Outline

• Past
• Present
• Future
• Conclusion
• Paving the Path for SHM Innovation

• SHM programs & guidance

• Building the Infrastructure

• End User
Past

• Why does the FAA care about SHM?
• Transport Standards Branch (Transport Aircraft Directorate)
  – Certification Issues
• FY11 with AANC
• Started with survey, review of SHM capabilities, gap analysis
• Perform a mock certification
Past-Emerging Technologies

- **Objective:** Partner with the AANC, Delta Air Lines, SMS/AEM and Boeing to conduct trial SHM certification & integration activity
- **Application:** Boeing 737 NG Wing Box fitting cracking problem as application. Boeing issued a service bulletin as a result of cracking after 21k cycles.
- **Accomplishments:**
  - Install on Delta’s 737-700 Fleet going thru Atlanta for 5 ½ day checks (6k cycles)
  - 7 aircraft completed in Feb/March 2014
  - Delta collected CVM data every 90 days as well as performing required NDI inspection
  - Boeing approved CVM Dec 2015 use –updated SB - June 2016
  - Review CVM project against SAE guidelines and determine what has been validated
  - Assess FAA rules and determine if adequate for SHM use
- **Outcome:**
  - Ensure safe implementation of emerging technologies
  - Develop FAA webinar for FAA ACO engineers
  - Delta/Boeing investigating further SHM numerous platforms
SAE AISCSHM Committee

- Develop standards for SHM for aviation community
- ARP6461 “Guidelines for Implementation of Structural Health Monitoring on Fixed Wing Aircraft” published Sept 2013
- Probability of Detection area of concern
- Reliability workshop April 2015 to determine path forward
- Developed 2 POD methodologies for SHM
- ARP being developed for POD
- Planning a second workshop in 2019
  - Develop the test program for validation of the methodologies
  - Develop useable data for public use
Present-Emerging Technologies

• To provide SHM capability to the TC Labs:
  – Emerging Technologies (Al-Li Panels)
  – Wing Box (ABST)

• To assess SHM capabilities and collect data
• History and Background:

Established: Dec. 1998 through partnership with Boeing

• Applies Major Modes of Loading to Fuselage Panels:
  – Pressure
  – Hoop
  – Axial
  – Shear
## Baseline Panel Design

### Internal View

<table>
<thead>
<tr>
<th>Specification</th>
<th>Measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Panel Length</td>
<td>125 inch</td>
</tr>
<tr>
<td>Panel Width</td>
<td>76 inch</td>
</tr>
<tr>
<td>Panel Radius</td>
<td>74 inch</td>
</tr>
<tr>
<td>No. of Frames</td>
<td>6</td>
</tr>
<tr>
<td>No. of Stringers</td>
<td>8</td>
</tr>
<tr>
<td>Frame Spacing</td>
<td>20 inch</td>
</tr>
<tr>
<td>Stringer Spacing</td>
<td>7.0 inch</td>
</tr>
<tr>
<td>Skin Thickness</td>
<td>0.055 inch</td>
</tr>
</tbody>
</table>

### External View

- Length: 125"
- Width: 76"
- Radius: 74"
- Frame Spacing: 20"
- Stringer Spacing: 7.0"
- Skin Thickness: 0.055"
# Test Matrix – Panels

