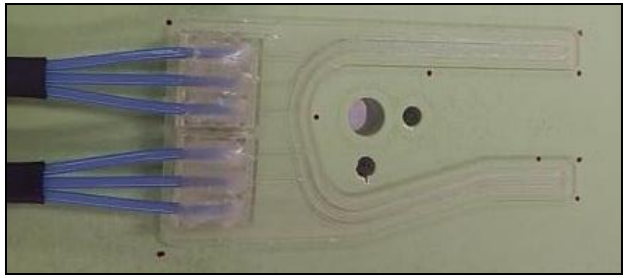
Integration of SHM and NDI for Optimized Monitoring of Commercial Aircraft



Dennis Roach, Ph.D.
Senior Technical Fellow

Trevor Lynch-Staunton
Chief Technical Officer

Structural Monitoring Systems

CVM SMART SENSOR SOLUTIONS™

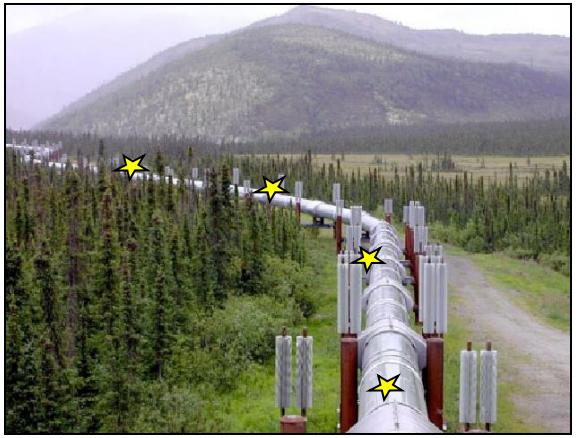
AEM™ ANODYNE ELECTRONICS MANUFACTURING CORP.

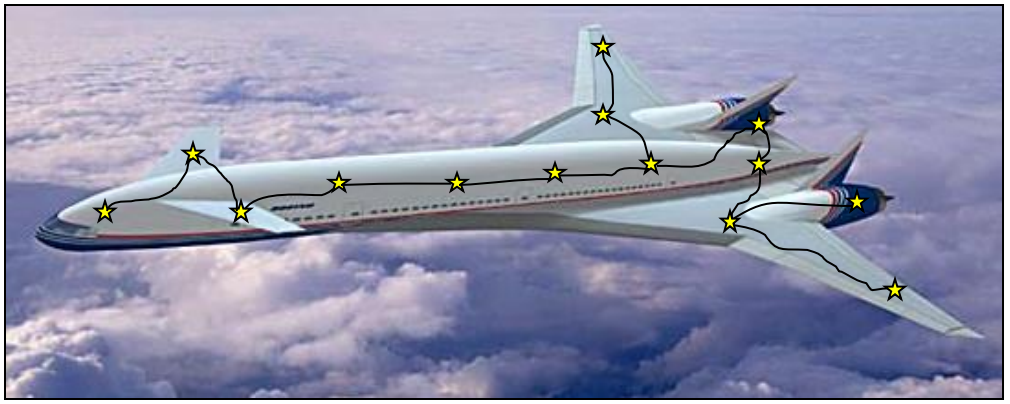
STRUCTURAL MONITORING SYSTEMS plc

Distributed Sensor Networks for Structural Health Monitoring

Smart Structures: include in-situ distributed sensors for real- time health monitoring; ensure integrity with minimal need for human intervention

- **Remotely monitored sensors allow for condition-based maintenance**
- **Automatically process data, assess structural condition & signal need for maintenance actions**
- **SHM for:**
  - **Flaw detection**
  - **Flaw location**
  - **Flaw characterization**
  - **Condition Based Maintenance**





SHM = In-situ NDI (has guided validation/certification efforts)

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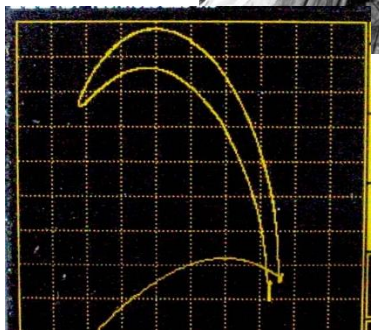
SHM Solutions & NDI Challenges

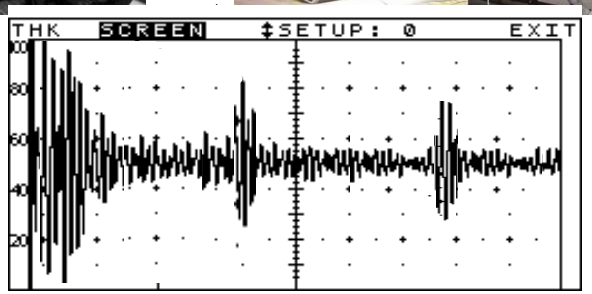
Difficulty in loads assignment, stress and fatigue calculations produces demands on NDI - "You want me to find a flaw where, and how small??"

Difficult Conditions

Lots of Rapid Data Interpretation

Viable NDI Signal??





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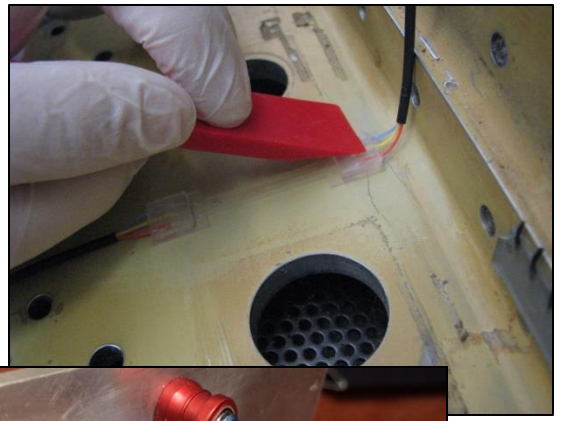
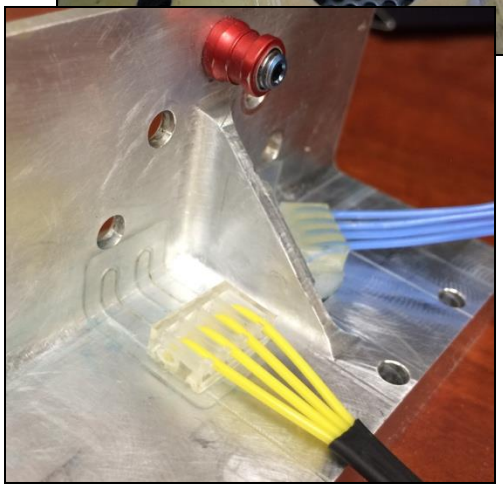
NDI vs. SHM – CVM Technology Deployment



Nondestructive Inspection (NDI) –

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



Structural Health Monitoring (SHM) – "Smart Structures;" in-situ sensing, allow for rapid flaw detection

