3D Backscatter and Advanced DR

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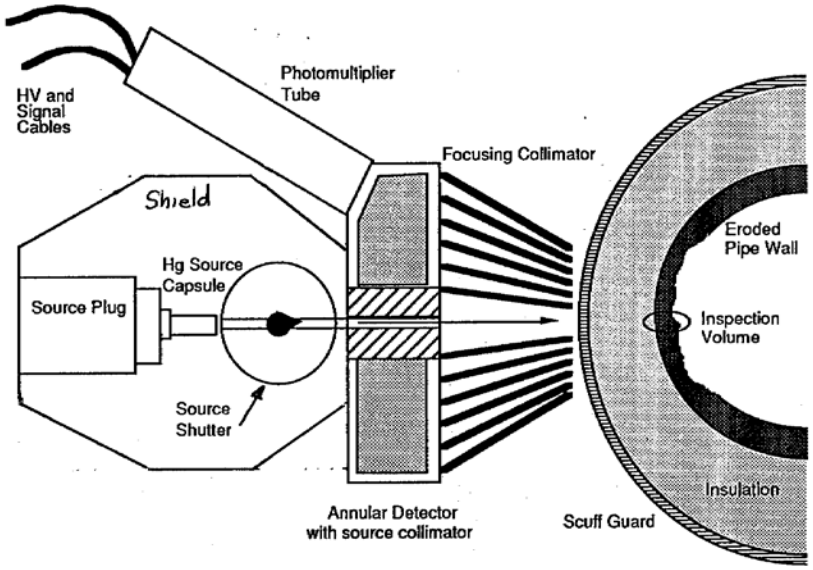
Approaches to Space and Airframe inspection for Pitting, Corrosion, Cracking

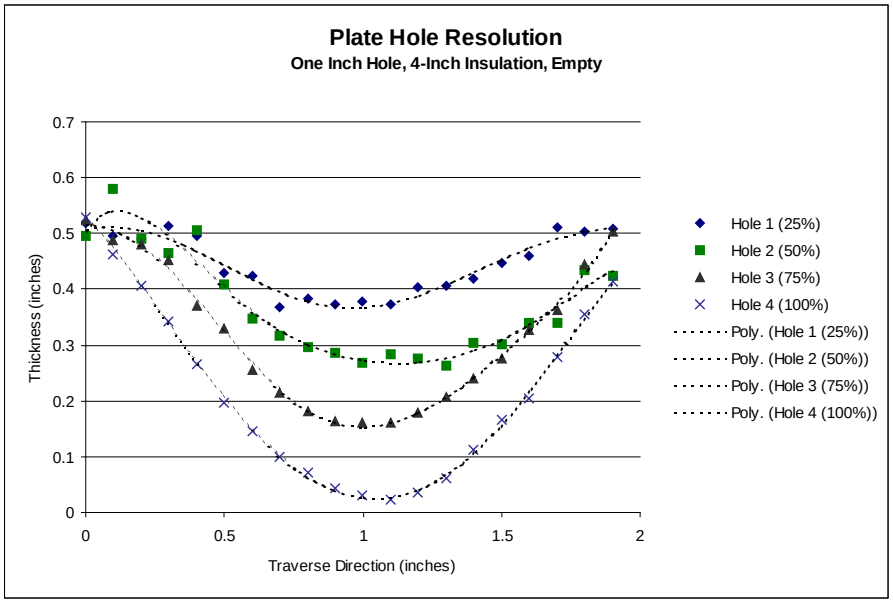
Technique	Single sided	Wide coverage	Detection through structures	Detection capability
Handheld backscatter	Yes	No, must be raster-scanned	Yes, with collimation or motion	Good – mm sized pits
Radiography	No	Yes, with reasonable spatial resolution	Yes, potentially reduced sensitivity	Excellent, sub-mm

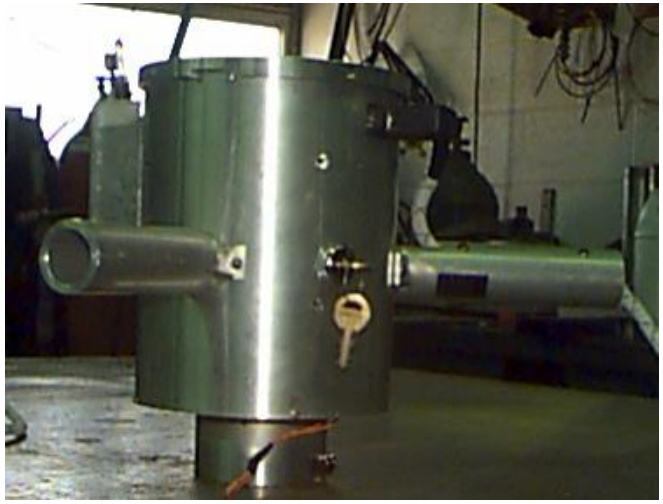
If two sided approach is amenable, radiography and micro-focus radiography can be used through walls, insulation and storage bins to interrogate skins with good success.

