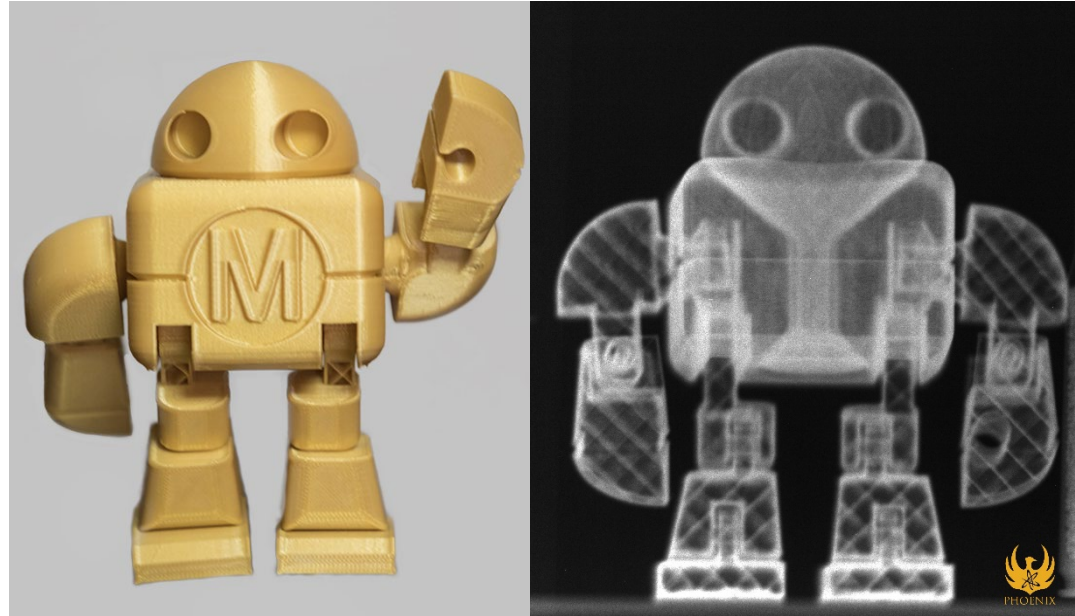


High-Resolution, Non-Destructive Imaging with Accelerator-Based Neutron Sources

KATIE RITTENHOUSE | DIRECTOR OF SALES | PHOENIX, LLC

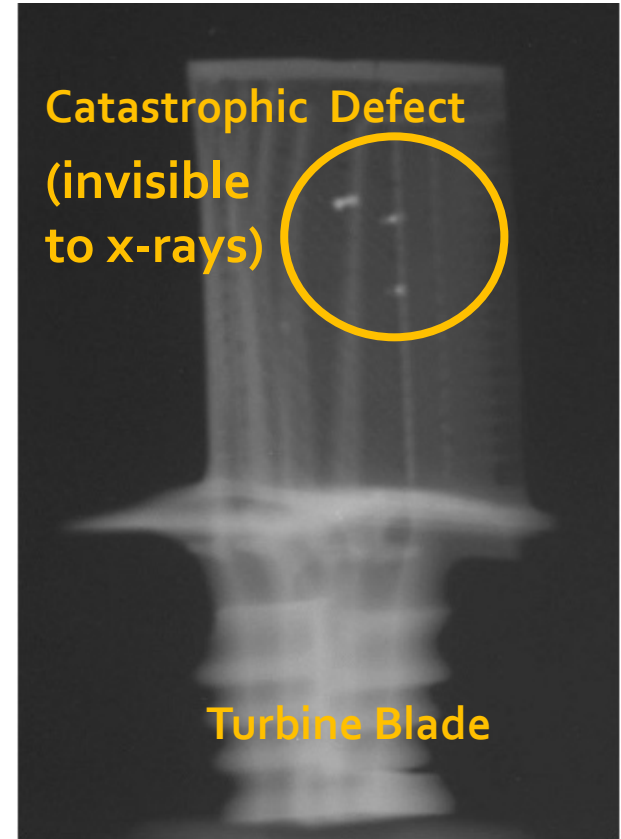
What is neutron imaging?

