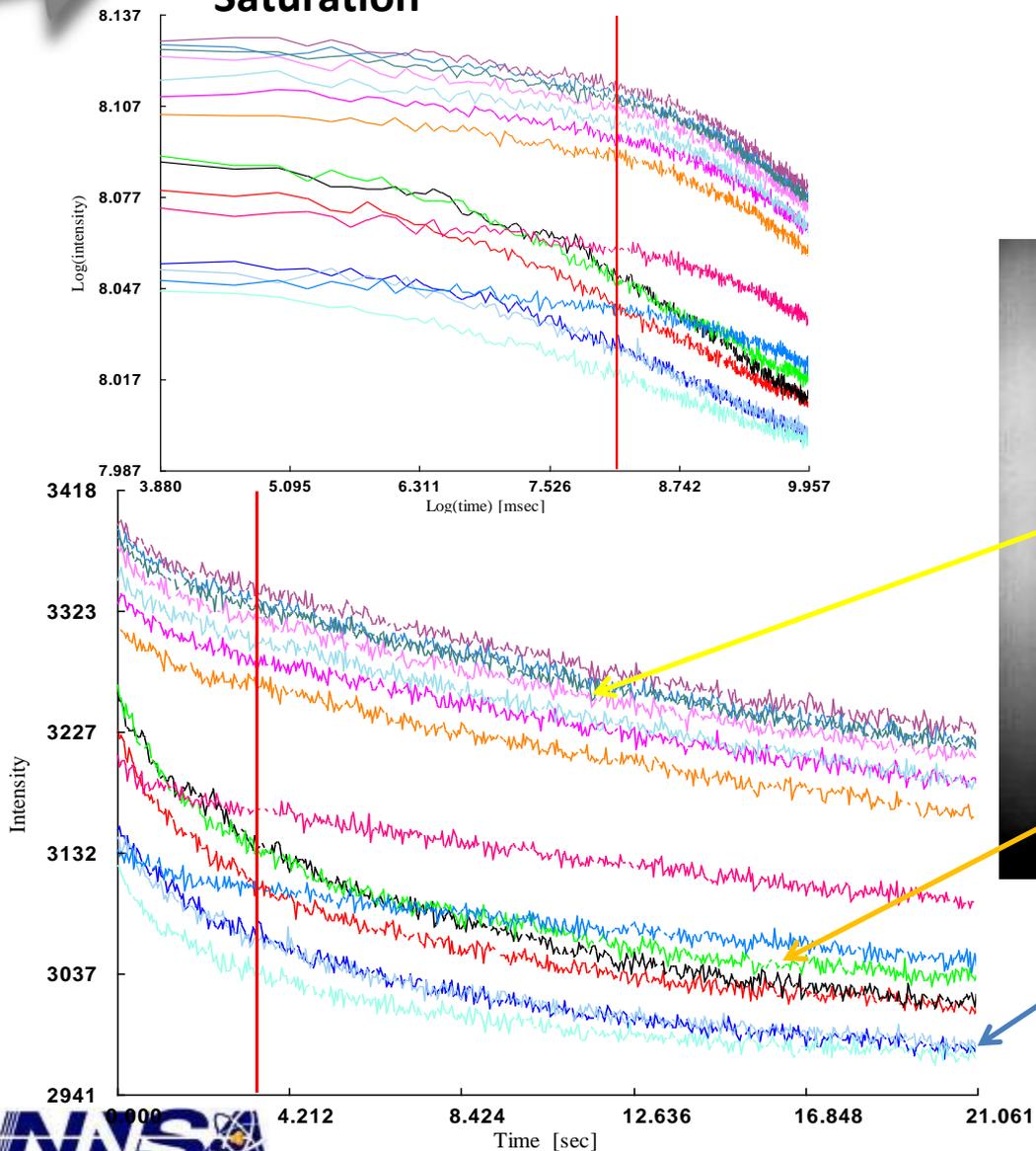


If high heat input levels are in the early frames the limits can be beyond the IR camera dynamic range. **Saturation occurs. Trapped water is still absorbed by the incident heat.**