Backscatter Imaging

Penn State[1] Handheld X-ray for CUI







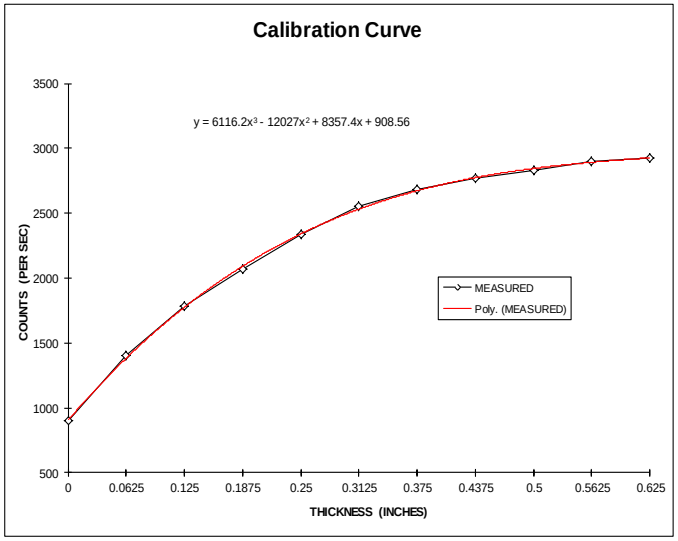
- Weighs <14 lbs, 6-in diameter, 8-in long, radiation safe, shielded, <1 Curie Hg-203, < 1mR/hr
- Crawler approach to map out regions, in a step and sample mode
- Backscatter quantitatively determines remaining wall thickness to within 2% of total wall thickness for walls under 0.25-in, 5% of total wall thickness for walls over 0.25-in, and is single sided

imagination at work

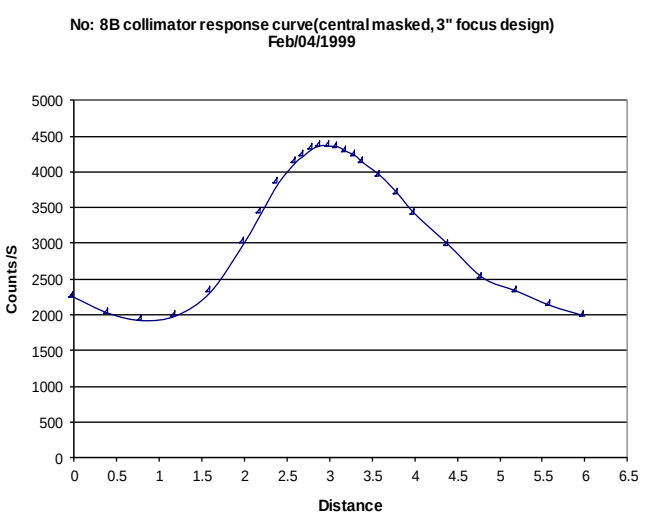
[1]"An Erosion-Corrosion Monitor Using Gamma Ray Backscatter" (with E. Klevans, E. S. Kenney, R. L. Baxter, K. A. Burkert, B. Petrovic, B. Wilks and W. J. Groszko), Proceedings of the EPRI 5th Piping and Bolting Inspection Conference (San Antonio, 1999)

Penn State[1] Handheld X-ray for CUI

Calibration Tests of backscatter unit



Calibration of response vs. metal thickness



Validation of collimation focal point

- Removing insulation is costly and time consuming
- Calibration curves needed to account for variation in sampling, i.e. temperature and orientation change in device, non-uniform thickness in insulation
- Actual thickness must be calculated according to application specific calibration curve

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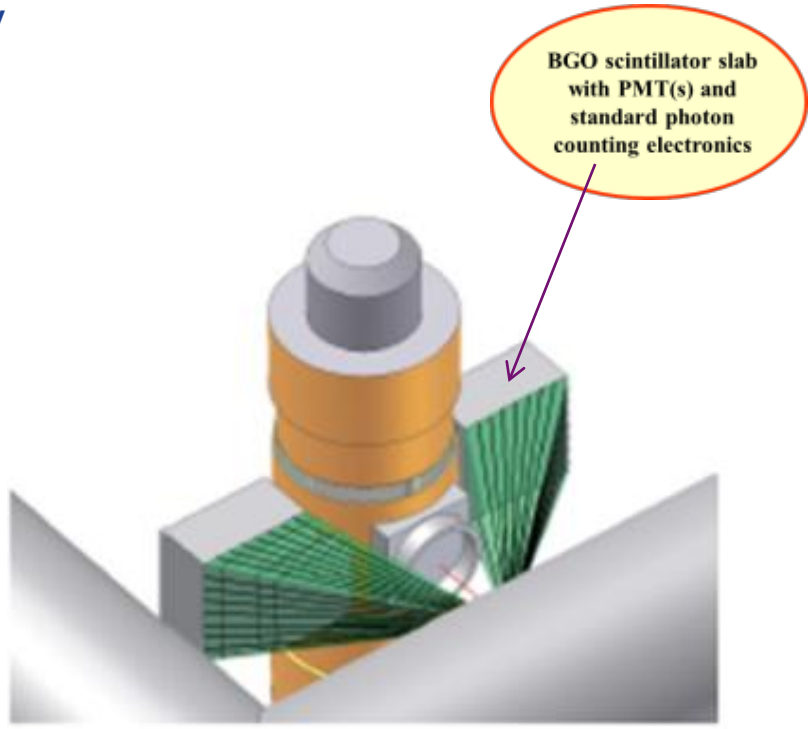
Commercialization of Penn State Design

