Scatter X-ray Imaging

X-ray Backscatter Imaging for Aerospace Applications

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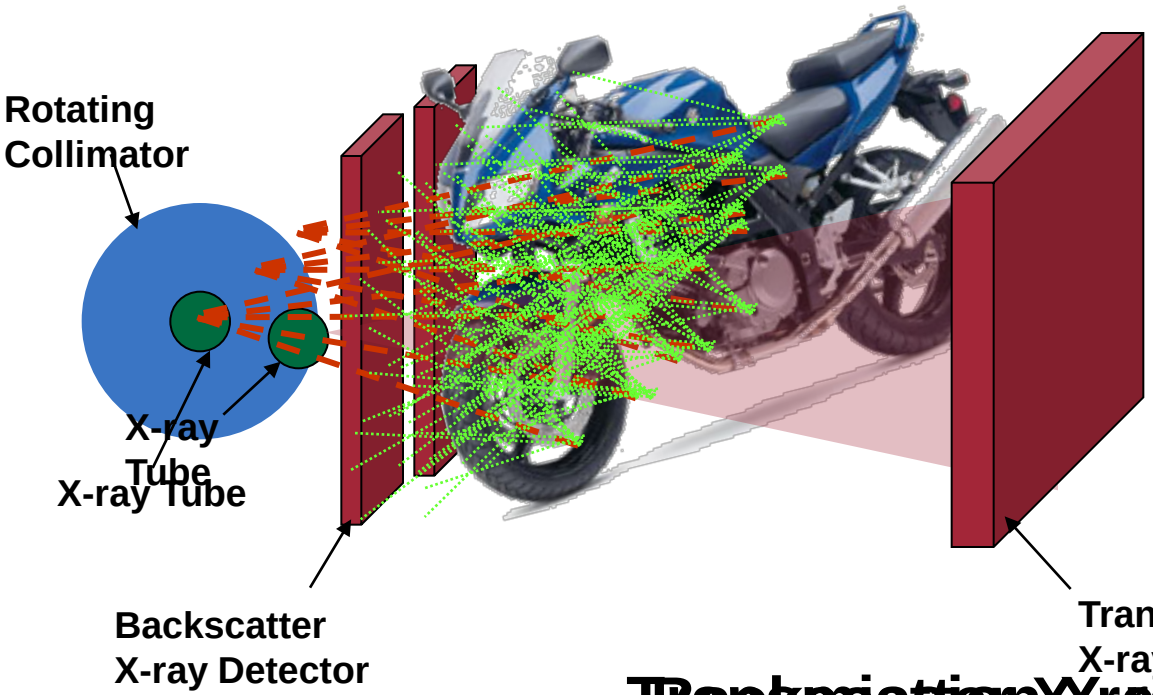
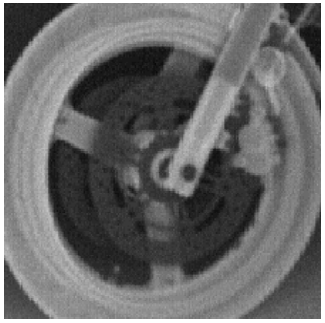
X-ray Backscatter vs. Traditional X-ray





X-ray Image

Backscatter X-ray

Transmission X-ray

Pros

- Simple Equipment
- Automated Collection
- Fast Data Collection
- Real time images
- Access to small areas
- Single sided process
- Large area images

Cons

- Ionizing radiation
- Requires access to both sides
- Large area coverage takes many shots
- Images require post processing for most