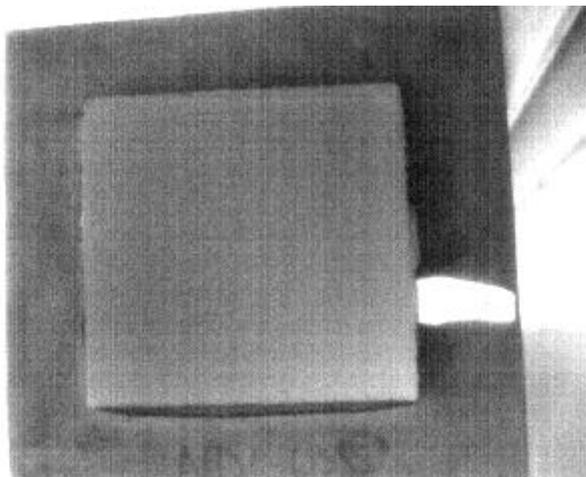
Intensity Time Plot (cont)

Saturation

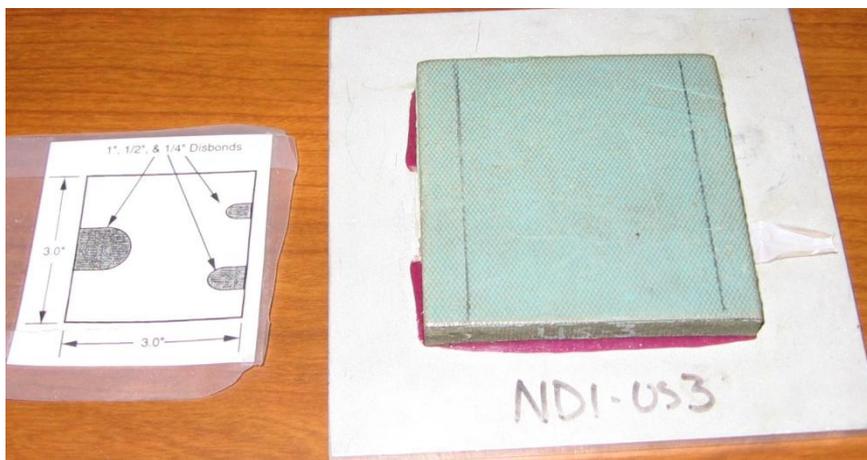
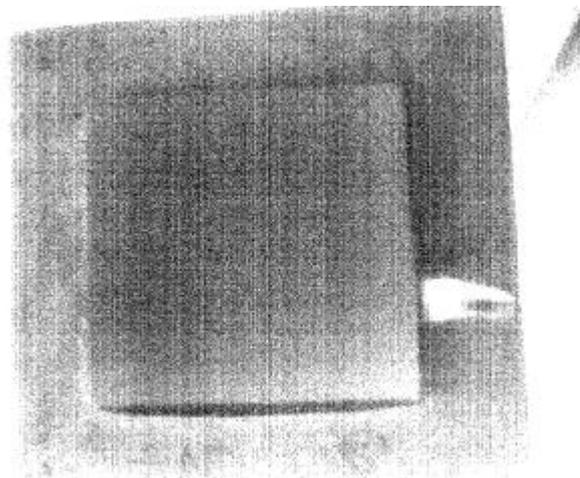