- Professor Klevans and Penn State are seeking commercialization options for this technology, and have offered unrestricted rights and hardware to facilitate this.
- System modernization and upgrades are certainly needed for improved usability that GE would undertake. Gage R&R and/or Probability of Detection capability studies would also be needed.
- A number of O&G companies have expressed interest
- GE is considering building/upgrading this device, pending further market interest

Higher Energy Backscatter Using an Energized X-ray Source - GE

- ~2-3 mm spatial resolution
- 0.5mm defect detection
- 0.2mm dimensional measurement accuracy
- Up to 450kVp x-ray source energies
- Depths to ~1inch steel
- Both analytic and Monte Carlo modeling employed



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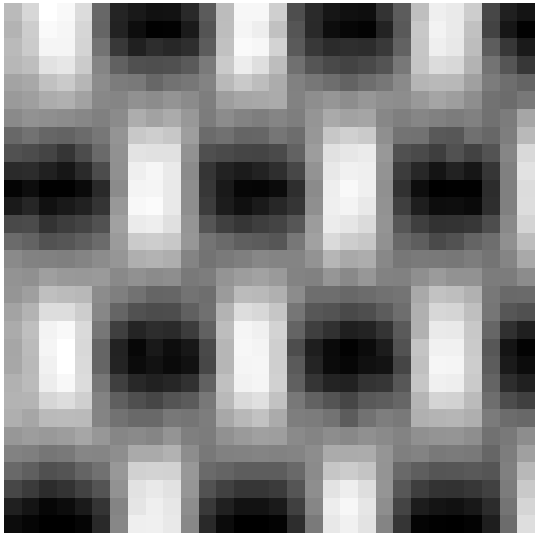
Higher Energy Backscatter Using an Energized X-ray Source - GE

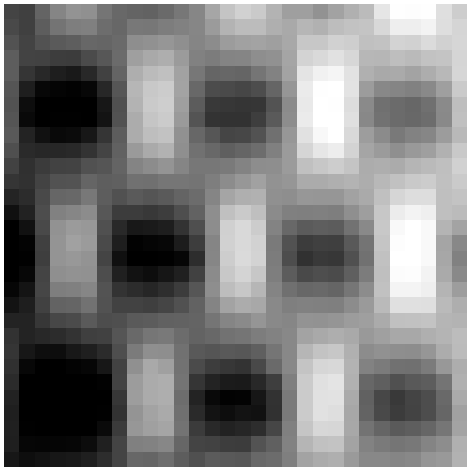
Scan of imbedded steel test plate (0.06” thick)
X-Y scans @450kVp (2mA) 1x4 beamspot, 30 x 30 grid, 1mm steps, 3secs./step

1/16” thick hole plate behind foam, an additional ¼” steel plate was added

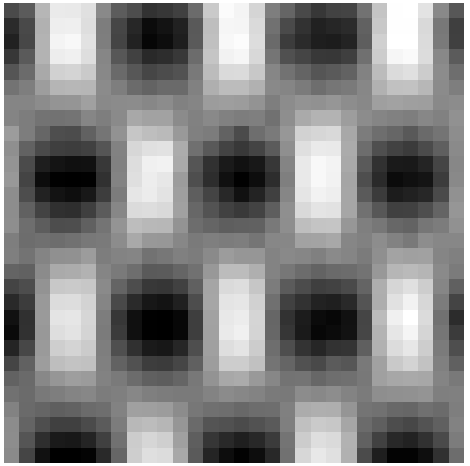
Black regions represent holes in the plate