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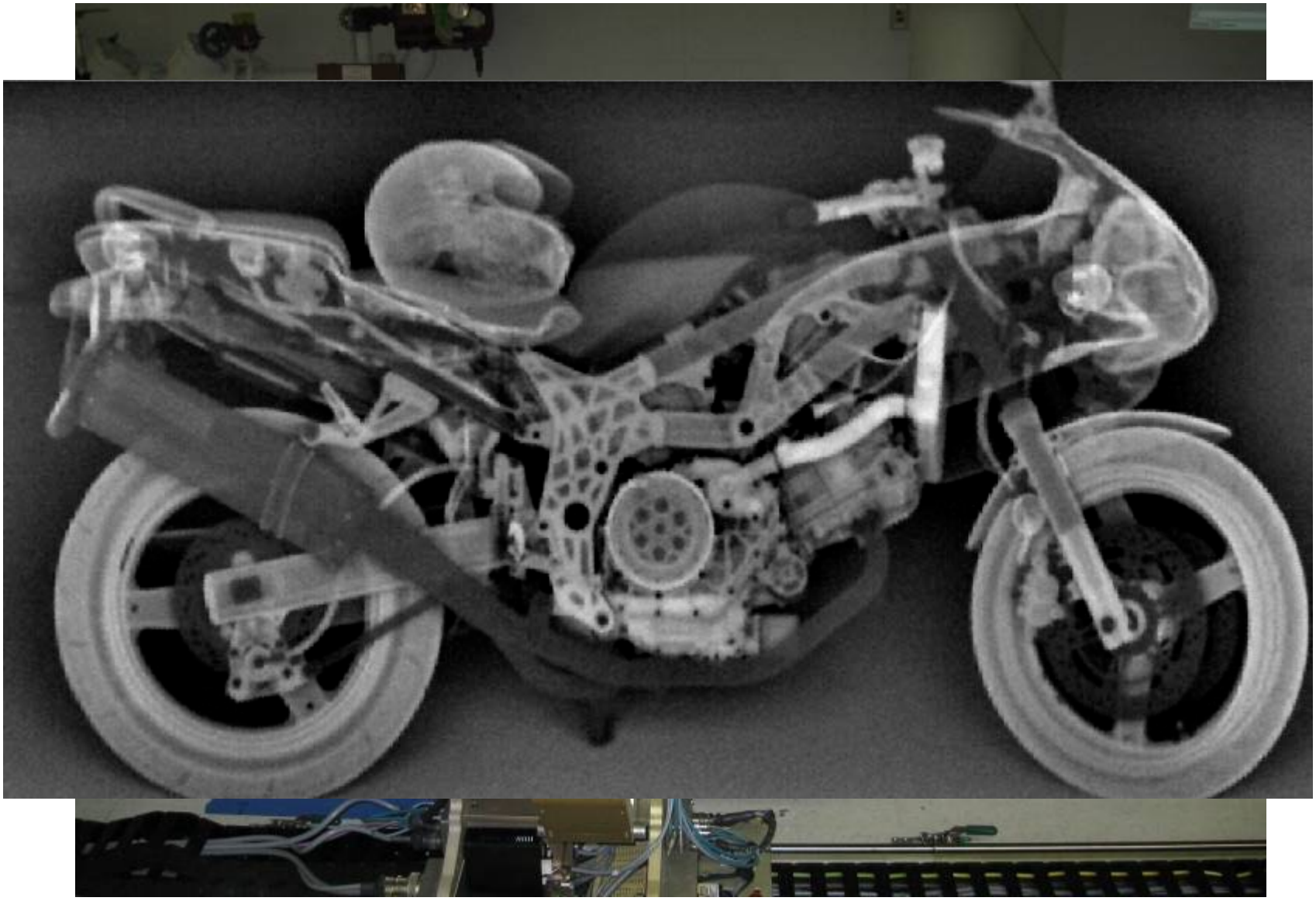
Example Image



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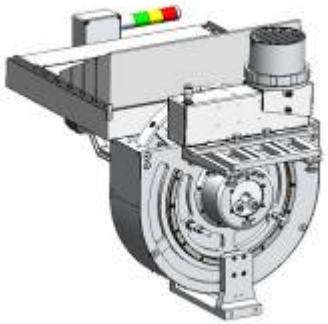
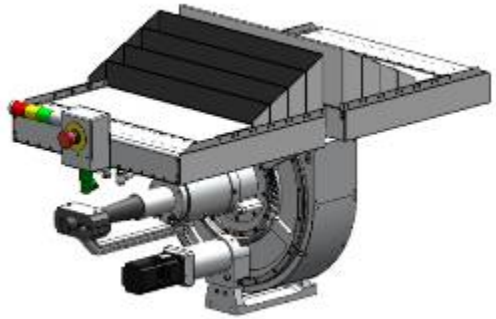
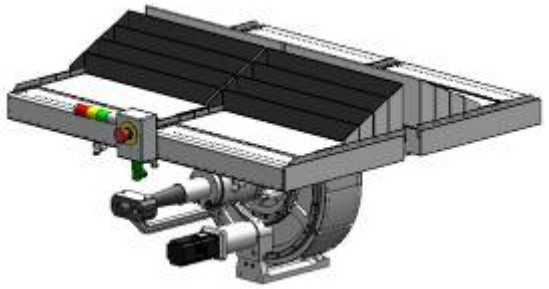
System Description

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







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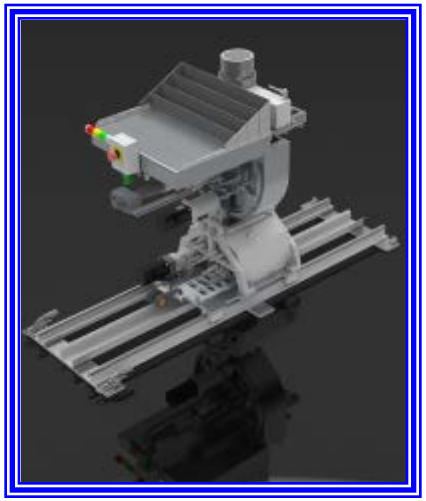
System Description (cont)

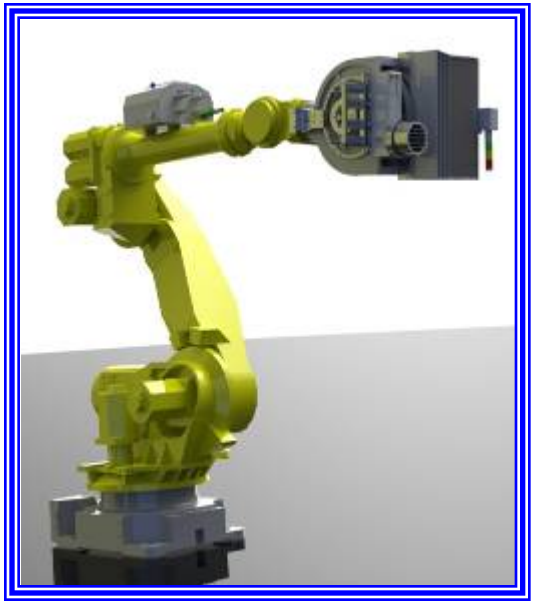
Mobile System

- 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



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Aerospace Operational Considerations - Portability