Uneven heating

Thick Composites with Pull Tab



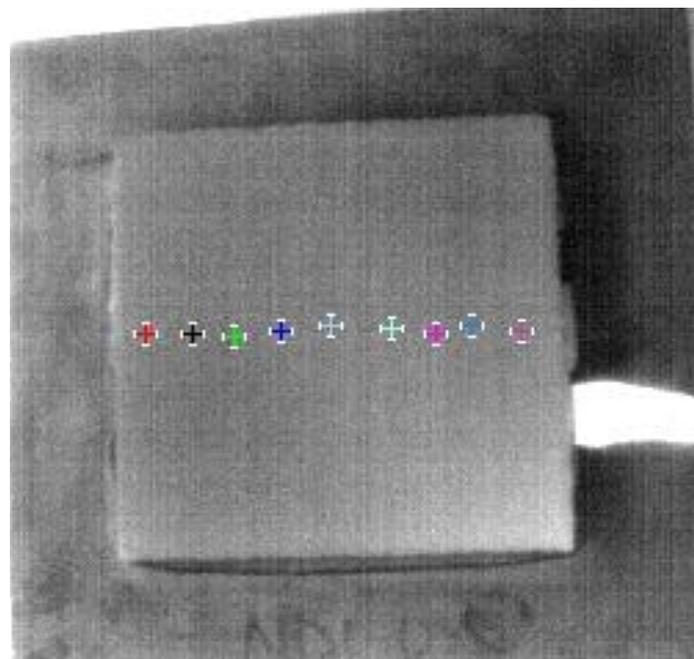
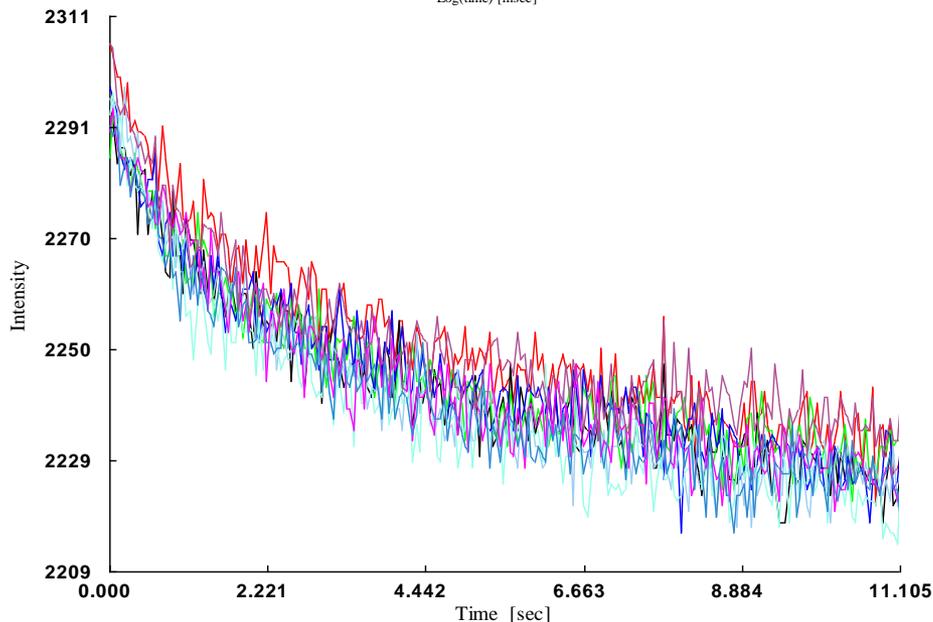
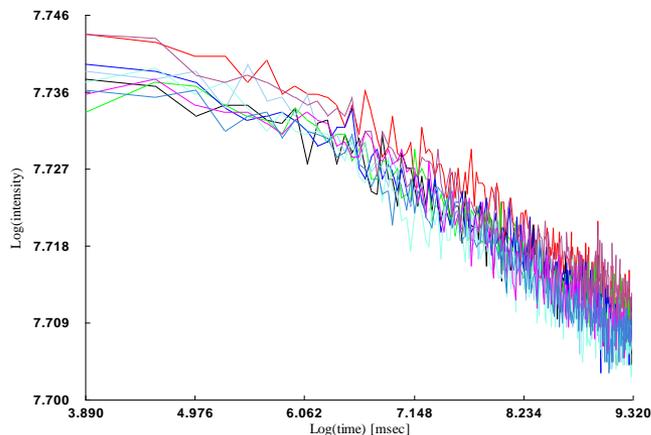
Pull tab



Thick composite bonded onto aluminum plate. Defects can not be detected using IR techniques.