Neutron imaging is an NDT method that characterizes the internal structures of industrial components that are otherwise hidden from other NDT methods.



Why Neutron Imaging for NDT?

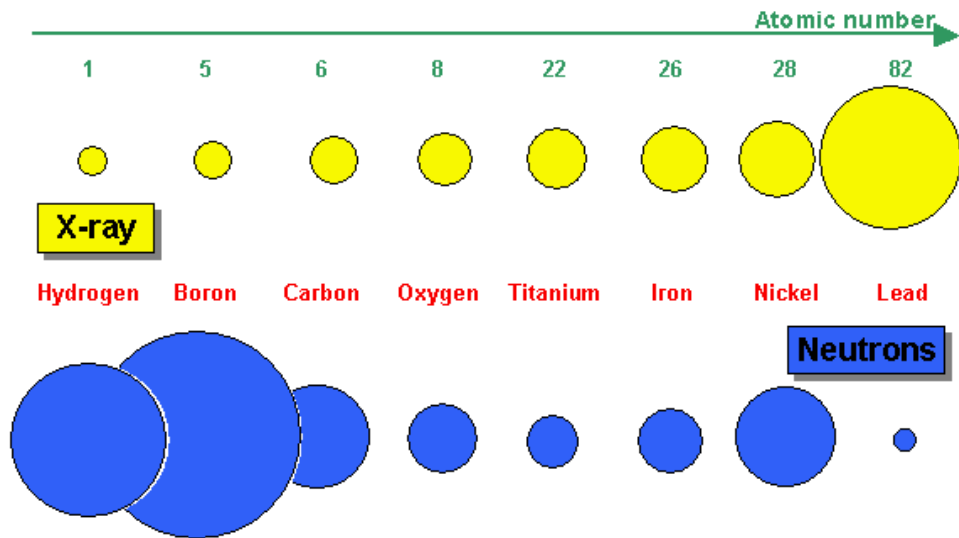
- Neutrons pass easily through high density metals and provide detailed information about internal low-density materials, cracks and voids.
- This property is extremely important for components with thick outer shells and internal structures such as engine turbine blades, munitions and spacecraft components.



Physics of Neutron Imaging

Because neutrons are inherently electrically neutral, they do not interact with the atomic electrons of elements in the same way that photons or electrons do. Cross section determined by nucleus composition, not material density

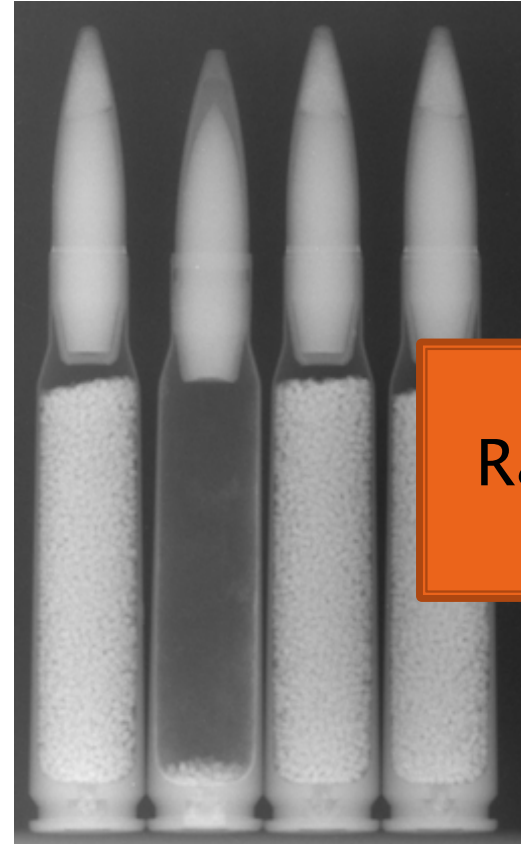
- Easily penetrate dense metal
- Absorbed or stopped readily by low density and hydrogen-rich materials. Water and plastics are great neutron shields!
- Because Gadolinium and Boron have a uniquely high cross section for neutron attenuation they can be used as contrast enhancers