- **Packaging design for use in and around aircraft**

Compatibility with Ground Support Equipment

Sized for ingress and egress

- **Minimize Potential for FOD**
- **Portability and Setup**
  - **Shipping size and Transportability**
  - **High Voltage Connections**
- **Power Service Requirements**

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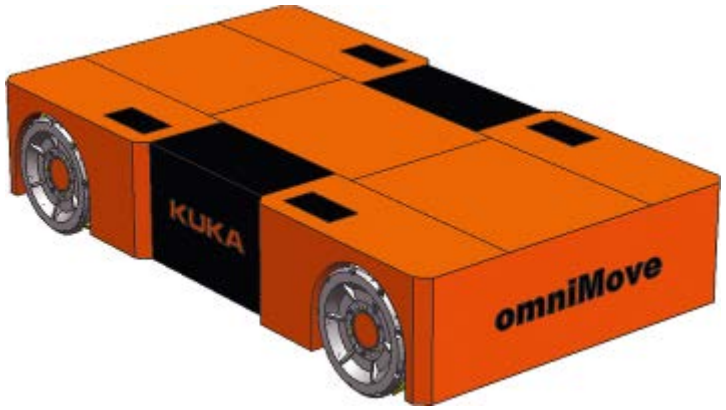
Aerospace Operational Considerations - Automation

- **Integration into manufacturing area**

Availability of Shop Floor Space



Compatibility with Ground Support Equipment

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

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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**

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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**

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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**

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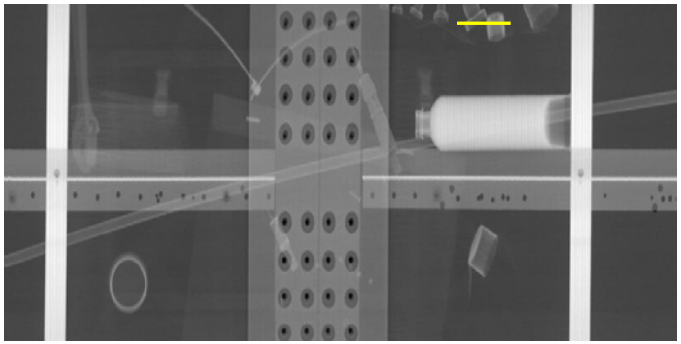
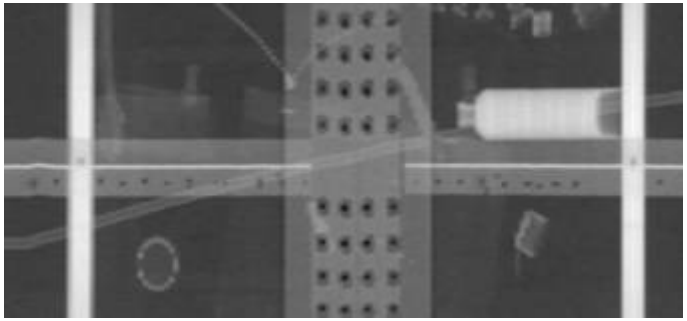
Affects of Standoff on Image Resolution

- **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

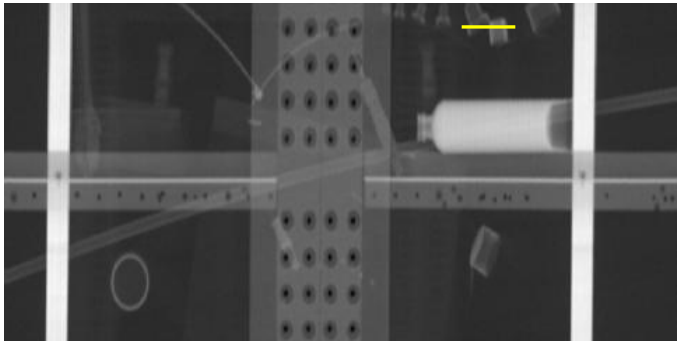


5 mm/s



100 mm/s

450 mm Standoff



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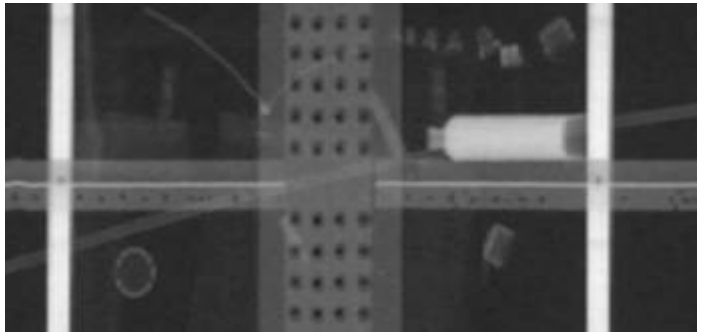