<table>
<thead>
<tr>
<th>Component</th>
<th>1 (Baseline)</th>
<th>2 (Advanced Density Reduction)</th>
<th>3 (Advanced Materials)</th>
<th>4 (Advanced Materials, FSW)</th>
<th>5 (FSW and Bonded Stringers)</th>
<th>6 (Baseline MSD)</th>
<th>7 (Advanced Density Reduction MSD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skin</td>
<td>Baseline</td>
<td>Advanced Density Reduction</td>
<td>Advanced Materials</td>
<td>Advanced Materials, FSW</td>
<td>FSW and Bonded Stringers</td>
<td>Baseline MSD</td>
<td>Advanced Density Reduction MSD</td>
</tr>
<tr>
<td></td>
<td>2524-T3 sheet</td>
<td>2060 - T8 Al-Li sheet</td>
<td>2029-T3 sheet</td>
<td>2029-T3 sheet, FSW</td>
<td>2060 Al-Li sheet, FSW joint and bonded FML straps</td>
<td>2524-T3 sheet</td>
<td>2060 - T8 Al-Li sheet</td>
</tr>
<tr>
<td>Stringer</td>
<td>7150 extrusions, riveted</td>
<td>2055 or 2099 Al-Li extrusions, riveted</td>
<td>2055 or 2099 Al-Li extrusions, riveted</td>
<td>2055 or 2099 Al-Li extrusions, FSW</td>
<td>2055 or 2099 Al-Li extrusions, bonded</td>
<td>7150 extrusions, riveted</td>
<td>2055 or 2099 Al-Li extrusions, riveted</td>
</tr>
<tr>
<td>Frame</td>
<td>7075-T62 - shear tied, extruded, riveted</td>
<td>2055 or 2099 Al-Li integral extrusions, riveted</td>
<td>2055 or 2099 Al-Li integral extrusions, FSW</td>
<td>2055 or 2099 Al-Li integral extrusions, bonded</td>
<td>2055 or 2099 Al-Li integral extrusions, riveted</td>
<td>7075-T62 - shear tied, extruded, riveted</td>
<td>2055 or 2099 Al-Li integral extrusions, riveted</td>
</tr>
</tbody>
</table>
SHM INSTALLED ON PANEL 1

- Phase I
- Phase II
- Phase III

Dimensions:
- 17" (horizontal)
- 4" (vertical)
- 3.25" (vertical)
- 2.5" (vertical)
- 1/2" (horizontal)
Airframe Beam Structural Test (ABST) Fixture

- Wing skin test panel (24 x 40 in.)
ABST Test Program

• Phase 1: Baseline mechanical and fatigue behavior of composite panels (pristine and open hole)
• Phase 2: Bonded Repair Size Limits
• Phase 3 (proposed): Fatigue and DT performance of bonded repairs intentional made deficient to encouraging damage growth
  – Calibrate analysis methods
  – Assess NDI and SHM to detect and monitor damage growth
Phase 1: Panels 1 and 2

S: Gage on external surface
IS: Gage on internal surface
Rosette gage
Uniaxial gage
SHM Sensor Layout-PZT
Future: Reliability

- Developed 2 methodologies for POD for SHM
- Data from FASTER and ABST tests may be of use to this effort
- Working with NASA to develop a model of the FASTER test fixture with SHM
- Working with SAE to develop industry std
Conclusion

• Boeing/Delta/AANC met in January 2018 in Seattle to discuss future SHM applications: SB - AD.

• SHM: “in situ” NDI. Equal or better. No new guidance needed. Evaluate on case by case basis.

• Dual inspections still required when SHM replaces NDI
Questions

- Paul.Swindell@faa.gov
- William J Hughes Technical Center
- Atlantic City, NJ
- 609-485-8973
SHM Utilization – Validation, Certification and Airline Perspective for Implementation

Dennis Roach
Sandia National Labs
FAA Airworthiness Assurance Center

David Piotrowski
Delta TechOps

Paul Swindell
FAA
Paving the Path for SHM Innovation

Building the Infrastructure

FAA William J. Hughes
Technical Center
Nondestructive Inspection (NDI) – examination of a material to determine geometry, damage, or composition by using technology that does not affect its future usefulness

- High degree of human interaction
- Local, focused inspections
- Requires access to area of interest (applied at select intervals)

Structural Health Monitoring (SHM) – “Smart Structures;” use of NDI principles coupled with in-situ sensing to allow for rapid, remote, and real-time condition assessments (flaw detection); goal is to reduce operational costs and increase lifetime of structures

- Greater vigilance in key areas – address DTA needs
- Overcome accessibility limitations, complex geometries, depth of hidden damage
- Eliminate costly & potentially damaging disassembly
- Early flaw detection to enhance safety & facilitate less costly repairs
- Minimize human factors with automated data analysis
- Move towards condition-based maintenance
Structural Health Monitoring

- Structural Damage Sensing (in-situ NDI)
- Structural Models and Analyses
- Loads and Environmental Monitoring

SHM for:
- Flaw detection
- Flaw location
- Flaw characterization
- Condition Based Maintenance

Reasoner

Structural Health

Prognostic Health Management
SHM Solutions & NDI Challenges

Difficulty in loads assignment, stress and fatigue calculations produces demands on NDI - “You want me to find a flaw where, and how small??”

