TECHNICAL BRIEF

AUTOMATING FLIGHT LINE TESTING

FOR

PROXIMITY SENSOR MAINTENANCE APPLICATIONS

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1. Background

Embedded passive position sensors in various aircraft locations (e.g., leading edge wing slats/flaps, hatches/doors, engine thrust reversers, etc.) exhibit substantial failure rates and have been the subject of considerable discussion within the industry for many years. Boeing Aircraft and ELDEC-Crane Aerospace are the primary authors of the sensor design specification and hardware manufacturer respectively. Thus, the commercial aviation industry has had little, if any, input regarding the sensor design and certification effort. However, inexpensive test equipment has been identified that can facilitate maintenance and troubleshooting operations as well as predict and analyze the failures of these embedded sensors.

To implement a test procedure that addresses the above described problem, R.H. Caldwell & Associates examined current methods associated with automated test applications and determined that aircraft electronic networks could benefit by employing the automated test techniques typically employed for testing electronic assemblies. The firm devised an Automated Test Equipment concept (i.e., “ATE”) in cooperation with Geotest - Marvin Test Systems, Inc. Working closely with Geotest, the group designed a sensor-interface network test system which could be easily installed in existing aircraft LRU locations during routine ground maintenance (Reference “Figure 1 - Flaps/Slats Proximity Sensor Reliability Improvement Program Flow”).

Current Test Method & Procedure for Proximity Sensors

**Aircraft: B737-400**
- ELDEC troubleshooting guides
- LCR meter measurements
- Boeing test fixture (breakout box)
- Test flaps / slats sensors per AMM

ATE – Based Test Method & Procedure for Identifying and Predicting Sensor Failures

**Aircraft: B737-400**
- Specify / acquire ATE system
- Develop AC signature method for sensors
- Develop FSIM LRU for access to sensors
- Build AC database for sensors
- Develop maintenance program based on acquired sensor data and predictive failure model

Develop training program and deploy on other aircraft

Figure 1 – Flaps/Slats Proximity Sensor Reliability Improvement Concept Overview
Upon completing the first iteration of equipment design/build and proof-of-concept ground testing, a second equipment design/build and ground test effort verified the final equipment package and software. The proof-of-concept ground tests were conducted in both controlled and MRO environments, and all testing was successfully accomplished.

The “failed sensor” impact upon operators was revealed during a Boeing-ELDEC Webex operators conference that occurred in early 2007. Per Figure 2a and 2b, flaps/slats sensor failures account for over half (53%) of B737-Classic fleet delays, while over a third of B737-NG delays (34%) are attributable to the same problem. Typical sensor degradation includes water ingestion at lead wire ingress-egress positions into the housing, corrosion, and internal component failure. Other “failed sensor” conditions are attributed to incorrect rigging, wiring problems or poor grounding to aircraft ground studs.

The sensor supplier (ELDEC-Crane Aerospace) has attempted to introduce upgraded versions of the current 1-899-29 rectangular sensor, and plans a complete design upgrade with product available in 1Q10-2Q10. However, regardless whether the new sensor design results in higher reliability, a reliable, inexpensive automated sensor test system is now available to facilitate simplified maintenance operations as well as provide predictive failure data information about proximity sensors.

![Figure 2a – 737 Classic – Sensor Related Aircraft Delays](image)
2. The Proximity Sensor Test Problem Solved

Current maintenance practices require manual testing of the sensor’s two wire pairs through an ARINC connector located in the aircraft electronics bay compartment after removal of the Flaps/Slats Indicator Module (FSIM). The testing is accomplished by locating the appropriate sensor pins on the ARINC connector and verifying sensor health by measuring DC resistance and inductance while placing the flaps/slats in various detent positions.

In early 2007, Boeing Aircraft provided drawings for operators to fabricate an extender box allowing enhanced access to the sensor pins located on the ARINC connector as referenced above. While the box provided some access relief for maintenance technicians, the test procedure was tedious and time consuming in order to verify all 20 sensors located in the flaps/slats network. Additionally, all measured sensor values required manual interpretation with technicians hand-scribing the values onto Task Card sheets – a tedious procedure and prone to error. (Reference Figures 3A, 3B for Boeing designed extender box).
By late 2007, engineers at R.H. Caldwell & Associates, in conjunction with other recognized engineering firms, determined that:

- Operators were still experiencing substantial delays, aircraft turnbacks and excessive expense associated with troubleshooting/replacing sensors during aircraft heavy maintenance or overnight checks,

- The lack of test fixturing and the use of manual techniques per the published Aircraft Maintenance Manual was impeding the ability to quickly identify faulty sensors, wiring or rigging,

- Aircraft electrical networks can be viewed as analogous to printed circuit board active and passive component networks, thus making Automated Test Equipment a viable solution to the current problem.