- Greater vigilance
- Overcome accessibility limitations
- Eliminate costly & potentially damaging disassembly
- Minimize human factors with automated data
- Reduced operating and maintenance costs
- Early flaw detection to enhance safety and allow for less costly repairs

- **Easy installation – peel-and-stick; sensors conformable to complex contours**
- **Sensors designed with a fail-safe mode**
- **Easy adoption of technology demonstrated by airlines**

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Why CVM? - Value Proposition

COMMERCIAL BENEFITS: APB PROGRAM

ACTIVE B737NG AIRCRAFT IN FLEET

71

+

MAINTENANCE AVOIDANCE

Avoid pulling the aircraft out of service for one (1) day to run LFEC inspection every 1,200 cycles

Reduce HFEC inspections on ~10-15% of the fleet

- Replaces hangar time with at-the-gate inspections.
- Restores valuable flight hours
- Eliminates false negatives. It's a 'go/no-go' gauge when it comes to structures
- Eliminates human error during inspections (no tight areas for probe position)
- Allows for shift to Condition-Based Maintenance

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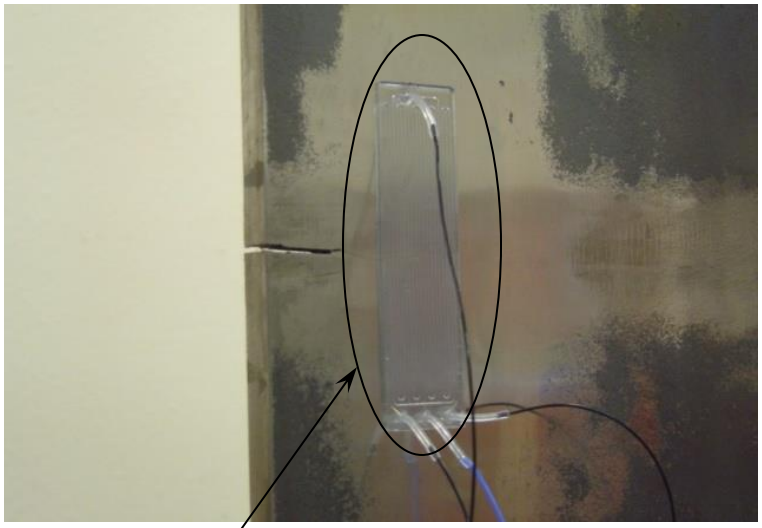
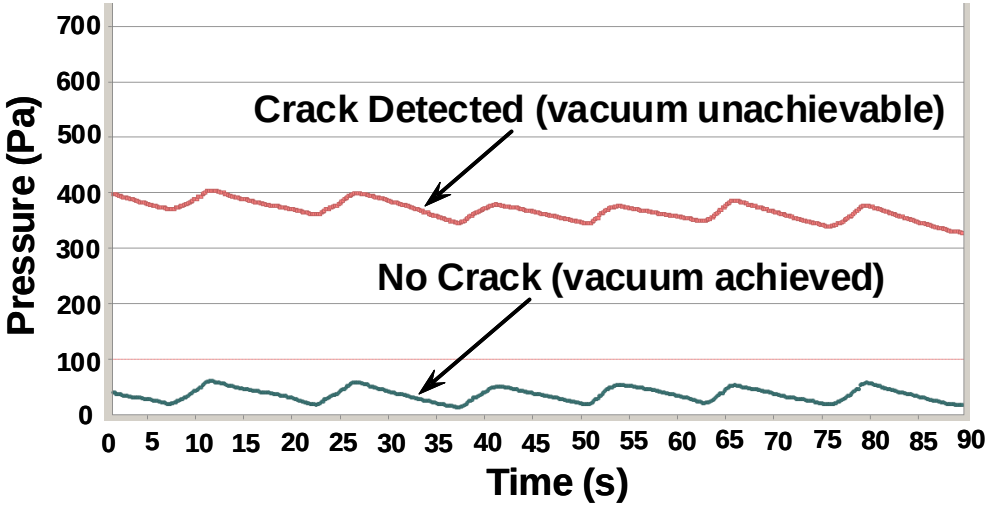
*SOURCE: DELTA AIR LINES

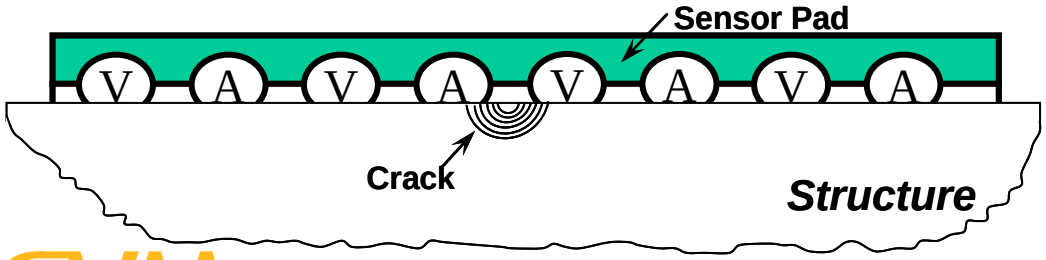
Comparative Vacuum Monitoring – How it Works

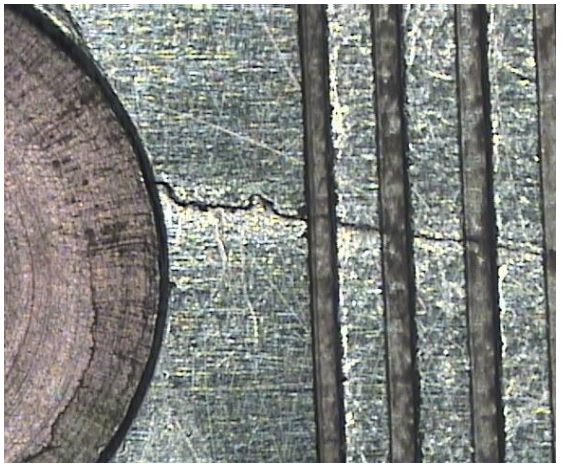
- Sensors contain fine channels - vacuum is applied to embedded galleries
- Leakage path produces a measurable change in the vacuum level
- Doesn't require electrical excitation or couplant