Difficult Conditions

Lots of Rapid Data Interpretation
Structural Health Monitoring – Integration into Routine Maintenance

Dennis Roach, Tom Rice
Stephen Neidigk

Paul Swindell, Dave Galella,
Ian Won, Mark Freisthler

David Piotrowski, Alex Melton
John Bohler, Joe Reeves
Chris Coleman, John Hays

Bernie Adamache,
Joe Zee

Jeff Kollgaard, JB Ihn,
Walt Jarecki, John Linn,
Matt Miller, Mike Wineland

Toby Chandler,
Mike Reveley

Trevor Lynch-Staunton
Henry Kroker, Brian Shiagec,
Dave Veitch

Mark Davis, Andrew Brookhart,
Preston Bates, Ray Beale

John Mitchell, Hin Tsang,
Maurizio Molinari, Marc Lord

Ricardo Rulli, Fernando Dotta,
Paulo Anchieta, Luis Santos

Amrita Kumar, Fu-Kuo Chang,
Howard Chung, Franklin Li

Jérôme Pinsonnault,
Colin Vollrath, Yves Theriault

Holger Speckmann

Clemens Bockenheimer,
Benjamin Eckstein, Marie-Anne De Smet,
Lorenz Wenk

Acellent

Delta Air Lines

Boeing

AEM Anodyne Electronics Manufacturing Corp.

Transport Canada

Aalborg Instruments for Terahertz Applications

Embraer

Bombardier

Airbus

FAA William J. Hughes Technical Center

Sandia National Laboratories
Synopsis of CVM Validation/Utilization Programs Supporting Safe Adoption of SHM Systems

2005

- General SHM Validation
  - Assess performance for fuselage applications
  - Lab & field testing

2008

- SHM R&D Roadmap
  - Industry survey
  - SHM TRL assessment
  - Industry perspectives
  - Validation methodology
  - Considerations for regulatory guidance

2010

- SHM for Commuter Aircraft
  - Trial on known damage prone area
  - Successful detection on-aircraft
  - Transport Canada participation
  - Assess repair as-needed

2012

- Certification for Families of SHM
  - CVM & PZT usage over range of A/C applications
  - Quantify performance
  - Use approval via SBs
  - ANAC & FAA interface

2014

- SHM Certification & Adoption by Airlines
  - Specific CVM application
  - Joint with FAA, Sandia Labs, Delta Air Lines & Boeing
  - Formal validation & flight tests
  - CVM added to NDT Manual
  - SB released – first routine use of SHM

2016

- SHM for Rotorcraft
  - Validation of local & global SHM approach
  - Process for routine use
  - Integration into rotor maint.
  - Mock certification with FAA
  - Integration into HUMS
Comparative Vacuum Monitoring System

- Sensors contain fine channels - vacuum is applied to embedded galleries so no electrical excitation required
- Overcome accessibility problems - real-time information or more frequent, remote interrogation

![Diagram of Comparative Vacuum Monitoring System](image)

<table>
<thead>
<tr>
<th>Time (s)</th>
<th>Pressure (Pa)</th>
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<tbody>
<tr>
<td>0</td>
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<tr>
<td>5</td>
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<td>10</td>
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<tr>
<td>30</td>
<td>600</td>
</tr>
<tr>
<td>35</td>
<td>700</td>
</tr>
</tbody>
</table>

**Crack Detected (vacuum unachievable)**

**No Crack (vacuum achieved)**

- Crack Engaging CVM Sensor

 FAA William J. Hughes Technical Center

[Logo: Sandia National Laboratories]
CVM Success on CRJ Aircraft

Pilot program with Bombardier and Air Canada

Inspect in the radius

Sensor Issues:
- Design
- Surface preparation
- Access
- Connection
- Quality control

Aft Equipment Bay
CVM Application on Forward Fuselage PAX Door Bracket

Installation Summary

- Date of Installation: Nov 2014
- Service Bulletin: SB190-00-0029
- Zone: Central Fuselage II
- PZT & CVM on Center Fuselage End Fittings