100 mm/s

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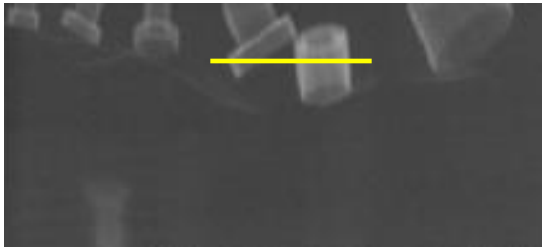
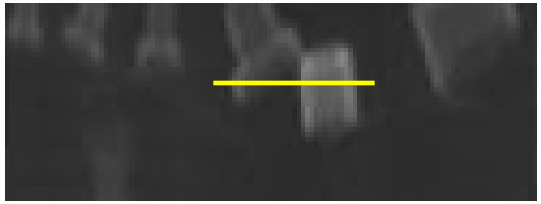
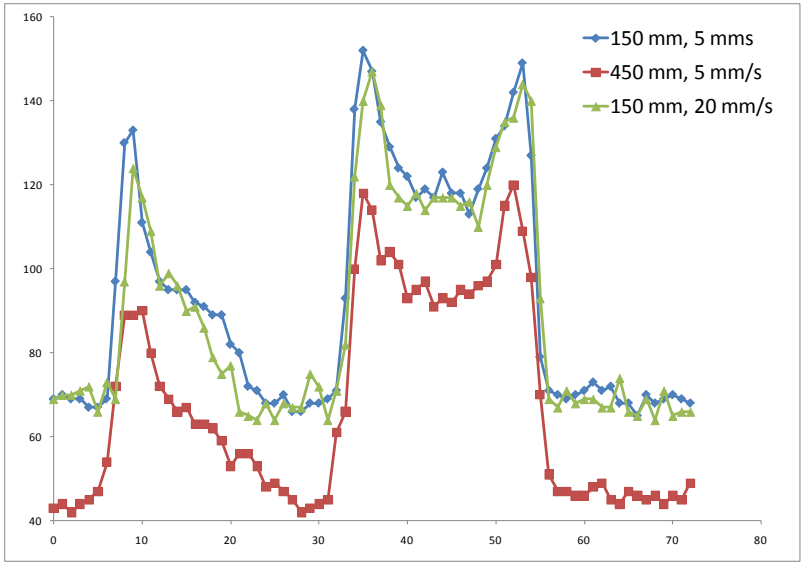
Affects of Standoff on Image Resolution (cont.)



SXI image at 150 mm standoff



SXI image at 450 mm standoff



- 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

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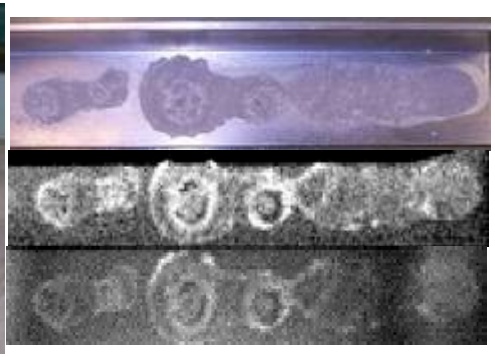
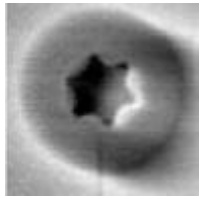
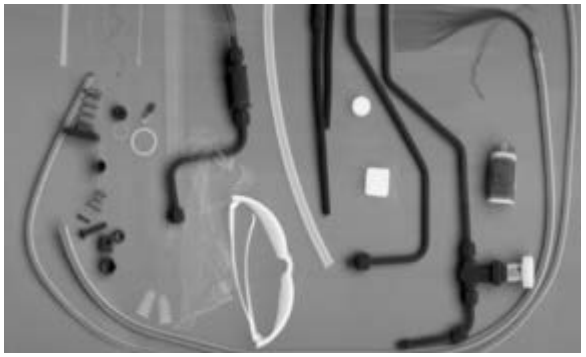
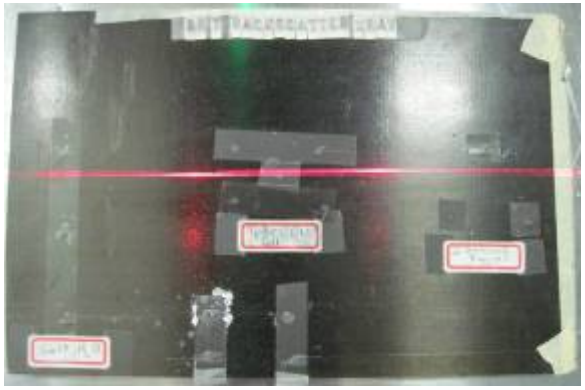
X-Ray Backscatter NDE Applications

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









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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**

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Snakes on a Plane

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Boeing Research & Technology
Seattle, WA