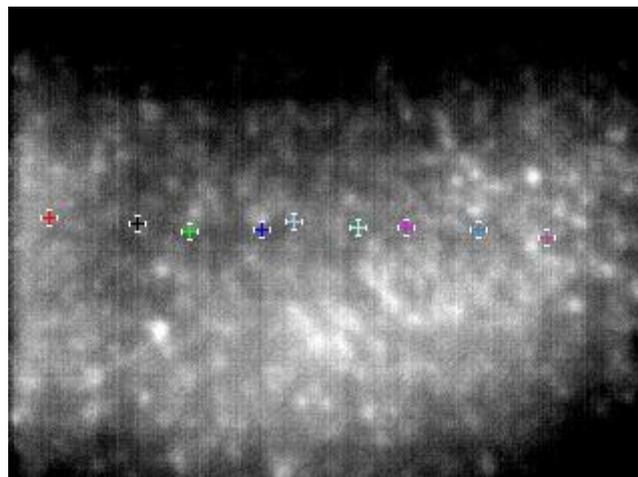
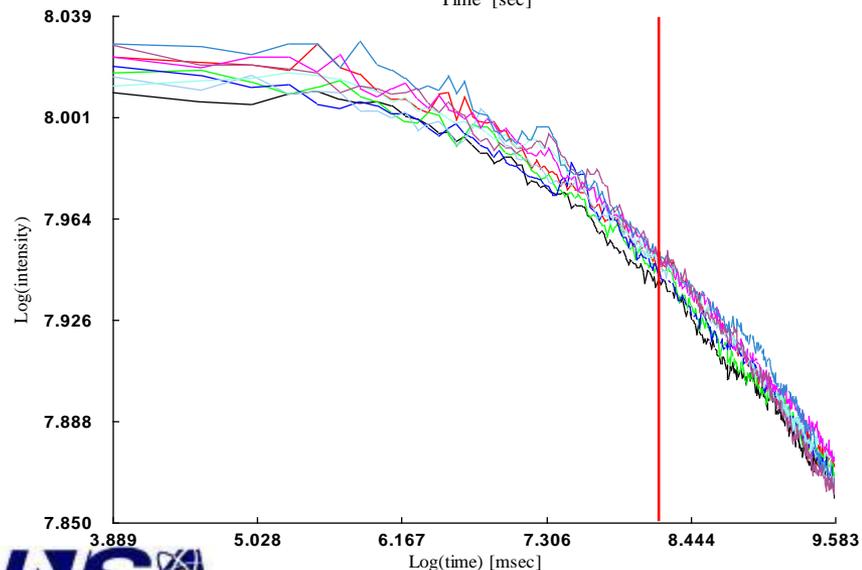
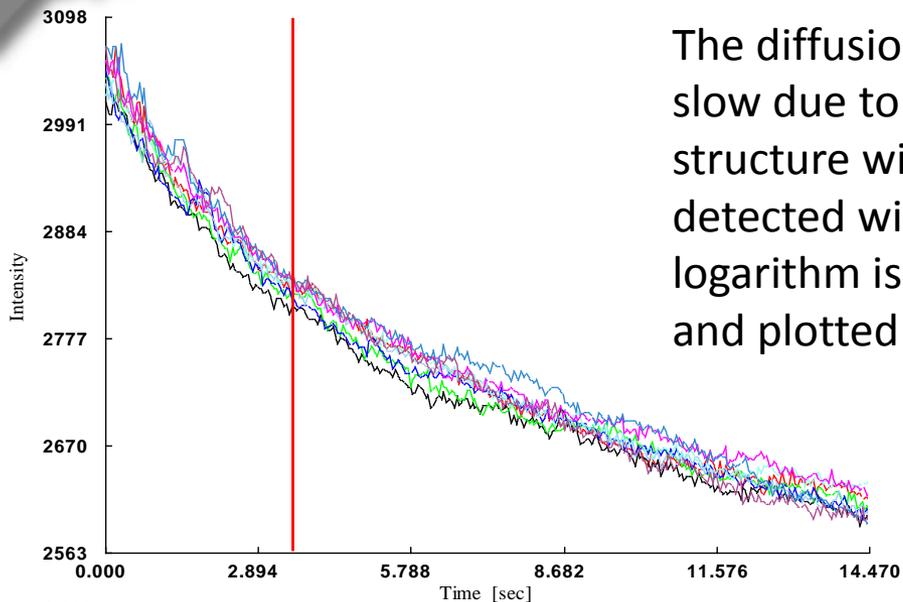
Intensity Time Plot With Defects

Thick composites create thermal absorption and scattering with every ply change. Thermal change occurs very slowly.