PZT Application on Forward Fuselage PAX Door Stringer

Possible damage scenario to be monitored
Delta-Boeing-FAA-Sandia joint effort to leverage airline activities

- Evolve the SHM certification path – address all “cradle-to-grave” issues for airlines, OEMs, and regulators
- Complete SHM indoctrination and training for Delta personnel (engineering, maintenance, NDI) and FAA as needed
- Hardware specifications, installation procedures, operation processes, continued airworthiness instructions
- Complete modifications to Delta maintenance program for SHM use
- Assess aircraft maintenance depots’ ability to adopt SHM and the FAA support needed to ensure airworthiness
CVM Sensor Network Applied to 737 Wing Box Fittings

- Multiple aircraft applications addressed
- Comprehensive performance assessments completed – sensitivity, reliability, durability
- Over 50 combined years of successful operation on flying aircraft
- Formal approval from aircraft manufacturers and aviation regulators
- Reached routine use on aircraft
737NG Center Wing Box – CVM Performance Tests
Quantifying Probability of Crack Detection

Test Scenarios:

<table>
<thead>
<tr>
<th>Material</th>
<th>Thickness</th>
<th>Coating</th>
</tr>
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<tbody>
<tr>
<td>2024-T3</td>
<td>0.040”</td>
<td>bare</td>
</tr>
<tr>
<td>2024-T3</td>
<td>0.040”</td>
<td>primer</td>
</tr>
<tr>
<td>2024-T3</td>
<td>0.071”</td>
<td>primer</td>
</tr>
<tr>
<td>2024-T3</td>
<td>0.100”</td>
<td>bare</td>
</tr>
<tr>
<td>2024-T3</td>
<td>0.100”</td>
<td>primer</td>
</tr>
<tr>
<td>7075-T6</td>
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</tr>
<tr>
<td>7075-T6</td>
<td>0.100”</td>
<td>primer</td>
</tr>
</tbody>
</table>

Summary of Crack POD Levels for CVM Deployed on Different Materials, Surface Coatings, and Plate Thicknesses

<table>
<thead>
<tr>
<th>Material</th>
<th>Plate Thickness (mm)</th>
<th>Coating</th>
<th>90% POD for Crack Detection (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2024-T3</td>
<td>1.02</td>
<td>Bare</td>
<td>1.24</td>
</tr>
<tr>
<td>2024-T3</td>
<td>1.02</td>
<td>Primer</td>
<td>0.53</td>
</tr>
<tr>
<td>2024-T3</td>
<td>1.80</td>
<td>Primer</td>
<td>1.07</td>
</tr>
<tr>
<td>2024-T3</td>
<td>2.54</td>
<td>Bare</td>
<td>6.91</td>
</tr>
<tr>
<td>2024-T3</td>
<td>2.54</td>
<td>Primer</td>
<td>2.29</td>
</tr>
<tr>
<td>7075-T6</td>
<td>1.02</td>
<td>Primer</td>
<td>0.66</td>
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<td>7075-T6</td>
<td>1.80</td>
<td>Primer</td>
<td>0.84</td>
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<tr>
<td>7075-T6</td>
<td>2.54</td>
<td>Primer</td>
<td>0.58</td>
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737NG Center Wing Box – Accumulating Successful Flight History

Aircraft Parked at Gate After Final Flight of the Day

Access to SLS Connectors Through Forward Baggage Compartment

Connecting SLS Leads to PM-200 to Monitoring Sensor Network

AC3601 Sensor CVM Readings
Building Block to Approval for Routine Use of SHM

Chapter 1 – Comparative Vacuum Monitoring
DO A DETAILED INSPECTION OR COMPARATIVE VACUUM MONITORING (CVM) INSPECTION OF THE CENTER WING BOX FRONT SPAR SHEAR FITTINGS FOR ANY CRACKS. IF ANY CRACK IS FOUND, REMOVE THE DAMAGED SHEAR FITTING, MAKE SURE THERE IS NO CRACKING IN THE UPPER PANEL AND INSTALL A NEW SHEAR FITTING AS GIVEN IN THIS SERVICE BULLETIN.