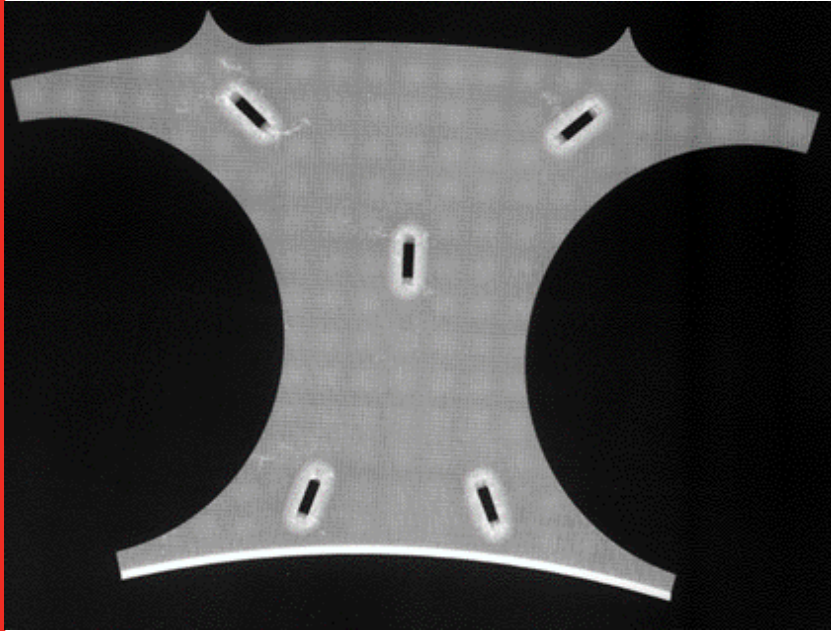
X-Ray Radiograph (x-ray)



Neutron Radiograph (n-ray)

