# Remote Expert NDE & Ultrasonic Inspection

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## ABSTRACT

With the increasing use of composite primary structure in the commercial aerospace industry, there is a critical need for rapid nondestructive evaluation (NDE) approaches that minimize the requirements for trained NDE expertise at every airport. Boeing has recently collaborated with Imperium to develop a wireless, remote inspection capability to augment Imperium's digital acoustic video technology, as embodied in the Acoustocam.

This presentation describes a portable NDE inspection system with the ability to provide real-time inspection guidance, data collection, communication, and image data analysis information while operating in environments ranging from airport ramps to repair locations to aircraft air-on-ground (AOG) or battlefield operations.

Composite commercial aircraft, such as the Boeing 787, will encounter potential exterior structural damage due to luggage cart and other impacts. The mechanic or support personnel can quickly create a wireless visual, data, and audio link to a remote NDE expert. The expert can guide an inspection using the Acoustocam, and evaluate and store the inspection data, which includes A- and C-Scan ultrasonic signal information. This presentation will describe the methodology and technology that enables this remote expert capability.

## 1. INTRODUCTION

NDE is commonly used to inspect aerospace structures for in-service damage. As instances on the tarmac or in flight are emergent and not part of scheduled maintenance inspection may be called for at locations without tradition NDE equipment and the trained personnel to perform the required inspections. With worldwide operations of aircraft with advanced structures, despite high costs associated with grounding aircraft to airlines or mission capability, low occurrence rates of incidents make it impractical to have trained personnel staffing many sites where inspections will be needed. This paper details a method and technology enabling such inspections to be made by qualified personnel at a centralized remote location with the aid of less trained operators at the aircraft.

### 1.1 Industry Needs

Advanced composite materials being used on newer platforms such as the 787, V-22, and Joint Strike Fighter are obviously subjected to harsh conditions. The most prevalent scenario involves the material being impacted during the course of normal use. However, there is no reliable, simple device for large area composite inspection. This

damage can often not be seen at all from the surface, making visual detection nearly impossible. This damage can have catastrophic results if not found before flight.

Currently, the technique of choice is tap testing or visual inspection. If nondestructive evaluation tools are used, the most common is a standard ultrasonic transmission (UT) probe providing pulse echo ultrasonic waveform data. The returning echo from the original ultrasonic pulse is digitized and processed electronically to provide information regarding the composite. Potential problems with the structure are identified with loss of back-wall echo and can be further characterized by reviewing the entire ultrasonic waveform data. This type of inspection generally requires someone trained on the equipment and significant training in the evaluation of the results.

# 2. DEMONSTRATION

## 2.1 Acoustocam Ultrasound Imaging Camera

The device is a field portable, simple handheld ultrasound imaging camera, requiring one day of training. The user is not necessarily a trained nondestructive inspection (NDI) technician. The device is meant as a first line of defense to finding internal composite damage in aircraft structures.

The system is essentially a camcorder for ultrasound. The quality of the information imparted by this real time video image is far superior to that of conventional A-scan amplitude data or phased array ultrasonics. The images are easier to read and have much greater spatial resolution. Integration of ultrasound energy over the time period of a video frame results in high signal to noise and sensitivity. This in turn allows reducing the device to a simple, portable, low cost tool that any inspector can use.

The Acoustocam system has the following key features:

- Can be used by non-specialist
- Quick simple alternative to tap testing
- Designed specifically for the evaluation of hidden structures and materials
- Proven in its capability to detect materials defects, composite delaminations thermal and mechanical damage
- Small, light weight, and low power
- Designed for real-time in-situ NDE
- Low cost
- Can work on flat or curved parts
- No disassembly or time consuming setup needed
- Provides real time, simple feedback
- Requires no extensive training
- Robust design capable of surviving hostile aerospace environments

The subsurface imagery generated by the C-scan ultrasound laboratory system is striking for its video appearance. The imagery appears qualitatively similar to that obtained with visible light cameras. The camera head is connected to a base control unit which contains electronics and a single board computer (SBC) to control the camera and chip. The control unit is operated by a graphical user interface with a touch screen. A typical system is shown in Figure 1.


Figure 1. Acoustocam Ultrasound Imaging Camera and controller unit. (Image courtesy of Imperium Inc.)

