Source of Acquisition
NASA Johnson Space Center

Advanced x-ray inspection of reinforced carbon composite materials on the Orbiter Leading Edge Structural Subsystem (LESS).

Jose M Hernandez[1], Robert F Berry[1], Robin Osborn[2], Clifford Bueno[3], Mark Osterlitz[3], Richard Mills[3], Philip Morris[3]; Robert Phalen[3], Jim McNab[4], Tahanie Thibodeaux[4], Kyle Thompson[5]

NASA Johnson Space Center and NASA Langley Research Center[1],
Lockheed Martin Space Operations[2]
GE Inspection Technologies and GE Global Research[3]
Oceaneering International, Inc[4]
Sandia National Labs[5]

The post return-to-flight (RTF) inspection methodology for the Orbiter Leading Edge Structural Subsystem (LESS) is currently being defined. Numerous NDT modalities and techniques are being explored to perform the flight-to-flight inspections of the reinforced carbon/carbon (RCC) composite material for impact damage, general loss of mass in the bulk layers, or other anomalous conditions that would pose risk to safe return upon re-entry. It is possible to have an impact upon ascent that is not visually observable on the surface, yet causes internal damage. Radiographic testing may be a useful NDT technique for such occurrences. The authors have performed radiographic tests on full-sized mock samples of LESS hardware with embedded image quality phantoms. Digitized radiographic film, computed radiography and flat panel digital real-time radiography was acquired using a GE Eresco 200 x-ray tube, and Se-75 and Yb-169 radioisotopes.

One of the options proposed by the team for radiographic inspection was to insert an isotope into the center of the LESS cavity through a small opening at the top skin of the leading edge (at the wing attach point) and irradiate the article in all directions. This affords a single skin inspection where film, computed radiography (CR) image plates, or digital radiography detectors can be located at the outer skin within the sphere of illumination. The diameter of the opening however allows only a small isotope to be inserted. This approach was compared to the more traditional x-ray approach where x-rays are transmitted through both skins and a detector is located on the opposing surface of the second skin. A photograph of the specimen with numerous image quality indicators (IQIs) located inside the cavity is shown in Fig. 1.

Figure 2 provides an x-ray radiographic image of the set-up in Fig. 1 showing the spatial resolution, dynamic range and contrast sensitivity IQIs used to evaluate image quality.

The two isotopes used had the following properties: Selenium-75 activity: 3Curies, at 195 keV and Ytterbium-169 activity:1.8 Curies at 63 keV. These isotopes were compared against the GE Eresco 200 tube with a tube voltage of

120 kVp in imaging experiments using the different detectors listed. Figure 3 provides images obtained with the Se-75 isotope and the x-ray exposure using the GE Real time DXR-250RT amorphous silicon detector.

Fig. 1. LESS test specimen with image quality indicators (IQIs) inserted onto inner surface of bottom skin

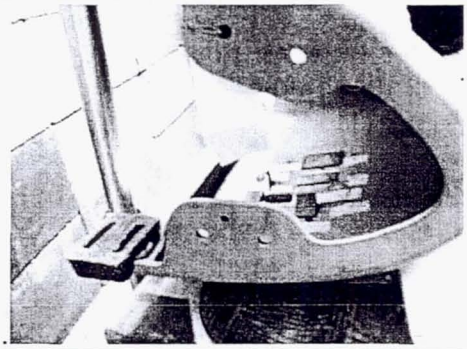


Fig. 2. Filtered digital radiograph of LESS specimen with IQIs in place acquired with DXR-250RT detector.

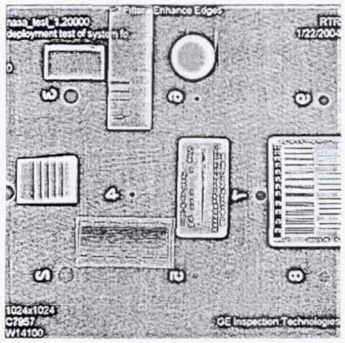
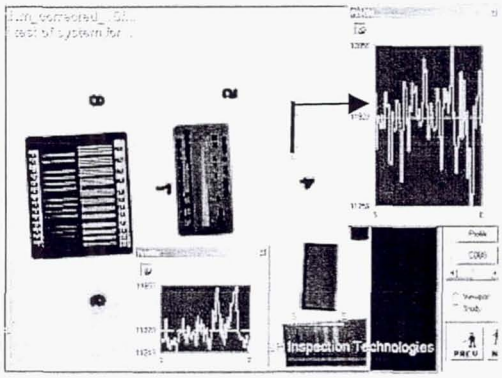


Fig. 3. Image quality comparison of the single skin isotope exposure and the dual skin x-ray exposure using the same GE Real time DXR-250RT detector.