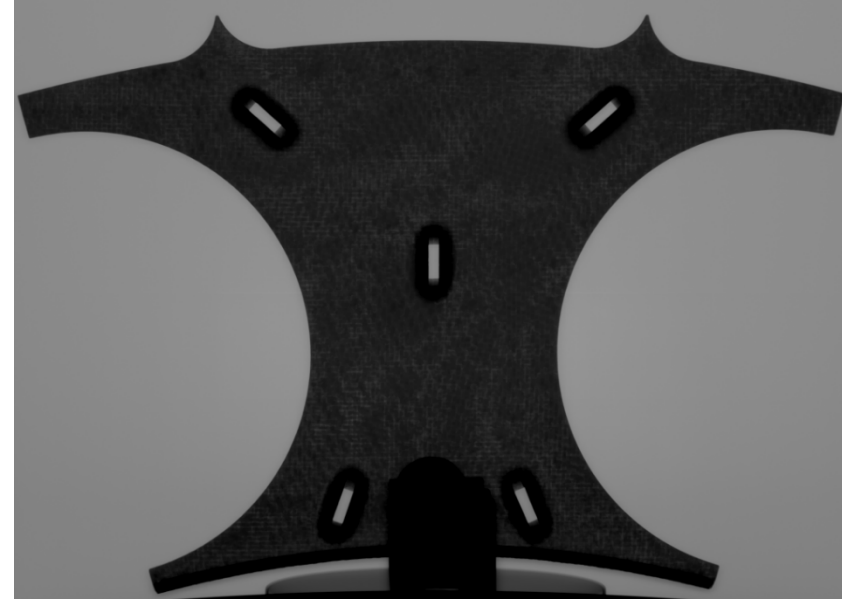


nRay Applications: Composites



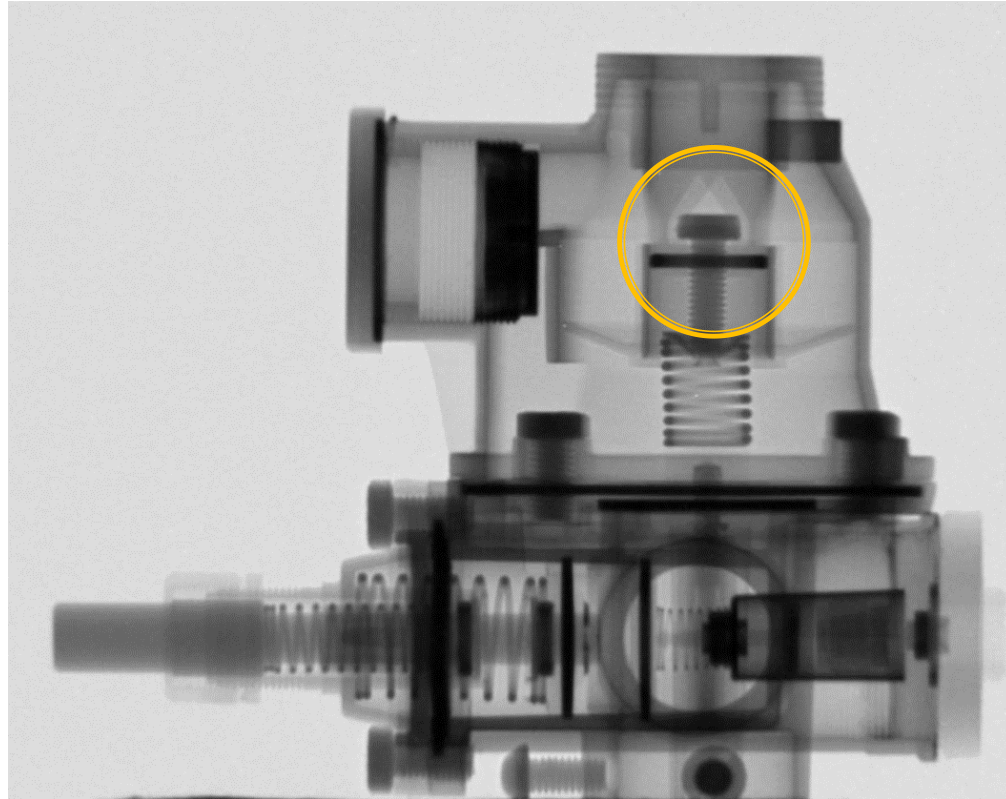
Neutron Image

*Tooling ports visible – uneven
distribution of BN in ceramic matrix
composites (CMC)*