NASA In-Space NDI Workshop
February 29- March 1
Houston, TX

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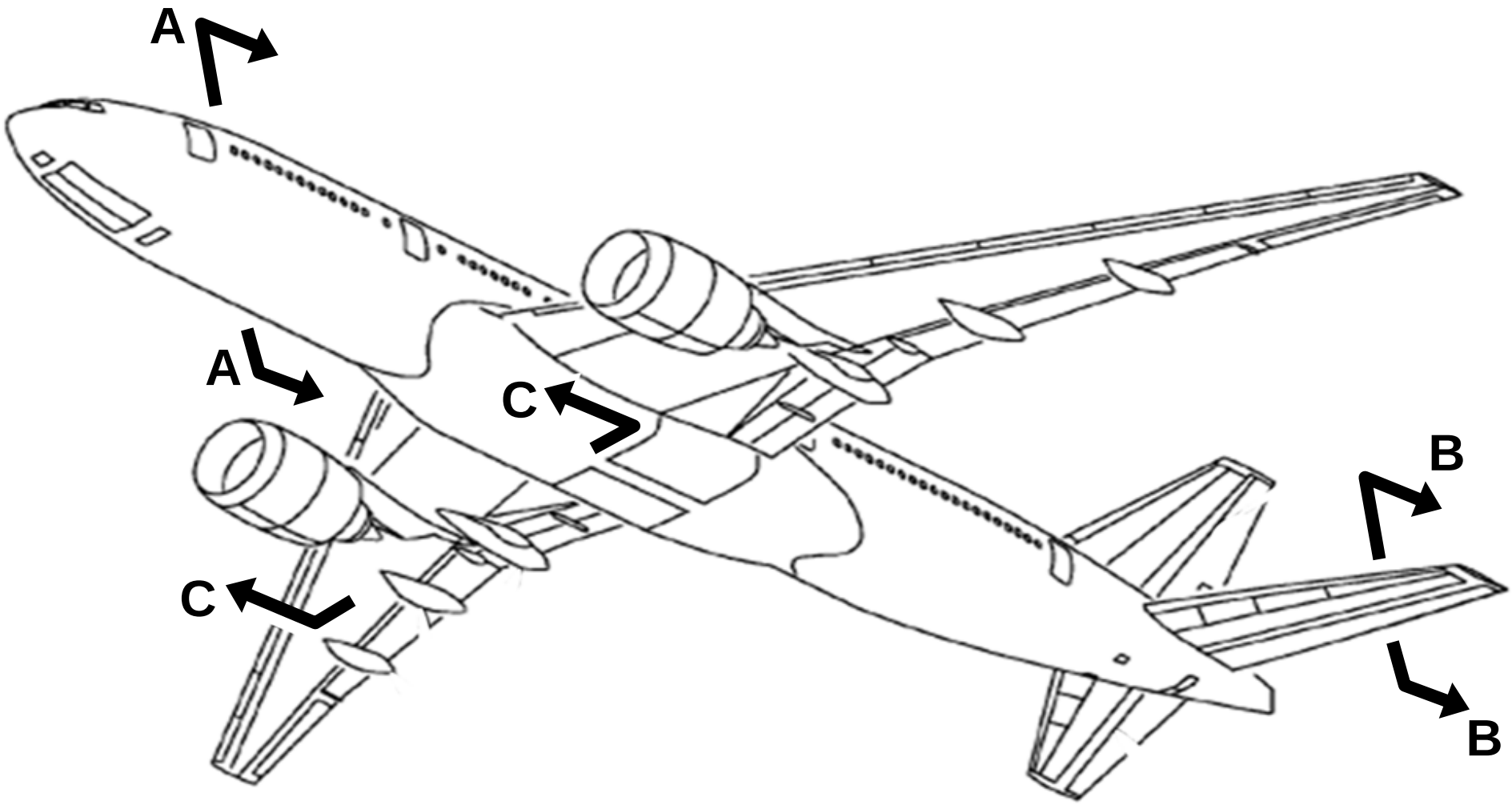
Planes have many difficult to access areas.



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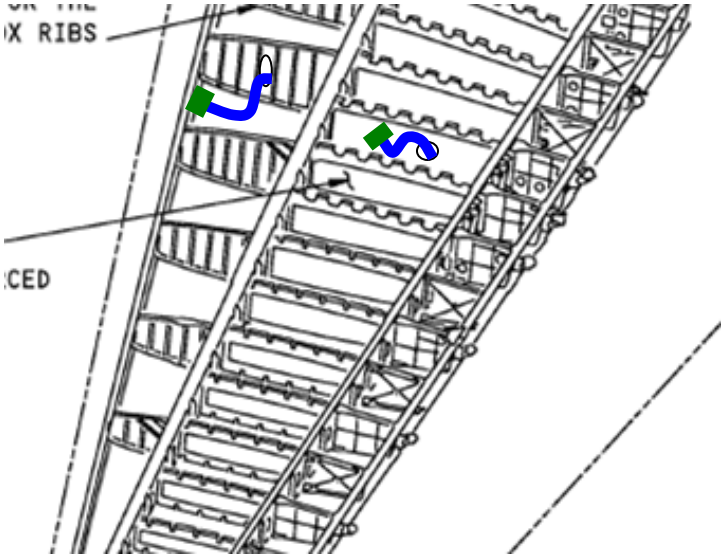
Snakes Can Move through Access Holes



B” – B”