AT EACH SHEAR FITTING, IF NO CRACKING IS FOUND IT IS OPTIONAL TO ACCOMPLISH THE PREVENTIVE MODIFICATION BY REPLACING THE SHEAR FITTINGS.

COMPLIANCE INFORMATION RELATED TO THIS REVISION

Effects of this Revision on airplanes on which Original Issue was previously done:

None.

REASON FOR REVISION

This revision is sent to add a Comparative Vacuum Monitoring (CVM) inspection as an alternative inspection method for the front spar shear fitting. In addition, illustrations in figures are changed to show correct views, footnotes are added in fastener tables for clarification and footnotes in figures are changed to clarify sealing instructions.
Moving Forward – Identified SHM Applications

737 APB - Inspection of the Web at the "Y" Chord

747 Fuselage Frame - Web Inspection

757 Fuselage Section - Frame Inspection
Conclusions on Use of SHM Approach

- Overall, there is a strong interest in SHM – multitude of applications covering all aircraft structural, engine, and systems areas.
- Recent advances in health monitoring methods have produced viable SHM systems for on-board aircraft inspections. SHM maturity has grown exponentially so desired usage and need for certification is expected to rise rapidly.
- Sensors must be low-profile, easily mountable, durable, reliable & fail-safe.
- Calibration for flaw identification (damage signatures) is key.
- Validation - Reliability/POD assessments and successful flight history are necessary.
- Ease of use allows for more frequent inspections – minimize repair costs.
- SHM can decrease maintenance costs (NDI man-hours; disassembly) & allow for condition-based maintenance.
- Application-oriented studies have led to approval for routine aircraft use & spawned larger, families of SHM applications (SHM Chapter in Boeing NDT Manual, Service Bulletins).
Conclusions on Use of SHM Approach

• AMOC for SBs and ADs or STCs – safety driven use is achieved in concert with OEMS & regulatory agencies; approval through regulatory framework established with Delta-Boeing-FAA-Sandia program

• Performance Database – testing levels expected to be higher until sufficient database is obtained (ref. NDI and POD currently)

• Airline SHM Usage –
  ➢ Proven ability to adopt SHM solutions – maintenance program mods
  ➢ Delta internal Engineering Documents and Job Cards created
  ➢ Education Process - personnel trained, then carried out SHM

“SHM can be the next level of NDT”
- Delta Air Lines
Validation of a Structural Health Monitoring (SHM) System and Integration Into an Airline Maintenance Program

Questions?
Reliable structural health monitoring (SHM) systems can automatically process data, assess structural condition and signal the need for human intervention. While ad-hoc efforts to introduce SHM into routine aircraft maintenance practices are valuable in leading the way for more widespread SHM use, there is a significant need for formal SHM technology validation and certification processes to uniformly and comprehensively support the evolution and adoption of SHM practices. Such a plan must contain input from aircraft manufacturers, regulators, operators and research organizations so that the full spectrum of issues including design, deployment, performance and certification is appropriately considered. The FAA has sponsored SHM system validation programs over the years to produce quantitative assessments for sensitivity, durability, and repeatability. This has provided a database on SHM performance and laid the foundation for implementation of SHM solutions. Several aircraft manufacturers (OEMs) have embraced SHM with some even incorporating it into their NDT Manuals. This paper presents an OEM—airline-Sandia Labs-regulator effort to move SHM into routine use for aircraft maintenance procedures. This program addressed formal SHM technology validation and certification issues so that the full spectrum of concerns, including design, performance, deployment, and certification is appropriately considered.

The FAA Airworthiness Assurance Center (AANC) at Sandia Labs, partnered with Delta Air Lines, the FAA, Boeing, Anodyne Electronics Manufacturing Corp, and Structural Measurement Systems on a study to develop and carry out a certification process for SHM. Validation tasks were designed to address the SHM equipment, the health monitoring task, the resolution required, the sensor interrogation procedures, and the conditions under which the monitoring will occur. Comparative Vacuum Monitoring (CVM) sensors were applied to seven B737-700s on the 10 Wing Center Section Shear Fittings, a known area of cracking. The passive system has been flown since February 2014 with periodic interrogation. The data from the flight tests were mated with a comprehensive suite of laboratory performance tests to produce a data package which ultimately led to formal approval for routine use of CVM sensors on aircraft.