CVM Sensor Adjacent to Crack Initiation Site







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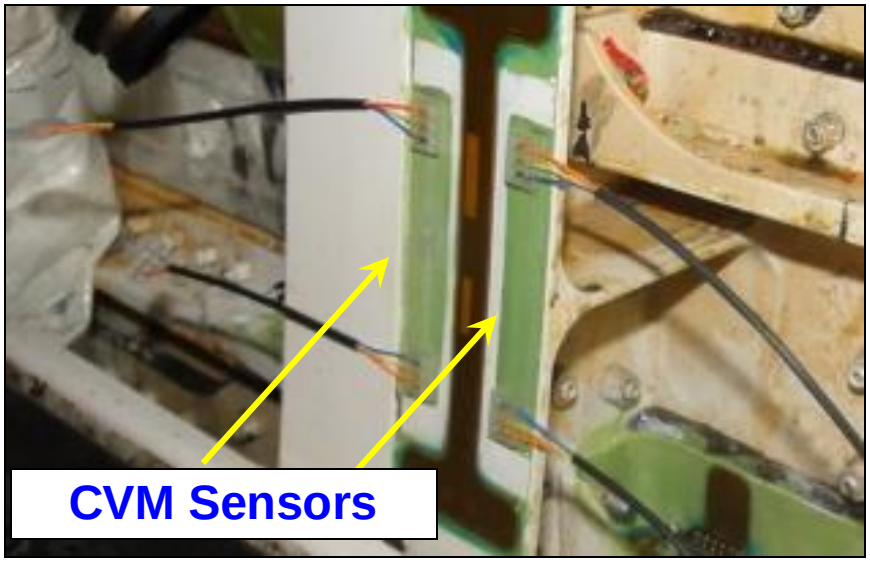
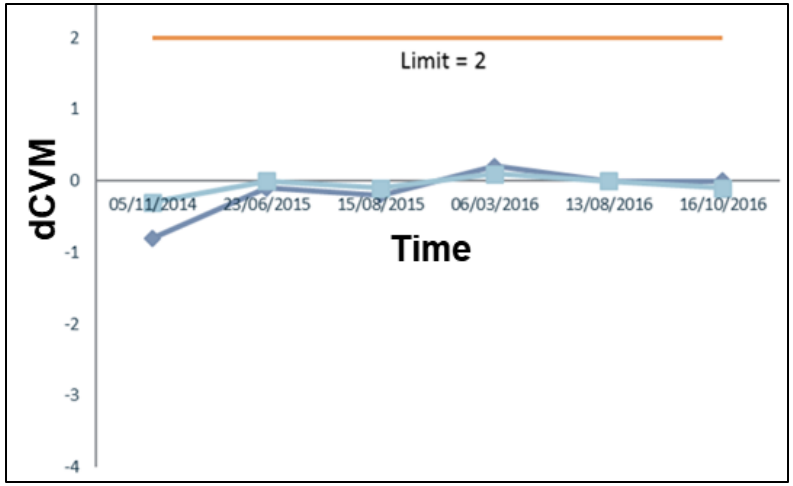
Embraer CVM & PZT Flight Tests – Azul Aircraft PR-AYW

Installation Summary

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





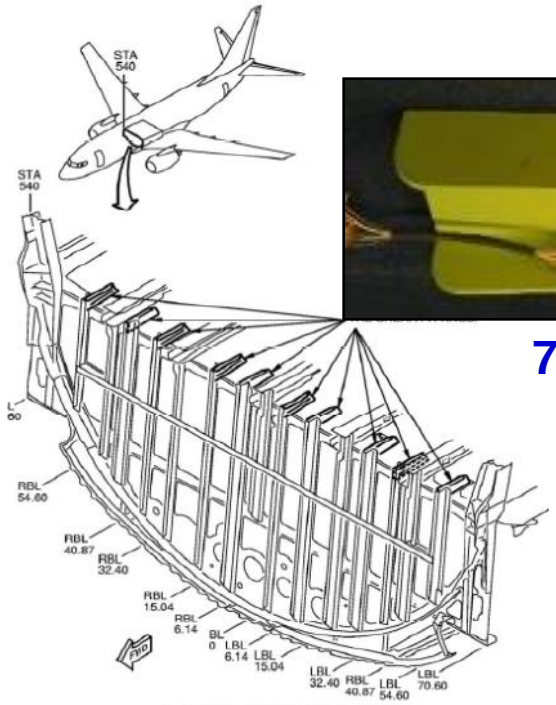
Consistent CVM Data Over Two Years of Flights - dCVM Well Below Damage Detection Threshold

CVM SMART SENSOR SOLUTIONS

CVM Sensor Network Applied to 737 Wing Box Fittings

Certification via Boeing SB 7373-57-1309 Rev 1

- **Comprehensive performance assessments completed: sensitivity, reliability, durability**
- **Flight testing: successful operation on flying aircraft**
- **Formal approval from OEM**



737 Wing Box Fittings

~ 1.75 M hours of successful flight history

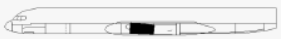
CVM SMART SENSOR SOLUTIONS

Adoption of SHM at Airlines –
Job Cards Produced to Guide All Aspects of CVM Deployment

CVM SENSORS AT WING CENTER SECTION SHEAR FITTINGS (STA 540), 737 - INSTALL; SECTION 01 -3

A/C **3602** Card **5711-01044-01-3** Crew **12**

Zone: 130 - Subzone - Body STA 540 to STA 727



7066542

WBS No.

DELTA **B737** A.A. Workcard **Page 2 of 4**

Scan Pages 2 of 4

Job # **059-0003**

INFORMATION:

For AA details, access the AA via the AA Management System. AA Management System and tutorial are located on TOHP under "Maintenance Links".

1. Ensure disposition of each of the 10 shear fittings from 5711-01044-01-2.

   A. If four (4) or more shear fittings contain cracks, then all 10 shear fittings will be replaced; contact Planning and proceed to 5711-1044-04 (N/A this card).

   B. If only one, two or three fittings are cracked, then only those fittings will be replaced (contact Planning and proceed to 5711-01044-04 for replacement of those fittings; N/A the steps corresponding to sensor installs for those affected fitting zones on this card).

      (1) The remainder of the fittings (in a non-cracked zone) will undergo sensor installation; proceed to next step.

Disposition
Inspector

2. Locate center wing box front spar shear fittings at Left Buttock Line (LBL) 54.60, 40.87, and 32.40 at Body Station (STA) 540. Install CVM sensors on all three fittings per Delta Technique Sheet SHM 100-57: B737-800 CVM Installation at Wing Center Section - Front Spar Shear Fittings (STA 540).

NOTE: If one or more of these fittings were found cracked in 5711-01044-01-2, then N/A the step for that fitting and replace only the cracked fitting or fittings via 5711-01044-4. Installation of CVM sensors will not occur on the affected fitting(s). Refer to Delta Technique Sheet SHM 100-57: B737-800 CVM Installation at Wing Center Section - Front Spar Shear Fittings (STA 540), for details about 'capping' the tubing to bypass the intended sensor location on the affected fitting(s).

NOTE: If the surface needs primer touch-up, accomplish via BSOPM 20-44-04 prior to installing sensors. Ensure surface meets requirements of Delta Technique Sheet SHM 100-57: B737-800 CVM Installation at Wing Center Section - Front Spar Shear Fittings (STA 540).