Back: through ¼” steel attenuator



Front



Middle

1/16” thick hole plate detected through 1/4” steel attenuator

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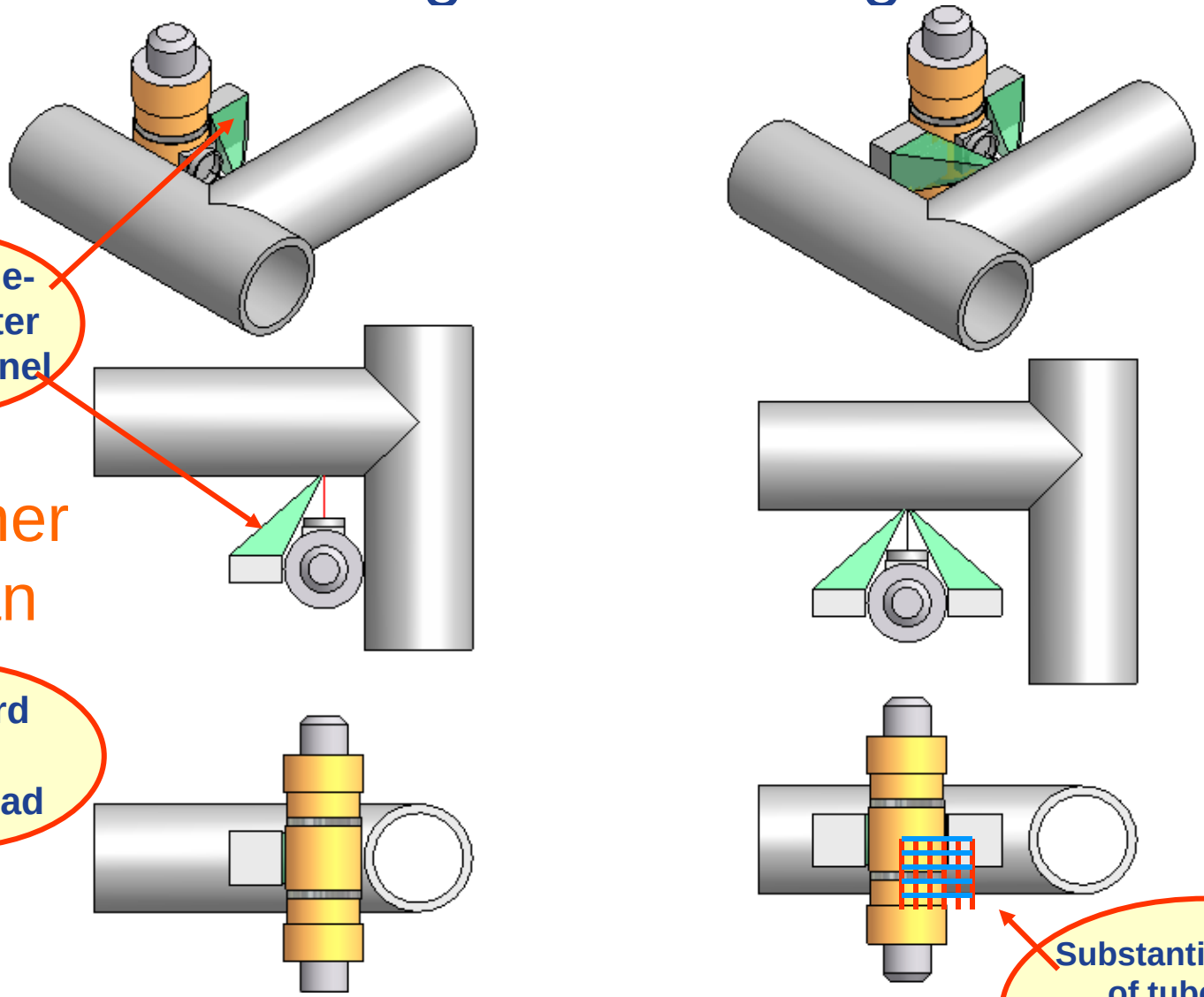
Scanning Head Configuration



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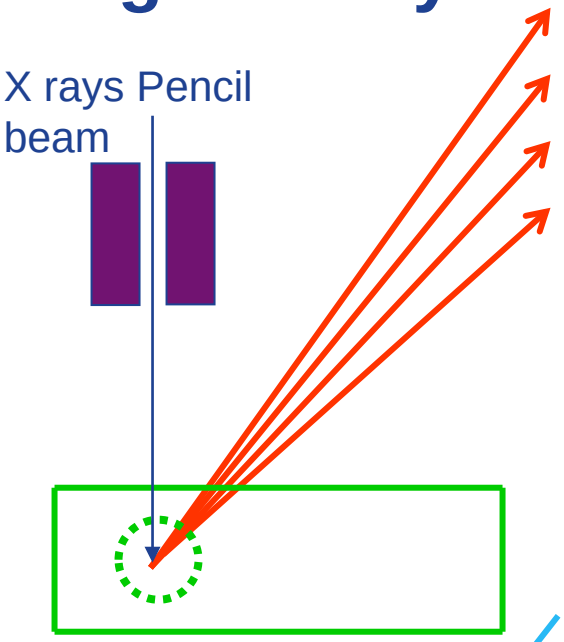
Technical approaches: detector geometry is the key

Cone-beam detector

(1) Entire detector receives scatter from a single localized scatter volume

(2) Advantages include: simplicity/robustness/cost of detector and maximization of signal for a single volume (beneficial where sweet spot can be rapidly located through scout scans and geometry baseline database)

(3) Disadvantage is that 3 axis (X-Y-Z) motion is required to produced a 3D raster scan