Formal SHM validation also allows the aviation industry to confidently make informed decisions about the proper utilization of SHM. It streamlines the regulatory actions and formal certification measures needed to assure the safe application of SHM solutions. The activities conducted in these programs demonstrated the feasibility of routine SHM usage and supported the development of industry guidelines and advisory materials to reliably and safely allow widespread adoption of SHM across the commercial aviation industry. This paper will discuss the validation data needs for SHM approval, perspectives from regulators regarding approvals and all the process/documents needed for airlines to adopt SHM. The issues range from Financial and Strategic to Engineering and Maintenance Job Task Cards. Additionally, lessons learned from several SHM programs will be covered to assist the industry with the adoption of SHM solutions.
SHM Utilization – Validation, Certification and Airline Perspective for Implementation

David Piotrowski
Senior Principal Engineer
Paving the Path for SHM Innovation

SHM programs & guidance

Building the Infrastructure

End User
So, where are we going?
• A lot has been done, the infrastructure is in place and the **applications are available.**

• Seattle FAA meetings conclusions  
  • “Hot spot” inspection is "like" in situ NDI so the FAA could address certification like it does with any NDI method.  
  • Guidance being generated by AISC-SHM  
  • FAA feels that that it does not need to jump in and produce a lot of FAA-based guidance

• So what now? What are the applications?
Finding Applications – “Hot Spot”

Deep Dive on:
- Mtc Planning Document
- ALI/SSID Document
- ADs

**Application musts:**
- Hard to access area
- Not at convenient mtc visits
- Short repetitive intervals
- Damage knowledge requirements
- Consistent, repeatable problem
Boeing B737 applications found!

737 Fus Aft Pressure Bulkhead

- SB 737-53A1248
  - Threshold 25,000 FC
- Repeat Intervals
  - LFEC 1,200 FC
  - HFEC 3,800 FC
- Airworthiness Directive AD 2005-21-06
- Airplane Models: 737-600, 737-700, 737-700C, 737-800, 737-900
Boeing B757 applications found!

Frame 1640
SB 757-53A0108

BS 1640 and BS 1681 Frame Inspections Are Typically Accomplished Together

Passenger Door No. 4

Frame 1640 inspection areas
Frame 1681 inspection areas
Boeing B757 applications found!

757 Fus Section 46 - Body Station 1640 Frame Inspection

- SB 737-53A0108
  - Threshold: 20,000 flight cycles
  - Repeat Intervals 3,000 – 6,000 FC
Boeing B757 applications found!
Boeing B757 applications found!

757 Fus Section 46 - Body Station 1681 Frame Inspection

- SB 757-53A0100
- Threshold: 31,000.
- Repeat Intervals: HFEC
  ~3.200 FC Repeat Intervals
Boeing 737NG applications found!

737 Maintenance Planning Data (MPD)
DTR 57-20-09 UT/HFEC Inspections

- 737 NDTM PART 6 57-30-08
- 737 NDTM PART 4 57-10-06
- Repeat Intervals
  - 2,400 FC HFEC
  - 4,300 FC UT
- Airplane Models: 737-600, 737-700, 737-700C, 737-800, 737-900

[Diagram showing inspection areas for UT and HFEC]
## Airbus applications found!

<table>
<thead>
<tr>
<th>A320FAM</th>
<th>A321</th>
<th>A330</th>
</tr>
</thead>
<tbody>
<tr>
<td>DET: FR20-21 continuity fitting</td>
<td>Cabin floor beam junction</td>
<td>DET: CWB - FR40 fitting</td>
</tr>
<tr>
<td>MPD 531157-01</td>
<td>MPD 532220/21/22/23-01</td>
<td>MPD 571102-01</td>
</tr>
<tr>
<td>TH:24000FC/INT:7000FC</td>
<td>TH:36900FC</td>
<td>TH:24200FC/INT:5500FC or TH:22400FC/INT:5100FC</td>
</tr>
</tbody>
</table>
STC applications found!