LBL 54.60	LBL 40.87	LBL 32.40
Mechanic	Mechanic	Mechanic

- **Job Cards point to 'Technique Sheet'**
- **Delta Technique Sheet used for CVM Installation**
  - **Date/revision controlled by Level III**
- **Second Delta Technique Sheet used for CVM Monitoring/Inspection**
- **Correct sign-offs needed (I/M)**
- **"What if" scenarios were covered**

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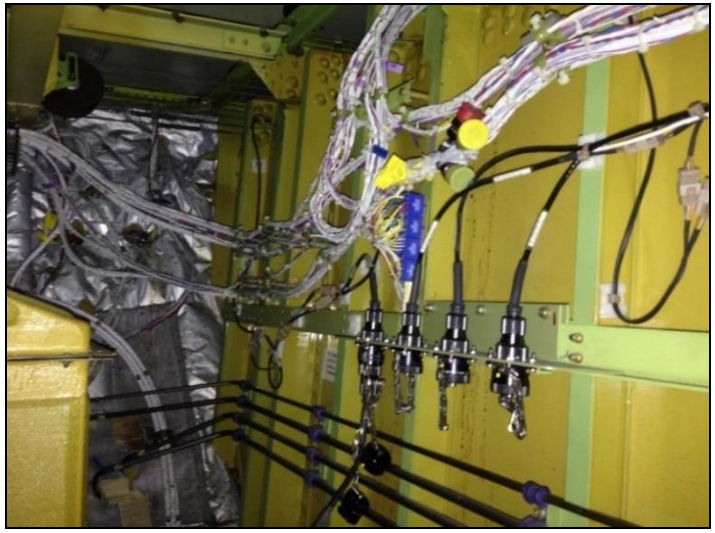
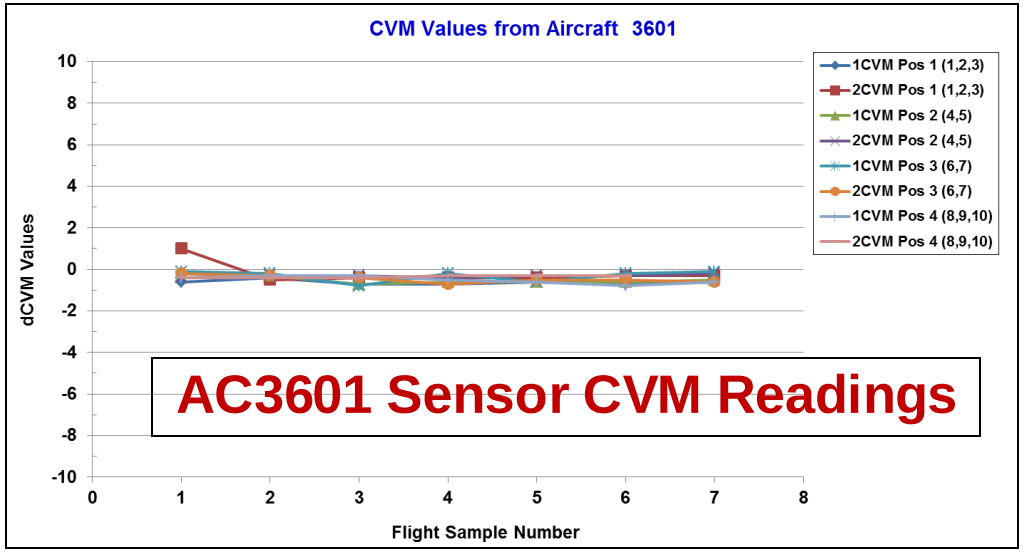
737NG Center Wing Box – Accumulating Successful Flight History