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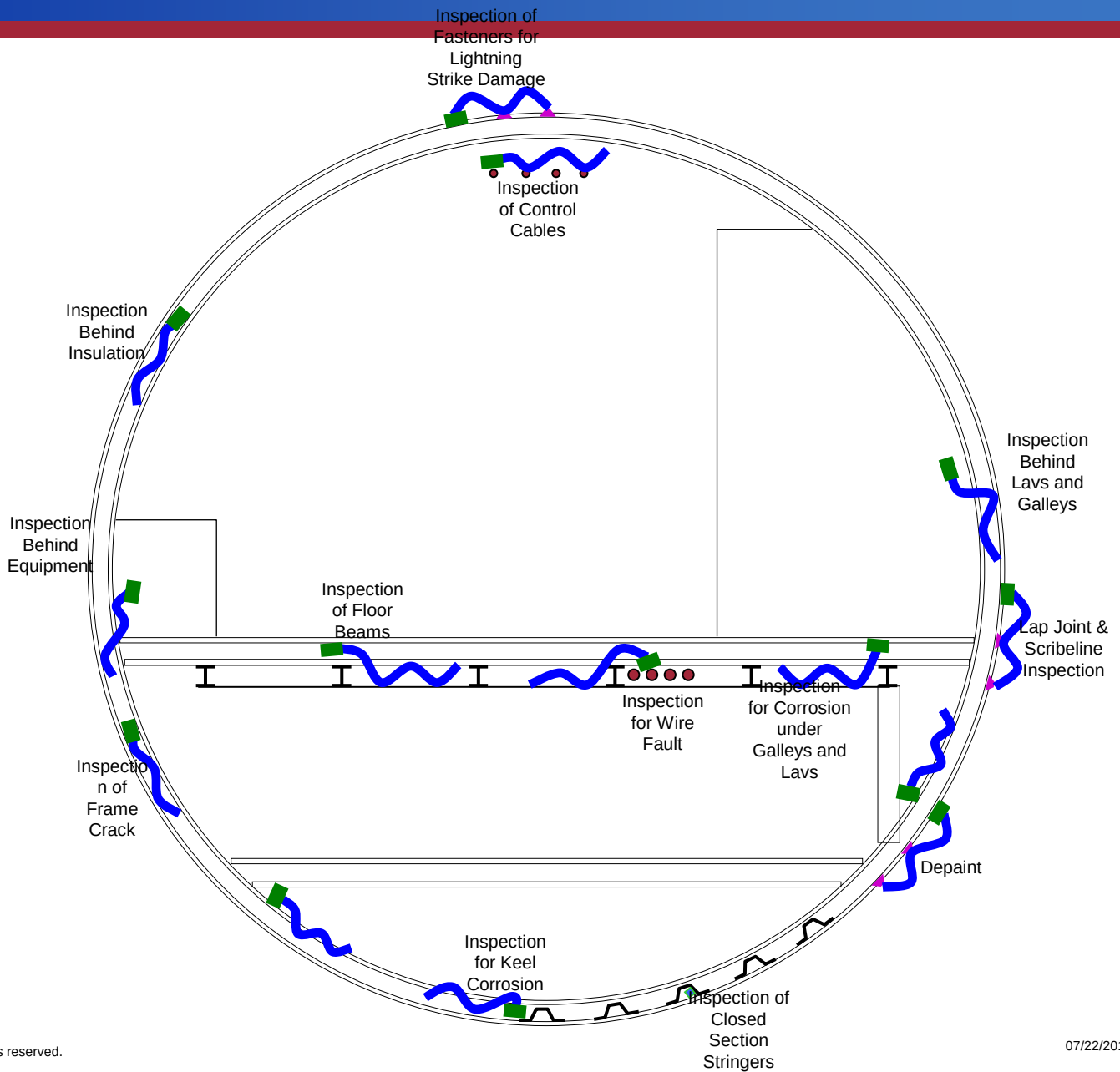
Potential Fuselage Applications



A - A

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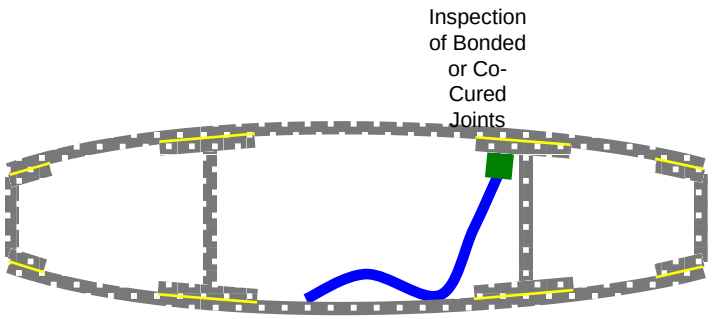
Inspection of Bonded Joints



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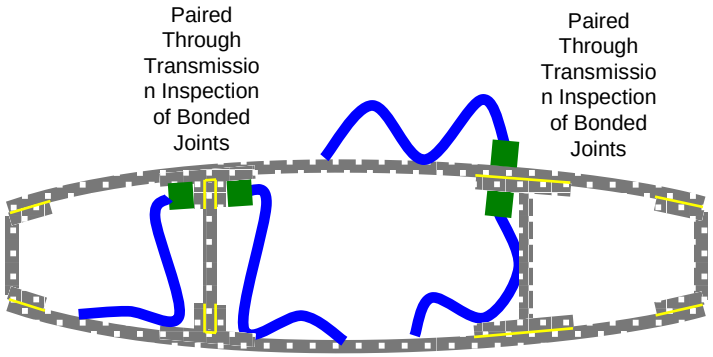

B”’ – B”’