- Panasonic
- Gogo
- Viasat
Safety is #1 Concern

- FAA tasking = Safety!
- AD for many ‘hot spots’
- Which is a safer philosophy?
  - #1 Cracking found at Heavy Check
    - Area only opened once every 6 years
    - Onerous access, Visual Insp, Eddy current inspection
    - Damage extensive, frame severed by the time damage is found (Major repair)
    - ‘Blind’ to damage until scheduled task
    - Possible AD?
  - #2 SHM system
    - Data taken frequently (or even daily)
    - Early warning of an issue
    - Ability to ‘monitor’ until can examine at next convenient opportunity
    - ‘Unscheduled’ mtc can become ‘scheduled’ mtc
    - Minor repair at next convenient visit
    - Apply new knowledge to rest of fleet (proactive instead of reactive)
Industry Efforts to Formalize SHM

- AISC-SHM Committee Efforts expanded
  - Use IVHM & other committees for increased exposure

- IATA, A4A MPIG group
  - Position paper 180

  MSG-3 logic should be amended to realize the benefits from AHM capabilities in scheduled maintenance development and to create a consistent industry approach. Relevant industry standards have been considered in developing this IP (e.g. SAE documents ARP6803, ARP5120, ARP6275 and AS4831A).

- SAE HM-1 Committee = Maintenance Credits

- Data-driven & enhancement to safety
  - Tail specific

Regulators are key stakeholders!
AIR 6900 ready for release!

SAE Aerospace Standard Types

AS Aerospace Standards – specific performance requirements used for design standards, parts standards, minimum performance standards, quality and other areas conforming to broadly accepted engineering practices or specs for a material, product, process, procedure or test method

ARP Aerospace Recommended Practices – documentations of practice, procedures, and technology that are intended as guides to standard engineering practices. May be of a more general nature or propound data that have not yet gained broad acceptance.

AIR Aerospace Information Reports – compilations of engineering reference data, historical information, or educational material useful to the technical community

Need to push this from AIR to ARP to AS!
What’s next for SHM?

• Technology ready, **philosophy** is not
  – **Industry education, awareness**
  – MSG3 documents => ‘NDT’ replaced with ‘NDT/SHM’
  – NDT, SHM not in CFRs (and should not be)
  – Easier acceptance when Industry Stds (ARP 6461) are utilized

3 parts envisioned on operator end:

• Part 1: S-SHM for ‘alternate inspection approvals’
  – “Hot spot monitoring”
  – Perform SHM reading at same scheduled interval (S-SHM)

• Part 2: Blend of S-SHM and ‘predictive/prognostics’
  – Early warning system (Proactive mtc.)
  – Extension of intervals (escalation)

• Part 3: ‘Condition based maintenance’
  – Philosophy shift to allow ‘monitoring’ or CBM; heavy OEM involvement
  – AD 2007-10-04/SB MD80-55A065 AMOC – Monitoring stop drilled holes

• Speed is dependent upon OEM and FAA ‘side-by-side’ timeframe.
  – Get comfortable with new technology/philosophy
  – Operator pay-back, financials directly dependent upon this!

Firmly in Phase 1, looking to Phase 2
Operator Concerns

• Side-by-side inspections (even temporary)
  o Kills Business Case; will not move forward
  o Technology dead-on-arrival
  o Blended program compromise?

• OEMs dominant
  o Aftermarket push = Sell as a ‘service’
  o IP ownership
  o Being charged for our own data

• Vendors/OEMs/Operator Relationships
  o Must be win/win/win

• Legal Ramifications
  o Systems could be used for punitive actions from FAA
  o No guidance for ‘inspection data’ retention – SHM data similar?
Summary

- FAA-no new rules needed for SHM as in situ NDI (local applications)
- FAA will handle SHM applications on case by case basis
- Airline SHM Usage
  - Proven ability to adopt SHM solutions –maintenance program mods
- SHM can decrease maintenance costs (NDI man-hours; disassembly) & allow for condition-based maintenance
- AMOC for SBs and ADs or STCs
  - Safety driven use is achieved in concert with OEMS & regulatory agencies
  - Approval through regulatory framework established with Delta-Boeing-FAA-Sandia program
- Plenty of applications!
- Royal flush