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

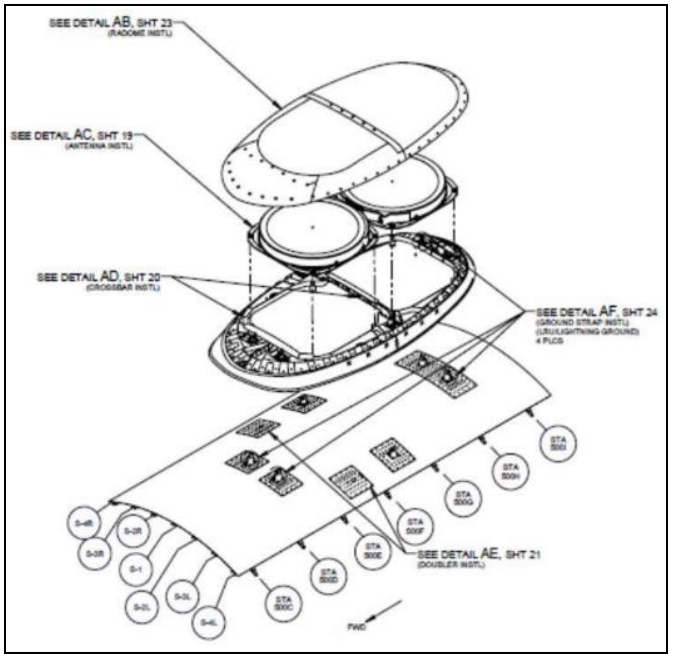


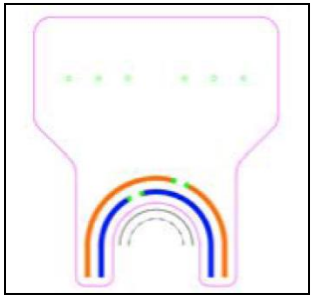
CVM SMART SENSOR SOLUTIONS

CVM Application – WiFi Antenna Installation Structure

Multiple aircraft types, multiple airlines

Certification via FAA STC ST04103NY

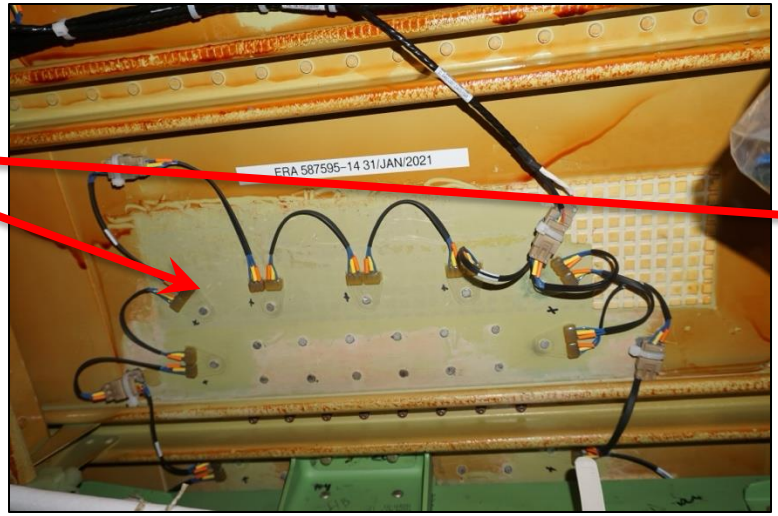


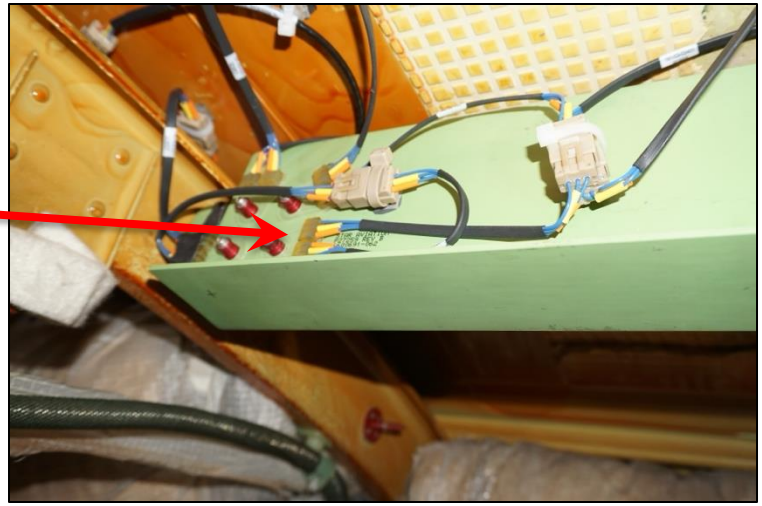


CVM Sensor Design

CVM sensors used to rapidly complete frequent, repeat HFEC/LFEC inspections required on internal structure hidden behind interior panels.

B737 Wi-Fi Antenna Support

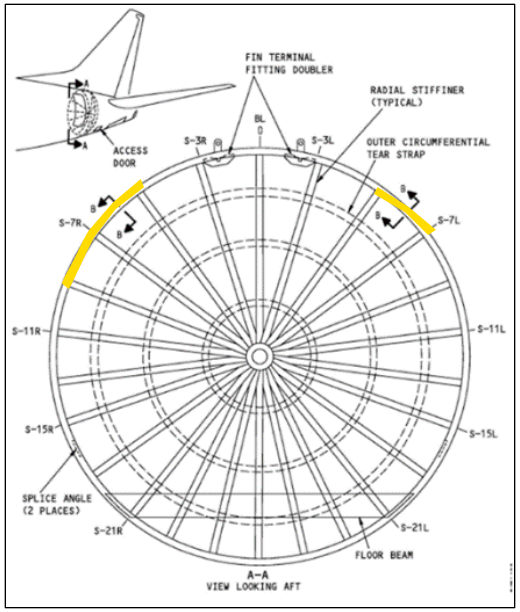




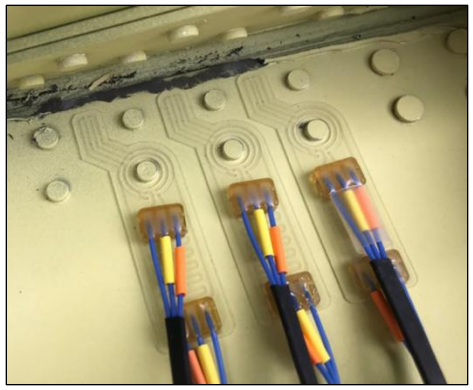
SMART SENSOR SOLUTIONS

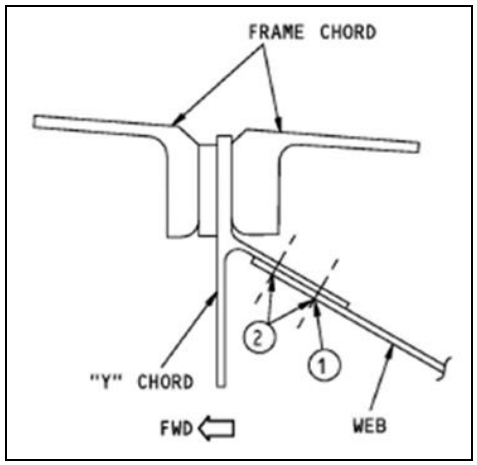
CVM Application – Aft Pressure Bulkhead Fitting

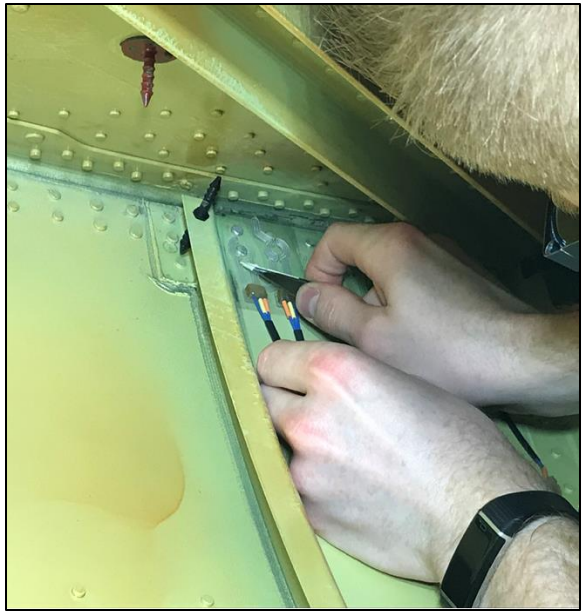
Circumferential cracks at fasteners connecting the web assembly to the bulkhead "Y" chord.