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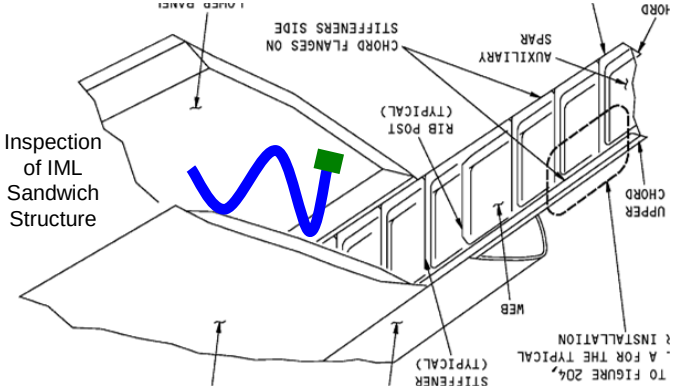
Inspection of Sandwich Panels



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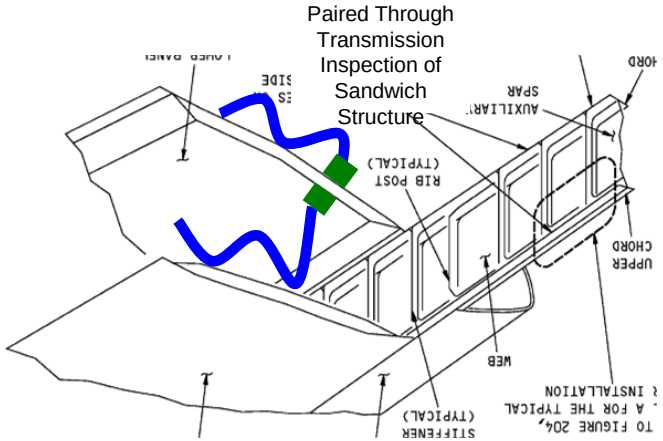

B - B

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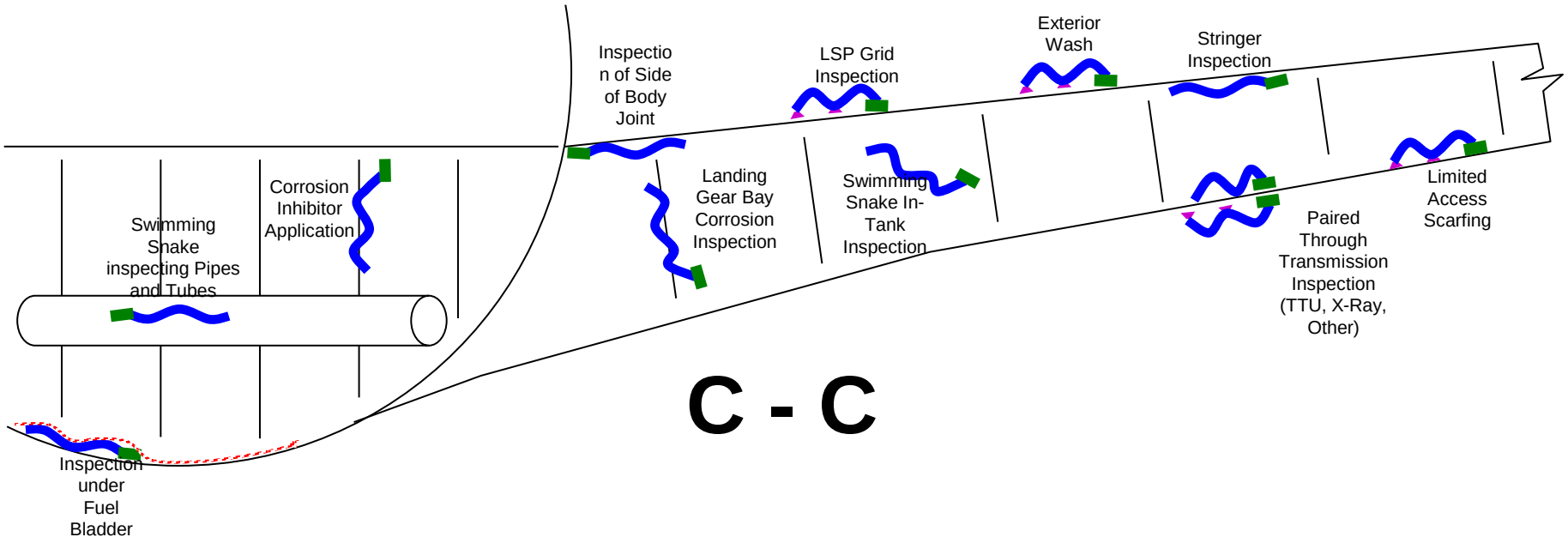
Potential Wing and Fuel Tank Applications