## 2.2 Inspection Scenarios

Trials of the remote expert NDE with the Acoustocam have been conducted at various sites throughout Boeing's enterprise. Two inspections were conducted from within Boeing factory facilities; the first on a 787 in the Everett factory and the second on V-22 parts in Philadelphia. In both cases Boeing's internal WiFi configured for outside users was used for data transmission from the Acoustocam controller to the remote expert. Cellular phones were used for voice contact and a webcam connected to the Acoustocam controller was used to transmit live video giving the remote expert situational awareness of the location of the inspection. WebEx, a commercially available web conferencing program was used to share the information displayed on the Acoustocam control unit and allow the remote expert to adjust settings such as the gain and gate locations, optimizing the inspection. Another inspection was conducted at Boeing Field International Airport. In addition to WiFi a 3G cellular modem was also used to transmit data. In addition to aircraft parts a composite panel standard with machined thickness gradients and flat bottomed holes and a mock structural panel of a 787 fuselage were used to demonstrate the system.

In each scenario a user playing the role of the inspector was on-site with the Acoustocam, webcam, and cellular phone. WebEx was used to share the inspector's screen and position with a remote expert Level III and with other interested viewers in an operations center. The desktop sharing feature of WebEx allowed the remote expert to adjust the settings of the Acoustocam, optimizing the scan to give the best data and images. With the phone and webcam the expert was also able to direct the inspector to scan the appropriate areas of interest.

## 3. RESULTS

Boeing and Imperium have successfully performed remote expert nondestructive evaluations. Evaluations have occurred on multiple occasions using several communications methods and from differing locations. In each test case the system demonstrated the ability to allow the remote expert to view the inspection data and control the parameters of the inspection. Utilizing the C-scan and the A-scan the expert was able to identify and quantify features in the structure being inspected including stiffeners, flat-bottom holes, and changes in thickness. A typical screenshot of what the remote expert sees is shown in Figure 2.

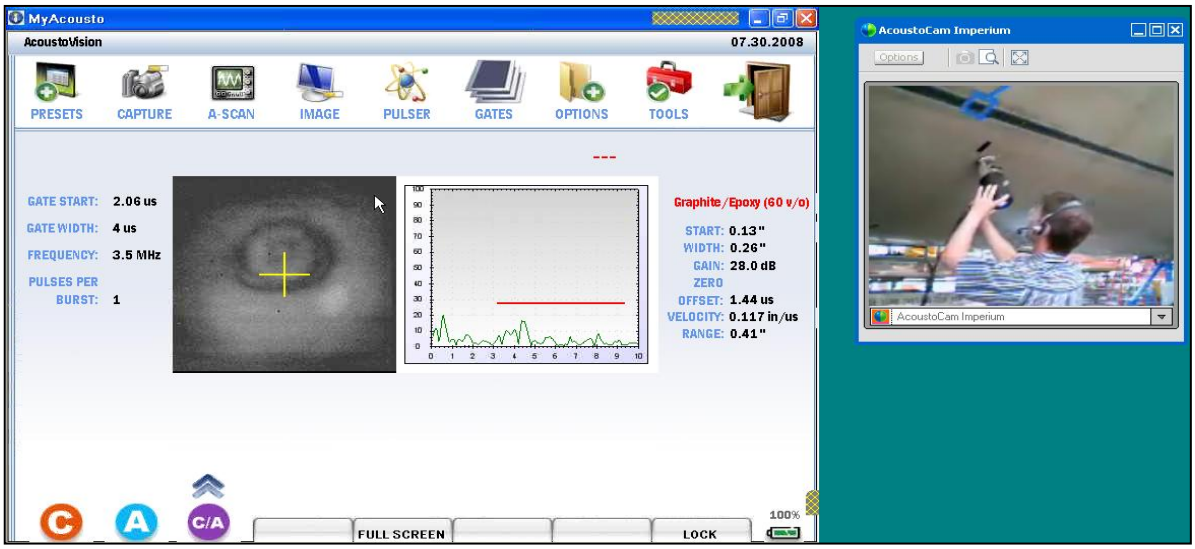


Figure 2. Screenshot from the remote expert's computer during and inspection showing the inspector's location on the aircraft and the structure revealed by the C-scan.

WiFi connections proved to have the bandwidth and update speed to transmit data in real time. Latency on the order of 3 - 4 seconds was common with the 3G card making timing of voice commands and the video more challenging.

## 4. CONCLUSIONS

The quality of these results has leads to hope of transitioning the camera to airport loading gates for quick inspection of composites on commercial aircraft, for internal defect detection by a non-specialized technician. The Acoustocam is a hand-held device that may be used as part of quick survey of suspected damage areas. The device shows subsurface defects that cannot be seen visually. The user simply places a probe against the aircraft structure and with proper equipment setup; subsurface defects appear on a handheld monitor in real time. The images can be monitored in real time via a local wireless network by an expert often thousands of miles away. The project will allow maintenance personnel to use the Acoustocam to quickly survey damage without having to bring in harder to set up, conventional ultrasound equipment - all from remote locations. As advanced aircraft are deployed to more widespread locations, while communication and NDE technologies continue to advance remote expert NDE will become a time and cost saving measure for the aerospace industry.