CVM Sensors on B737 Aft Pressure Bulkhead





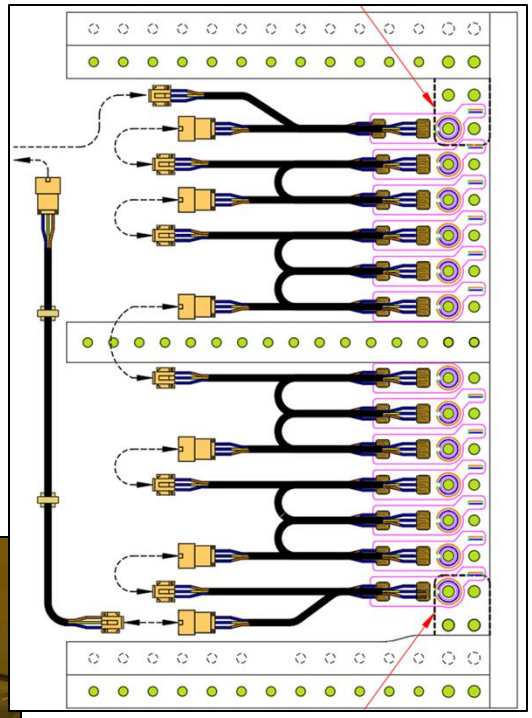


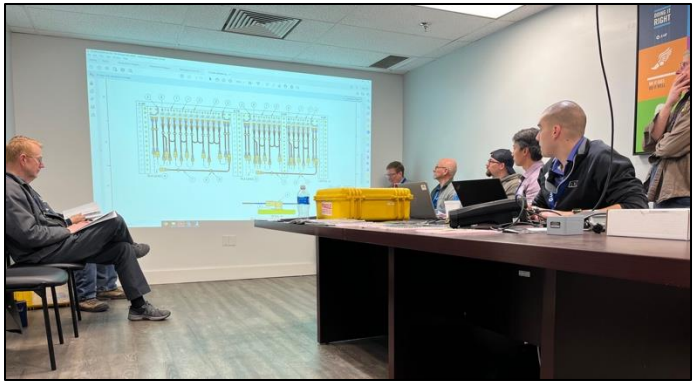
CVM SMART SENSOR SOLUTIONS

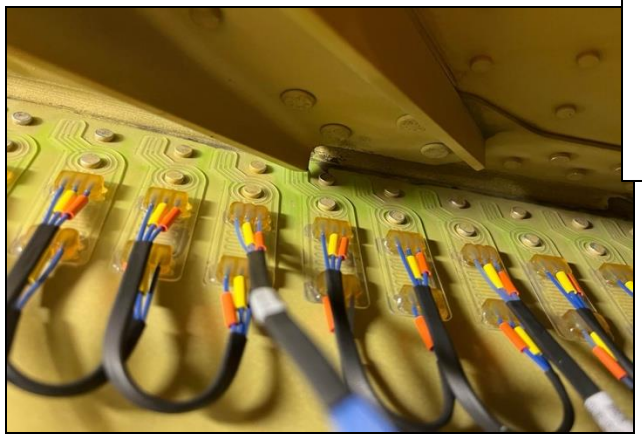
CVM Sensor Installation on Aft Pressure Bulkhead Fitting

- Total of 21-23 smart CVM sensors used to monitor up to 47 fasteners per application
- Installation and monitoring training (on-site) – hands-on guidance

Two-day Installation & Check-Out Process



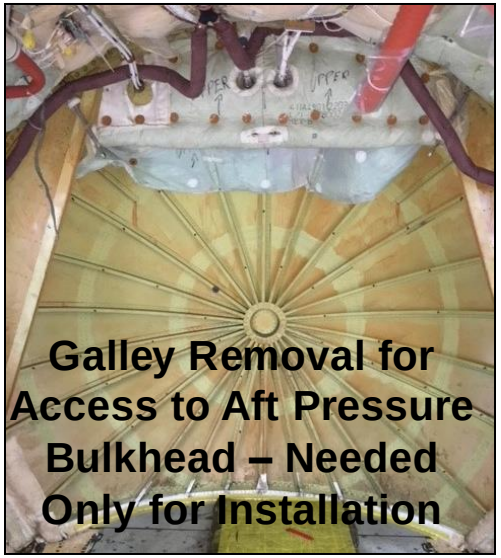




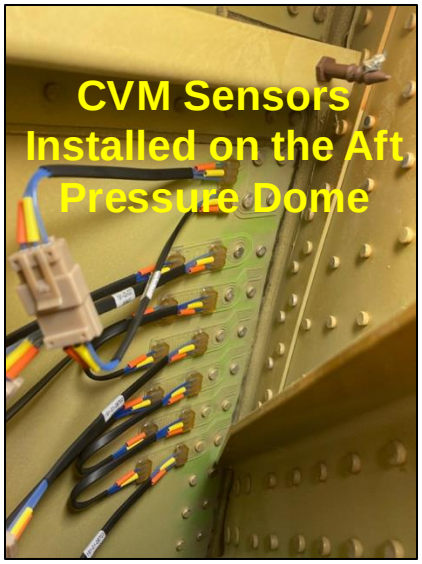
Pending Service Bulletin 737-53-1418

CVM SMART SENSOR SOLUTIONS

CVM Sensor Network Monitoring on Aft Pressure Bulkhead



Galley Removal for Access to Aft Pressure Bulkhead – Needed Only for Installation



CVM Sensors Installed on the Aft Pressure Dome

CVM Air Line Routing to SLS Connectors

Access to SLS Connectors

SLS connectors

Inspection - PM200 Monitoring Device

PM200 Verification Block – Confirms Proper Equipment Operation

SHM procedures are found in the Boeing 737 NDT Manual thus, inspectors perform the monitoring. When a procedure has the possibility of inspector interpretation – it is an inspector task.

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CVM Flight Testing – In-Service Reliability

- Fail-safe check – want continuity (flow) high = no gallery blockage
- Crack detection: if dCVM (vacuum) is low = no crack

737 Wing Box Fitting

- 70 CVM sensors on 7 Delta aircraft monitored every 90 days for over six years, producing over 1,400 sensor response data points

737 Aft Pressure Bulkhead

- Delta Air Lines installed CVM on 737NG APB 35+ aircraft (May 2019 – present); monitored every 90 days
- Over 250,000 flights hours producing over 2,900 sensor response data points

  - Seven MRO facilities trained for CVM Installation: Atlanta, Indianapolis, Kansas City, Oklahoma, Mexico City, Querétaro, San Salvador
  - Oklahoma information session for APB (May 2023) - Attendees from FAA, Boeing, Southwest, American, United, Delta
  - Exceptional success rate when training program has been deployed
  - Estimated over 1.75 M succesfull flight hours of in-service

No in-service issue with CVM on 737NG APB after addressing any issues during installation

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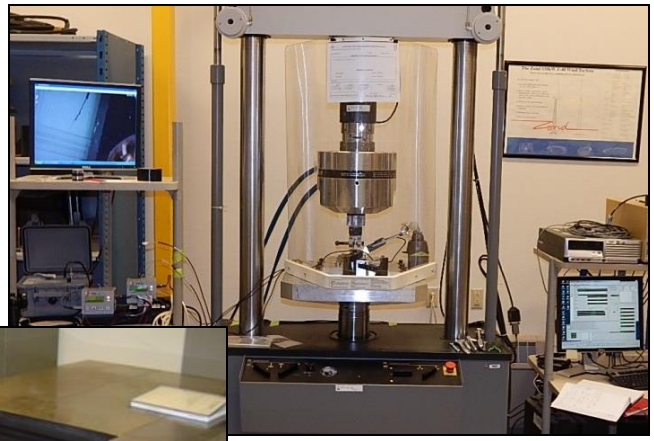
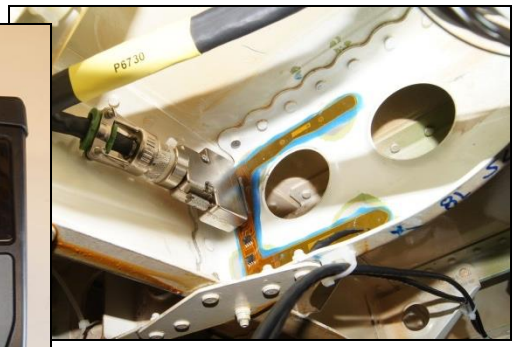
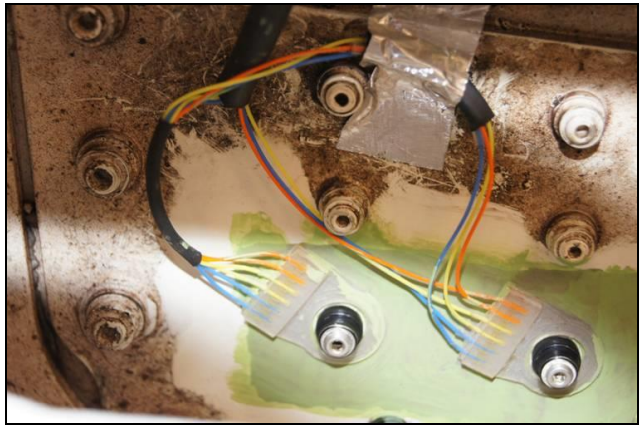
Validation of SHM Capability – Certification for Use