To address the above issues, it was decided to pursue an automated test configuration that would incorporate test fixturing, instrumentation, and control / data collection software. The resulting solution offered the following features:

- Quick installation into existing aircraft LRU locations,

- Automated access via a switching system to the entire sensor network with measurement and control performed by an easily modified, off-the-shelf, Windows-based applications software environment. Additionally, the software and the associated computer platform logs all data obtained from the aircraft under test (i.e., "UUT") providing a reliable and accurate record of the aircraft’s sensor network.
• Ability to review and process the logged data allowing operators to formulate “predictive analysis” models whereby an entire aircraft fleet’s performance may be examined to best predict impending sensor/network failure.

• Ability to differentiate between a sensor or wiring problem and a rigging problem.

• Intuitive software design, user interface, and system interconnect allowing for quick operator and maintenance technician training and equipment set-up.

• Complete portability and packaging into ATA shipping cases allowing shipment of the test “tool” to any repair location.

Figures 4a and 4b depict the third generation fully automated test equipment (ATE) suite. The ATE is based on the PCI eXtensions for Instrumentation (PXI) card – modular architecture. The system employs a laptop computer to control the PXI chassis which offers up to 8 slots for instrumentation and signal switching. For this application, the ATE system is configured with a DMM capable of measuring resistance / inductance and a switch multiplexer allowing access to all 20 sensors on the aircraft under test program control.

Figure 4a – ATE Equipment Suite
4. Proximity Sensor ATE Components

The Flaps/Slats Proximity Sensor Automated Test Equipment suite is typically composed of the following components (Reference Figures 5a-5c):

- FSIM replacement e-compartment Extender Box allowing access to the aircraft sensor network.

Figure 4b – System Configuration

Figure 5a – FSIM Replacement Extender Box
• ATE System Breakout/Interconnect box allowing full access to the aircraft proximity sensor network signals/wiring for manual or automatic test.

Figure 5b – ATE System Breakout/Interconnect Box

• Automatic Test Equipment (ATE) Chassis and laptop computer.

Figure 5c – Automatic Test Equipment (ATE) and Laptop Computer

• Other equipment/document options include:
  
  • Extension cables from FSIM Replacement Extender Box in 10 ft. length multiples (or custom length(s) per operator requirement). (10 ft. standard length cable supplied with baseline equipment order)
  
  • ATE System Breakout/Interconnect Box and Extender Box combination with associated custom cables for manual test only.
  
  • Unique laptop controlled ATE system with application specific software and customized user interface features (Figure 5d)
• Customized operator features of any of the above equipment/cabling options.

• Custom Maintenance Manual detailing operator procedures published per ATA specification. Incorporation of required task cards can be included into an existing maintenance program.

• System training and data analysis at operator’s facility or offsite.

• Incorporation of the ATE System into a “compact” format whereby the ATE Chassis and Breakout/Interconnect box are a single unit.

• Extender Box fabrication per original Boeing Aircraft drawing C27081 specification.

Figure 5d – ATE User Interface for Measuring Flaps and Slats Sensors
5. Future Applications

Building upon the above technology, future applications include, but are not limited to supporting additional aircraft test applications including:

- Upgrading of proximity sensor ATE equipment to support any airframe using similar proximity sensor technology with access through typical ARINC or other aircraft interfaces.

- Test and verification of aircraft fuel system components. Such tests include health checks of wiring, latching relays/modules, pumps and gauges.

- By augmenting the current ATE system with Time Domain Reflectometry (TDR) instrumentation, the performance and verification of coaxial cable and antenna components can be performed.

- Verification and location of faults for long wire runs throughout the aircraft structure can be performed using Time Domain Reflectometry (TDR) techniques.

- Any maintenance procedure which involves an electrical interface within the aircraft is a potential candidate for this type of test system. And since the system’s hardware and software offers expandability and flexibility, the ATE can be configured for a variety of test interfaces and applications based on a user’s specific needs and requirements.