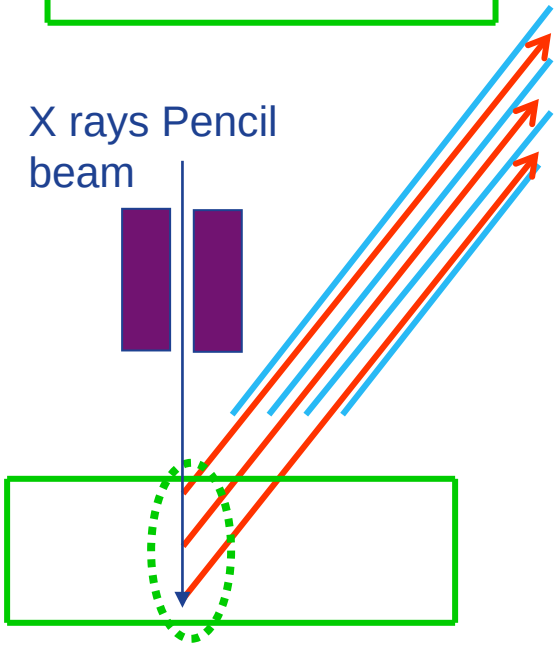


Multi-layer annular detector

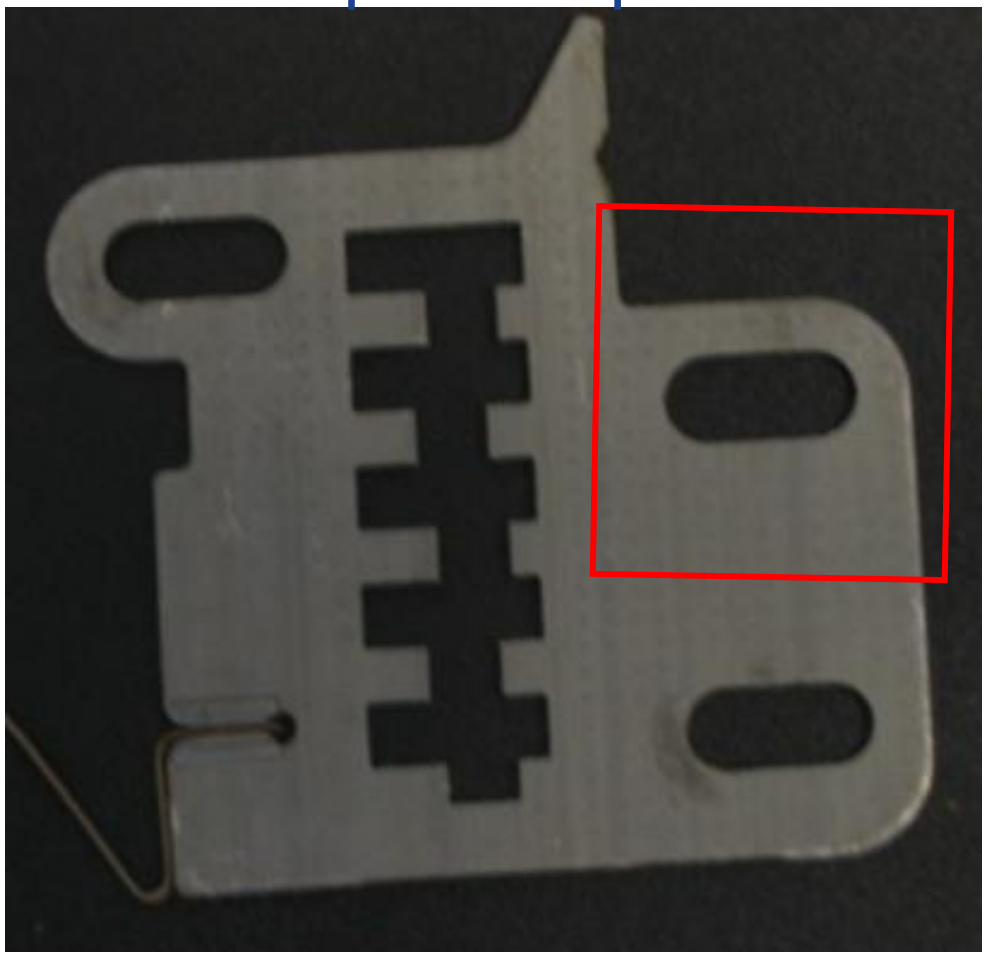
(1) Each layer of detector receives scatter from a single localized scatter volume

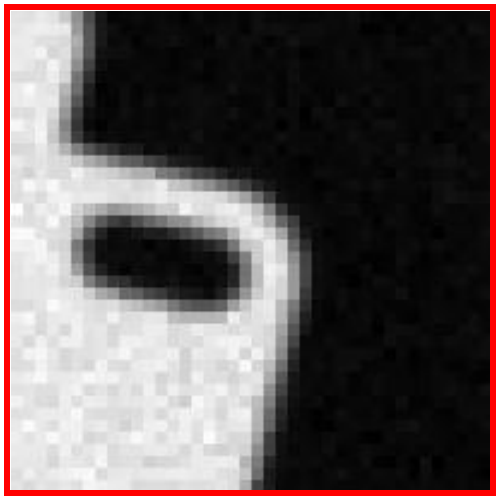
(2) Advantages include fixed "in-depth" imaging and 2 axis motion to provide a 3D scan