Laboratory Tests - quantify performance (POD), durability, reliability

Flight Tests – properly deployed with airlines, accumulate successful flight hours, safe adoption by maintenance programs







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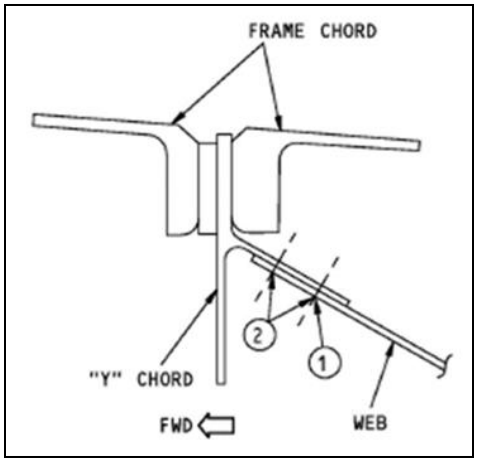
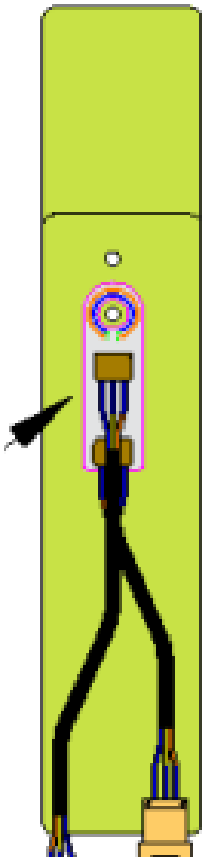
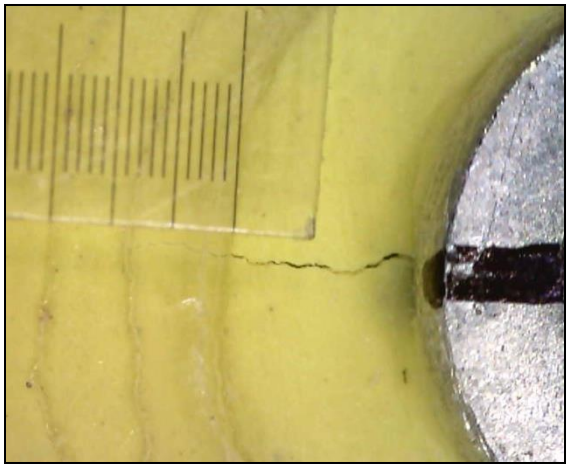
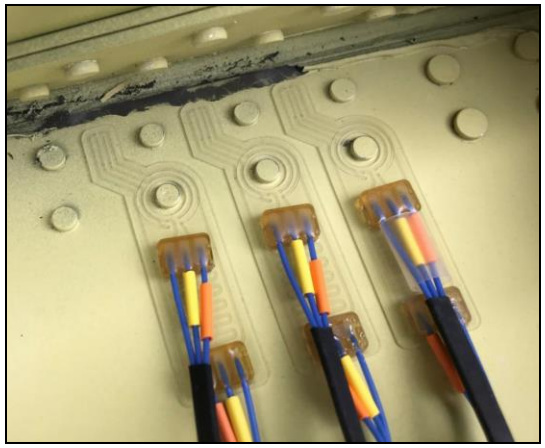
Validation Specimen Used to Determine POD for CVM









Test conditions	Value
Cold temperature (F)	39
Hot temperature (F)	104
Moisture (%)	95%RH
Pressure (feet)	10,000

737 Aft Pressure Bulkhead

Materials will match the B737 structure; 0.032” thick to match the APB web thickness, fastened to a 0.080” thick portion that takes the place of the Y-chord.

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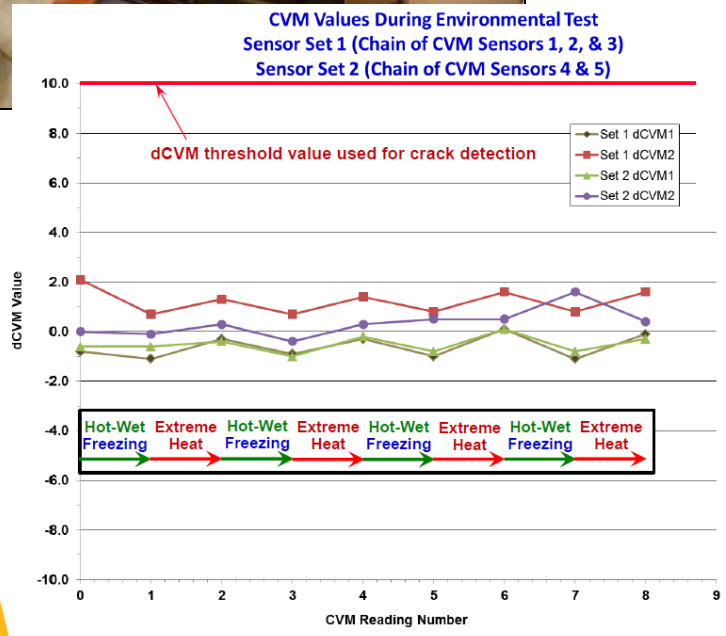
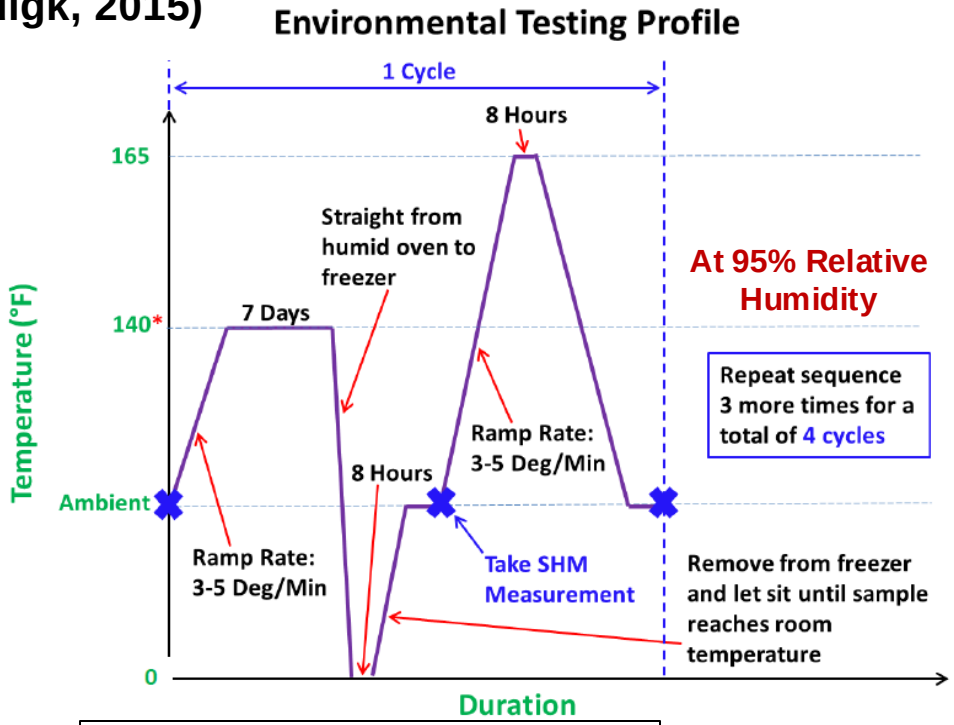
CVM Sensor Durability