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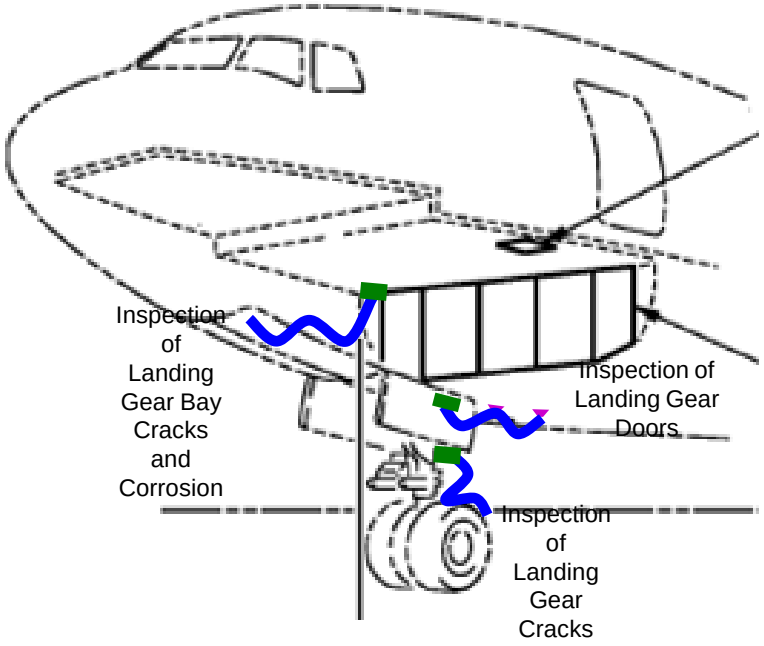
Landing Gear and Wheel Wells



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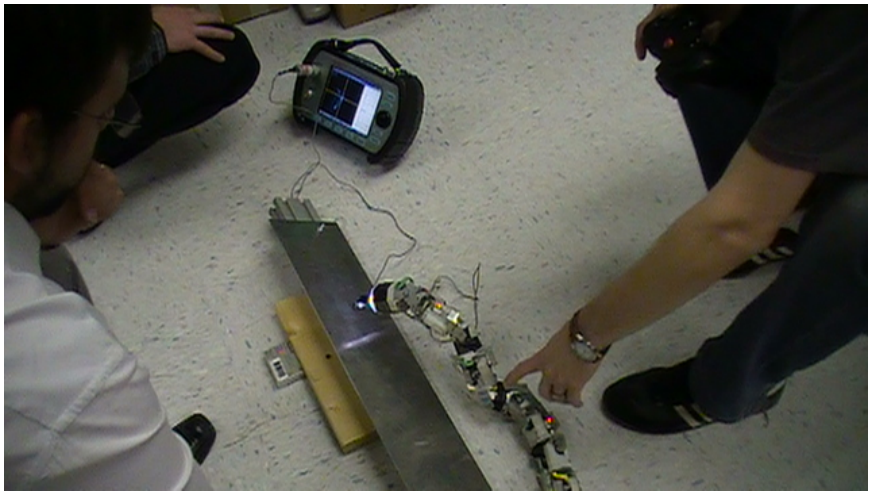
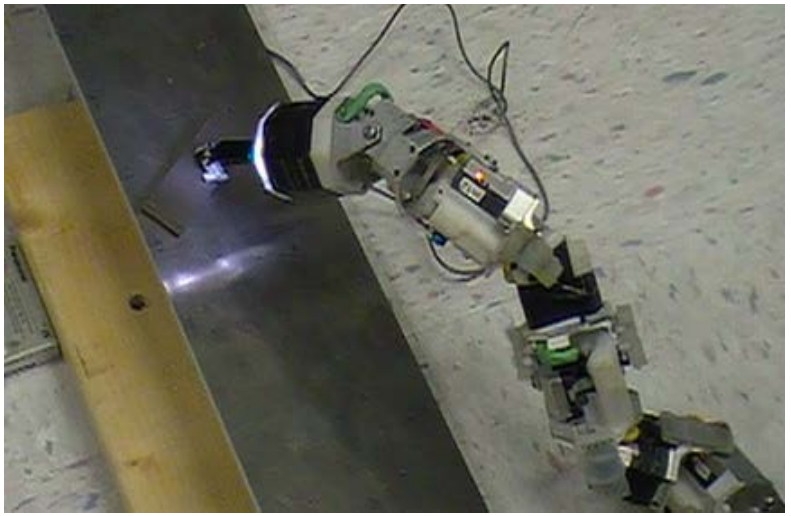
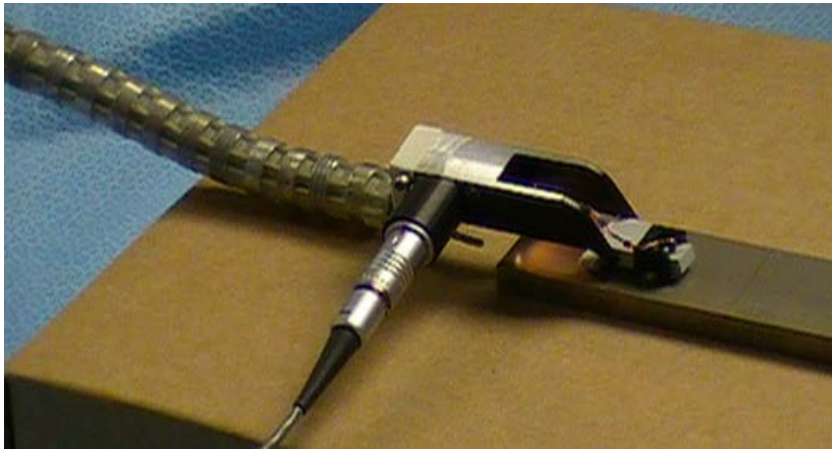
Robotic Snakes are of interest to Boeing







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