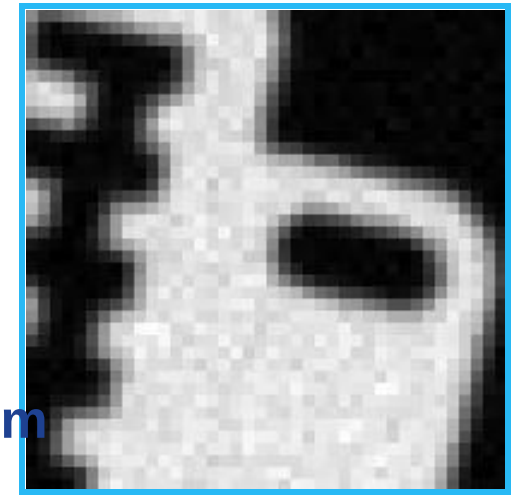
(3) Disadvantage is a much slower "directed" scan where imaging of a localized scatter volume is desired



Example of X-Y scan at plate depth







1mm resolution raster scan of hole phantom

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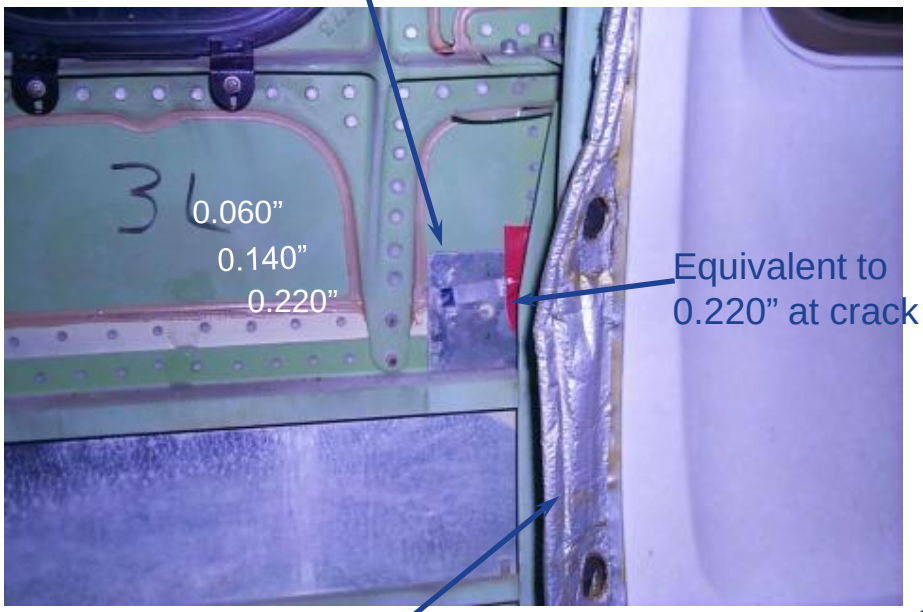
Radiography on Airframes

Lap Joint Inspection on 737

Set-Up

Manufactured crack plate placed on interior at lap



Equivalent to 0.220” at crack

Insulation and sidewall returned for imaging

- Thickness measured by UT gage
- Conditions: 55 kV, Magnification 2, SDD = 30-in.