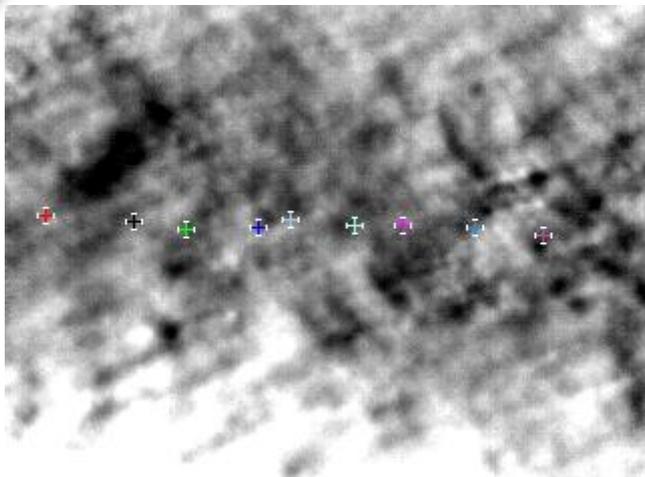


Thick Fiberglass Sample

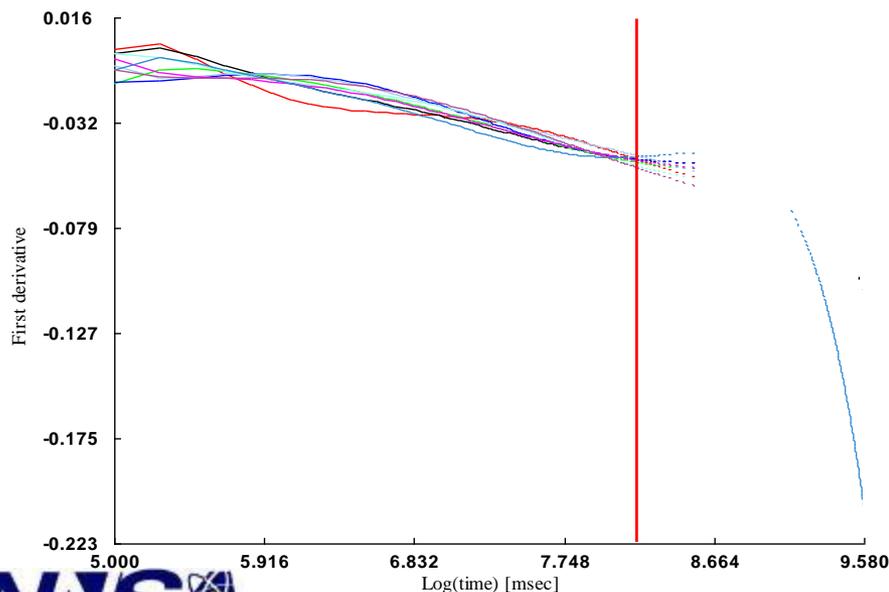
The diffusion rates into this material is very slow due to air pockets. Visually the lower structure within the fiberglass can not be detected with infrared technologies. A logarithm is applied to the intensity time pairs and plotted below.



Thick Fiberglass Sample(cont.)