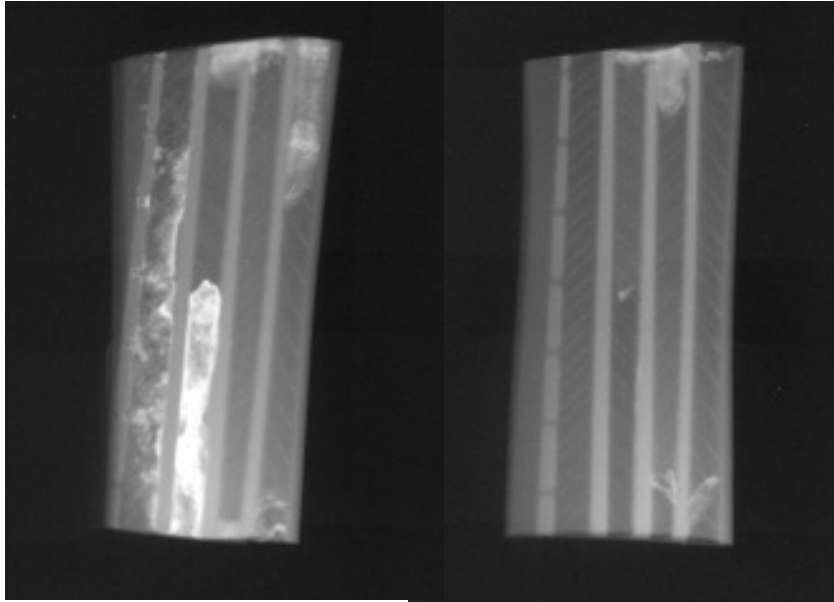


X-Ray

nRay Applications: O-Ring Identification



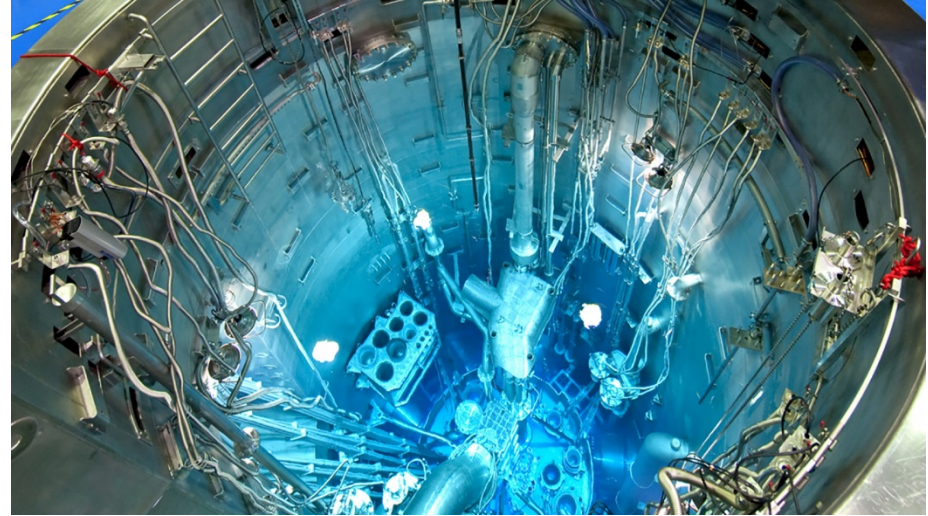
Unique Properties: Gd Penetrant



- Gadolinium has a very high cross section for absorption for thermal neutrons, meaning it reacts strongly to neutron radiation.
- The penetrant process causes foreign matter or gaps to appear bright on radiographic images, standing out in stark contrast to their surroundings.

Neutron Imaging History

- The technique has been used for decades on critical, high cost of failure aerospace and defense components.
- Until now, specialized research reactors were the only practical sources for neutron imaging
 - Availability is limited and shrinking
 - Significant logistical challenges, especially with energetic materials



Phoenix Neutron Imaging Center

- First operation expected fall of 2019
- Capable of accepting energetic materials
- ATF Compliant & Permitted
- Compliant with DoD Ammunition and Explosives Safety and Security Manuals (4145.26 & 5100.76)
- Phoenix accelerator-based neutron generation system





NDT in Canada 2019 | June 18-20 | Edmonton, AB

Quality and Throughput

Calculations	Nuclear Reactor (current baseline)	Phoenix High Yield System
Regulatory Burden	High	Minimal
L/D Ratio	105	105
Thermal Neutron Flux @ Image Plane (n/cm ² /s)	3.00E+06	3.20E+05
Neutron : Gamma Ratio	>1E6	>1E6
Cadmium Ratio	>5	>4
Annual Film Capacity (# Exposures)	>20,000	>25,000
Annual CR Capacity (# Exposures)	n/a	>35,000

Future of Neutron Imaging

- Neutron radiography is and will continue to be a crucial part of ensuring the safety and reliability of critical components.
 - For example: canopy separation charges, ejection seats, flight termination charges
- Reactorless imaging systems will enable use for new applications:
 - For example: artillery shells, body armor, detonating fuzes, shape charges, grenades, etc.
 - Fast neutron imaging for larger components
- Advanced capabilities will become more accessible
 - Fast neutron imaging for large components
 - Fast and thermal neutron CT
 - Neutron/X-Ray data fusion for composite images

Thank you!



PHOENIX

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