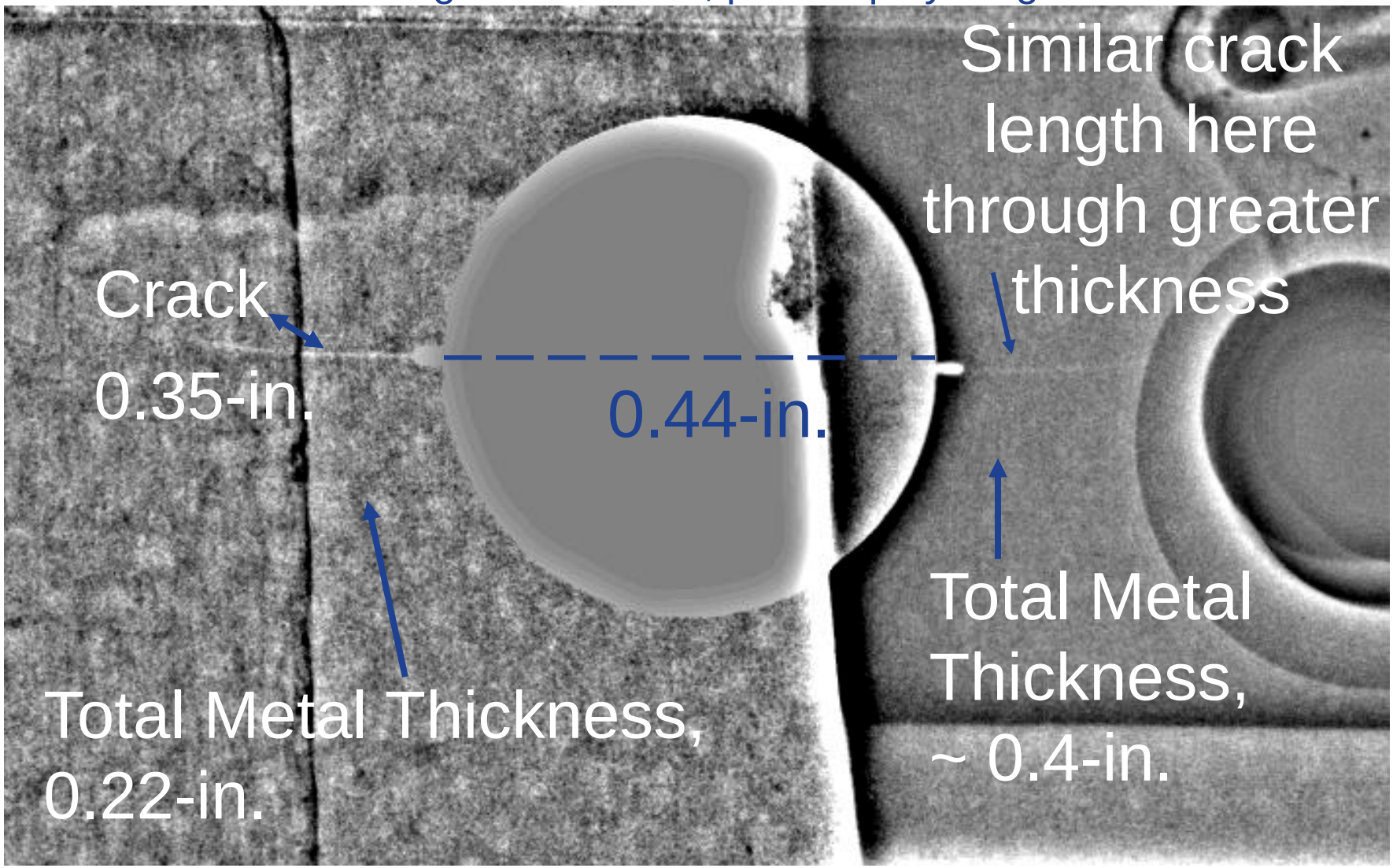
Detector off skin

Tube close to side wall

Lap Joint Inspection on 737

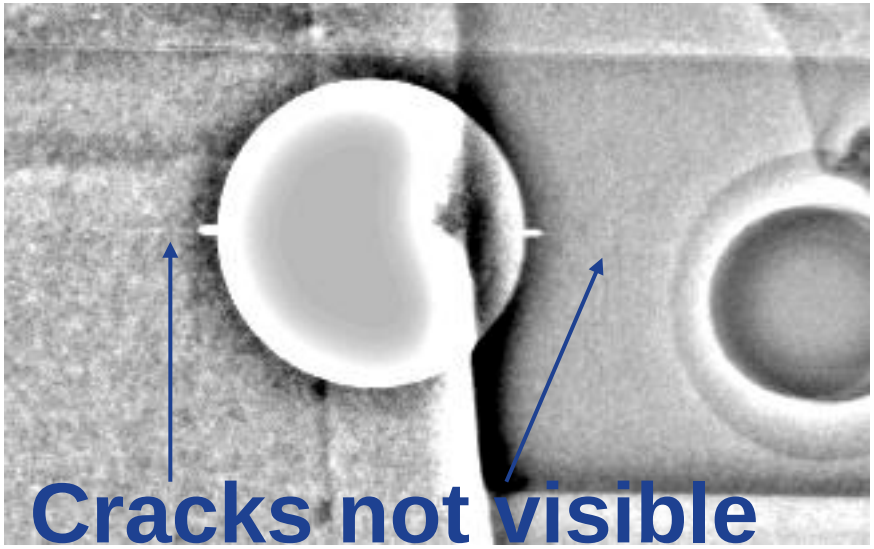
Cropped view

Geometric Magnification of 2, plus display magnification

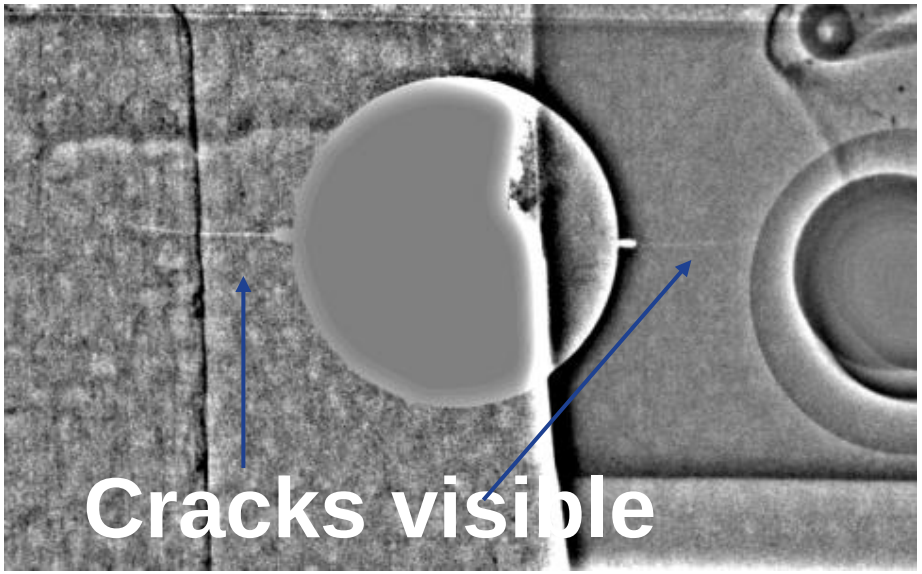


Geometric Magnification Helps DR Images Detect Cracks

Mag 1 unsharpness = 0.02”



Mag 2 unsharpness = 0.065”



Fine fatigue cracks detected on airframes using geometric magnification techniques with DR panels

Can be used on other structures, i.e., Space Vehicles to detect pitting, cracking

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Radiography on Airframes

- Need geometric magnification techniques to bring the crack size above or closer to pixel size
- Though unsharpness is technically worse, magnification effectively makes cracks larger
- If two sided approach is amenable, radiography and micro-focus radiography can be used through walls, insulation, storage bins to interrogate skins with good success.

Rugged & Flexible Digital X-Ray

Flexible DXR Concept