Isotope

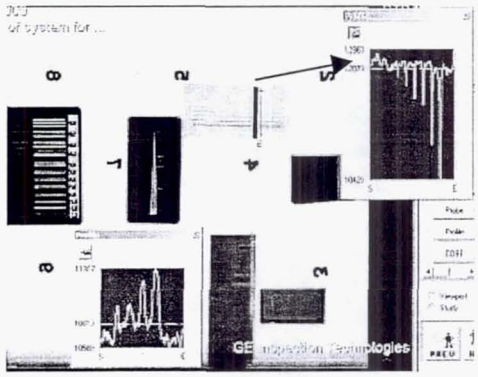
Se-75, 150 sec total exp



- Photon noise dominates using isotope
- Wires in wire penetrameter not readily observable

X-ray

120 kV, 2.7mA, 30fps x 1000 frames – 30 sec exposure (10 sec is similar)

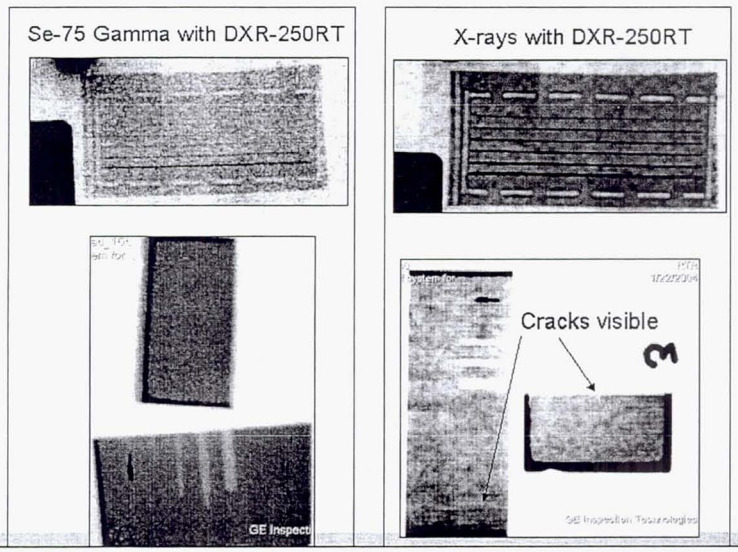


- RCC phantom shows good separation between holes
- All wires in wire penetrameter fully observable

Figure 4 provides a magnified view of the gamma-isotope and the x-ray approach, and indicates a clear performance benefit of the 2-skin x-ray method over the single skin isotope method using this isotope activity. In the x-ray approach, the fine composite structure is observed in the bottom set of images, all features are visible, and fine cracks are apparent in the two specimens. The

gamma ray approach does not reveal these fine features. Both isotopes provided similar image quality indicating that a much higher activity is needed to provide the level of detail required for this examination. Also note that the isotope images required much longer exposure times even though only one skin was transmitted using a much shorter focal detector distance than the x-ray approach. This longer exposure time ultimately makes the isotope approach a more costly inspection technique, albeit the initial capital cost is much lower than for an x-ray tube.

Fig. 4. Magnified views of the comparison of the single skin isotope exposure and the dual skin x-ray exposure using the same GE Real time DXR-250RT detector.



The images collected with the GE Real time DXR-250RT were sampled at a frame rate of 30 frames/sec (33-msec exposures), but numerous frames were averaged to reduce the noise in the resulting image. Observing the imagery in real-time revealed many of the features shown here. It may be possible to scan this structure in real-time and if a suspect area is identified, frame averaging can be used to provide more detail within this area. Alternatively, CR plates or even film sheets can be adhered across large areas of the structure and an x-ray tube can be translated from the opposing surface of the LESS for imagery to be obtained in a stop and expose mode. The image quality of these detector approaches was comparable to that of the GE Real time DXR-250RT detector.