X-ray Backscatter Imaging for Aerospace Applications

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X-ray Backscatter vs. Traditional X-ray

**Pros**
- Simple Equipment
- High resolution in favorable conditions
- Access to small areas

**Cons**
- High radiation field
- Requires access to both sides
- Large area coverage takes many shots
- Images require post processing for most

**Backscatter X-ray**

**Pros**
- Automated Collection
- Fast Data Collection / Real-time imaging
- Low radiation field
- Single sided process
- Large area images

**Cons**
- System cost
- Physical size/complexity of system
- Resolution dependent on standoff

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System Description

X-ray Backscatter Scanning Head

- Scanning head consist of
  - x-ray tube
  - Illumination beam collimator
  - Detectors to measure the backscatter signal

- Can be adapted to use any X-ray energy
  - Energy required dependant on application
  - Uses COTS X-ray tubes
  - Currently systems available from 160-225 kV

- Design of collimator and aperture
  - Can be pointed in different directions
  - Tailoring of aperture size for different applications

- Configurable Detector Arrays
  - Different size detectors and detector combination allow for easy customizations to applications
  - May use Radiography by Selective Detection (RSD) to enhance image contrast and subsurface resolution
System Description (cont)

Mobile System

• The linear rail system is mobile and can be expanded to image different lengths

• Designed to work in different orientations (straight-up, up-side-down)

• Modular to setup and move with 2 people

Robotic System

• X-ray backscatter imaging for any complex motion profile

• Allows end user customized motion

• Combines state-of-art off the shelf motion with x-ray backscatter imaging

• Robotic System offers customized motion for each application
Aerospace Operational Considerations - Portability

- Packaging design for use in and around aircraft

- Minimize Potential for FOD

- Portability and Setup
  - Shipping size and Transportability
  - High Voltage Connections

- Power Service Requirements
Aerospace Operational Considerations - Automation

• Integration into manufacturing area

Availability of Shop Floor Space

• Motion programming
• Multiple DOF require additional safety planning
• Mounting provisions and power service

Compatibility with Ground Support Equipment
Aerospace Operational Considerations (cont.)

- Safety to aircraft electronics
  - FCC testing for EMI/EMR shielding
  - Affect of ionizing radiation on sensitive solid state electronics

- Radiation safety
  - Long exposure times required create the need to implement multiple layers of safety into deployable system
  - Occupational & nonoccupational exclusion zones
  - Defeating perception of danger based on experience with traditional transmission X-ray
  - Challenge in measuring field strength of highly collimated moving source with traditional field survey meters

- Other safety considerations
  - Robotic motion hazards
  - Ergonomics of handling, assembling and disassembling in confined areas
Application of X-ray Backscatter for Aircraft NDE

• Low z materials typical to aircraft suited to backscatter
• Many NDE inspections at known locations and depths
• Ability to image through multiple layers
• Continuous contact with nested layers not required as with other NDE techniques
Contributors to Image Quality

• Speed – directly related to image quality by counting statistics (inherence noise in the image)

• Standoff
  • Illumination pencil beam diverges from the x-ray source
  • Backscatter signal decreases with a $1/R^2$

• Size and Weight – related to image quality at given speeds
  • More intense x-ray sources (higher mA) require larger tubes, generators and cooling capacity
  • Larger area detectors can increase capture of scatter
  • Type of detector material
Affects of Standoff on Image Resolution

- Standoff is driver in spatial resolution of images
- At reduced standoff, edge definition is significantly improved, contrast has increased, and much smaller features can be resolved

150 mm Standoff

![Image 1](image1)

450 mm Standoff

![Image 2](image2)
Affects of Standoff on Image Resolution (cont.)

- At 3x the standoff, contrast decrease by about 9%
- Resolution falls off with contrast as the standoff is increased.
- Statistical noise increased from 1.26% to 1.54% or increased by 20%.
- Statistical noise increases with standoff follows Poisson counting statistics varying with the square root of the contrast intensity value.
- Resolution lost by standoff partially recoverable using smaller apertures
  - Scan speed must be reduced by a factor proportional to the reduction of the open area of aperture.
  - Standoff is critical to application development
X-Ray Backscatter NDE Applications

- Corrosion Detection
- FOD Detection
- Fluid Intrusion
- Cracks and Defects
Conclusions

- **Advantages of X-ray Backscatter Imaging**
  - Ability to image large area from with single sided access
  - Real time imaging allows recursive scanning
  - Low radiation field allows smaller exclusion zones
  - No continuous media required for second layer inspection
  - Image based technique allows for easy interpretation

- **Challenges to adoption of technique**
  - Development of new standards/procedures
  - High scan speeds require large equipment
  - Limited available of tailored x-ray sources
  - Detailed depth information requires longer scans
  - Site specific radiography requirements
Snakes on a Plane

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NASA In-Space NDI Workshop
February 29- March 1
Houston, TX
Planes have many difficult to access areas.
Snakes Can Move through Access Holes

B’’ – B’’
Potential Fuselage Applications

- Depaint
- Lap Joint & Scribeline Inspection
- Inspection for Corrosion under Galleys and Lavs
- Inspection for Wire Fault
- Inspection of Control Cables
- Inspection of Floor Beams
- Inspection of Frame Crack
- Inspection Behind Insulation
- Inspection Behind Equipment
- Inspection of Closed Section Stringers
- Inspection of Fasteners for Lightning Strike Damage
- Inspection of Keel Corrosion
- Inspection of Equipment Behind
Inspection of Bonded Joints

Paired Through Transmissio
n Inspection of Bonded Joints

B”” – B”’

B”’ – B””
Inspection of Sandwich Panels

B - B

Paired Through Transmission Inspection of Sandwich Structure

B - B
Potential Wing and Fuel Tank Applications

- Corrosion Inhibitor Application
- Landing Gear Bay Corrosion Inspection
- LSP Grid Inspection
- Exterior Wash Inspection
- Stringer Inspection
- Paired Through Transmission Inspection (TTU, X-Ray, Other)
- Limited Access Scarfing
- Swimming Snake Inspecting Pipes and Tubes
- Inspection under Fuel Bladder
Landing Gear and Wheel Wells

- Inspection of Landing Gear Bay Cracks and Corrosion
- Inspection of Landing Gear Doors
- Inspection of Landing Gear Cracks
Robotic Snakes are of interest to Boeing.