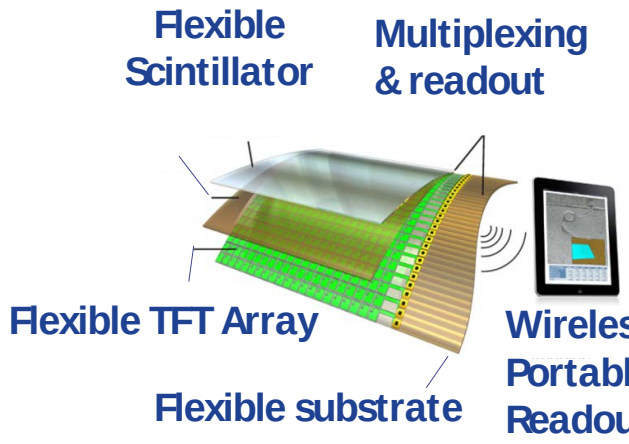
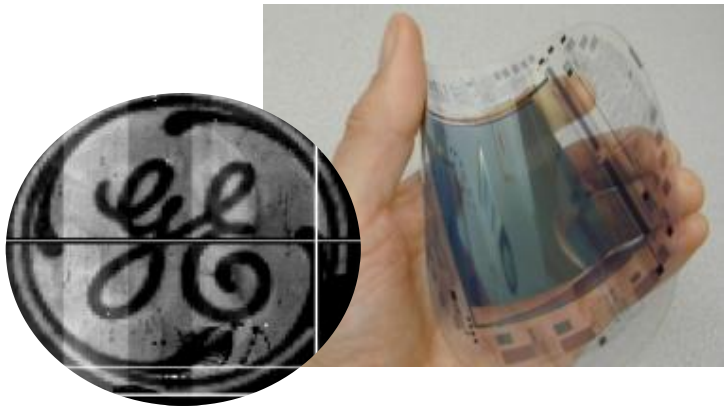


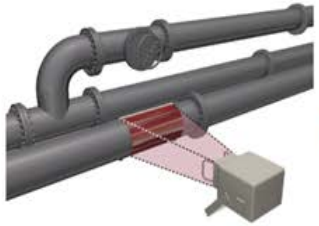
Image Sensor on Flexible Array



NDE Applications

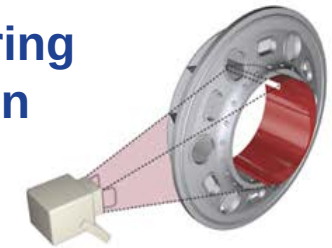
- No glass panel
- Can be permanently installed

Pipeline inspection



Battlefield Medical

Manufacturing inspection



IED Detection

Summary

- Single-sided backscatter imaging, may show promise for micro-meteorite damage detection. Size and density of pitting will likely affect results.

- DR has been shown to detect fatigue cracks through aircraft internal walls, and insulation using geometric magnification. Similar approach can be used on Space Vehicles for pitting.

- Backscatter and DR will provide rough estimate of depth of pitting/corrosion

- Non-breakable, flexible arrays under development: roll-up for storage, roll-out for use. Can be permanently mounted, inside or out – Can Cosmic rays be used for imaging??

Questions?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Back-up

Examples of profiles from X-Y scans