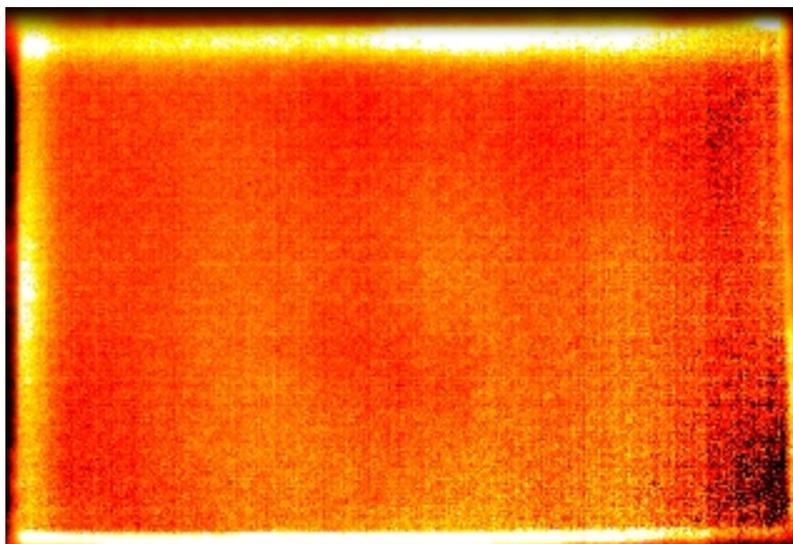
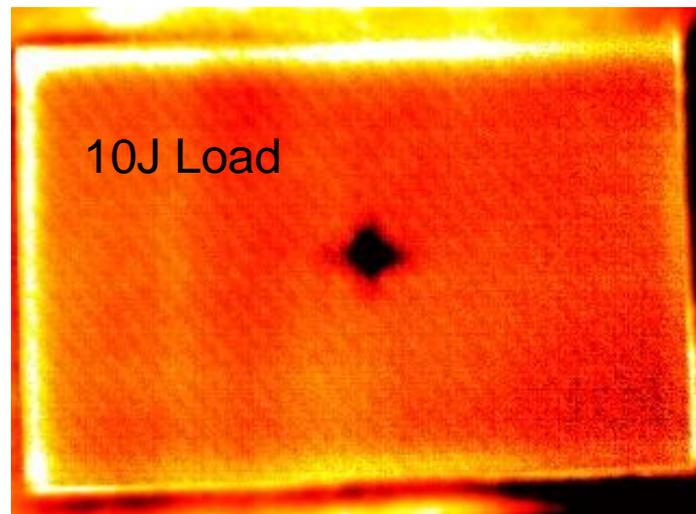


Thermographic Signal Reconstruction fits the raw log-log data with a smooth function and uses the replica for additional processing. Once the coefficients are in the Log domain, a transform can be created to produce a first or second derivative. Below is the first derivative of each chosen pixel.

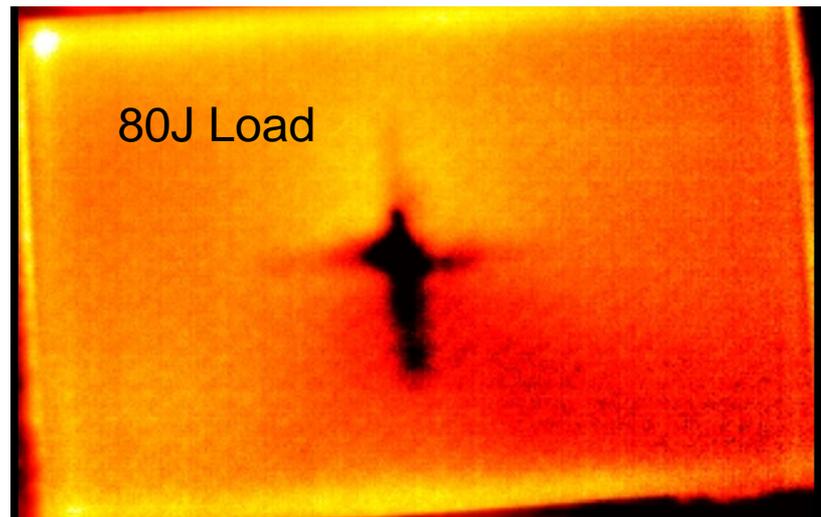


Thermal Impact Studies

An engineering study is underway to address tool impact on composite layups. Loads of 10J through 80J were applied to composite samples. A thermal load was applied to each sample. The thermal decay of the composite was collected. Baseline, 10J and 80J impact samples are shown.



baseline



Infrared Capabilities and Limitations

- If the surface is shiny then light will be reflected from it. This may not allow enough heat to be deposited into the sample (low signal). A coating of low reflective paint (black) is required.
- Painted surfaces can be deceptive. The surface may be shiny however, the IR emissivity and optical absorption may be enough to produce data. A test with/without paint may be required. In many cases the derivatives remove reflection artifacts that appear in the raw image.
- Most composites appear shiny but can be imaged without painting. The slope processing features extract most required data.
- Many samples generate a reflection of the detector in the image. This effect can be removed in the TSR process or by subtraction of pre-flash images.
- If the log plot of a defect free point is extremely distorted then reflected radiation is the predominate signal and not conductive cooling.

Conclusions

- Infrared technology will enhance Sandia's Nondestructive Inspection Laboratory diagnostic capabilities for future production needs.
- As new products mature IR inspection will be implemented (as required) to assist engineers.