Previous testing for durability of sensors: Boeing Data Package – Validation of a dCVM Structural Health Monitoring System for AMOC Integration Into an Airline Maintenance Program; (Roach, Rice, Neidigk, 2015)





DO-160G Section		Cat.		
4	Temp. & Altitude	C2	15	Magnetic Effect
	Loss of Cooling	-	16	Power Input
5	Temp Variation	B	17	Voltage Spike
6	Humidity	B	18	AF Conducted Susceptibility
7	Shocks & Crash Safety	B	19	Induced Signal Susceptibility
8	Vibration	U2	20	RF Susceptibility
9	Explosion Proofness	-	21	RF Emissions
10	Waterproofness	Y	22	Lightning Susceptibility
11	Fluids Susceptibility	F	23	Lightning Direct Effects
12	Sand and Dust	-	24	Icing
13	Fungus Resistance	-	25	Electrostatic discharge
14	Salt Spray	-	26	Fire, Flammability

DO-160 ENV: some existing some additional testing

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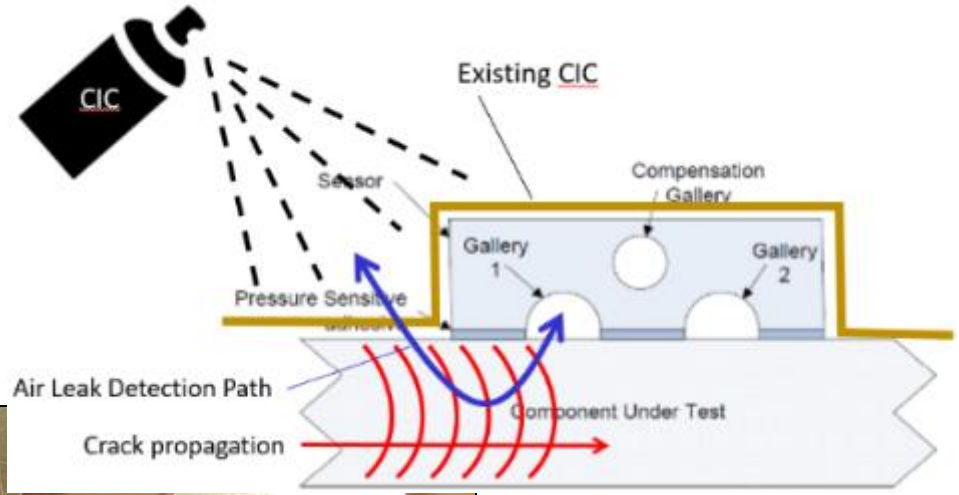
Corrosion Inhibiting Compounds –
Assess Effects of Chemicals on Sensor Performance

Corban-35 and AV-8 CIC applied to extreme levels: Spray inside of faying surface directly and then assemble panel; excessive accumulation/pooling



CVM
SMART SENSOR SOLUTIONS

CVM Validation - Planning and Execution

Sample Boeing Docs

Boeing Proprietary July 28, 2022
737-CSE-22-057

COORDINATION SHEET

To: Auslander, Kristin M 1536808 66-CQ-EC40

Cc: Akdeniz, Aydin 2597 66-CQ-EDAP
Klein, Jaclyn H 344748 66-CQ-EC40
Cigolini, Luca R 2644862 66-CQ-EC6R
Membrila, Armando X 2198772 66-CB-YJ30

Group Index: Customer Support Engineering:

Model No.: 737-NG

Subject: Comparative Vacuum Monitoring (CVM) – Structural Monitoring Systems (SMS) Ltd. Qualification Plan for Service Bulletin (SB) 737-53A1248 Aft Pressure Bulkhead Alternative Inspection Method

Boeing Proprietary May 1, 2023
737-CSE-23-071

DINATION SHEET

1536808 66-CQ-EC40

66-CQ-EC6Q Miller, Theresa K 186030 66-CB-YS50
66-CQ-EC40

Group Index: Customer Support Engineering: Customer Support Engineering:

Model No.: 737-NG

Subject: Test Requirements to Address Effects of Corrosion In
Comparative Vacuum Monitoring (CVM) for Service B
Pressure Bulkhead Alternative Inspection Method

FAILURE MODE AND EFFECTS ANALYSIS

P/N: **737APB-SXXSXX-IKCVM** Description: **APB Installation Kit**
Document: **655-0** Rev: **2.00**

BOEING

CAGE Code 81205

Test Report: Long-term Durability and Probability of Detection Capability of Comparative Vacuum Monitoring (CVM) System for 737NG Aft Pressure Bulkhead Web Inspection

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737APB-S5RS9R-IKCVM
Comparative Vacuum Monitoring Installation Kit

Technique Cover Sheet

737APB-S5RS9R-IKCVM-536-0 Rev. 1.32

January 24, 2024

Sample AEM Docs

QUALIFICATION ANALYSIS

Part #: **737APB-SXXSXX-IKCVM** Description: **APB CVM Qualification Analysis**
Document: **737APB-SXXSXX-IKCVM-652-0** Rev.: **1.01**

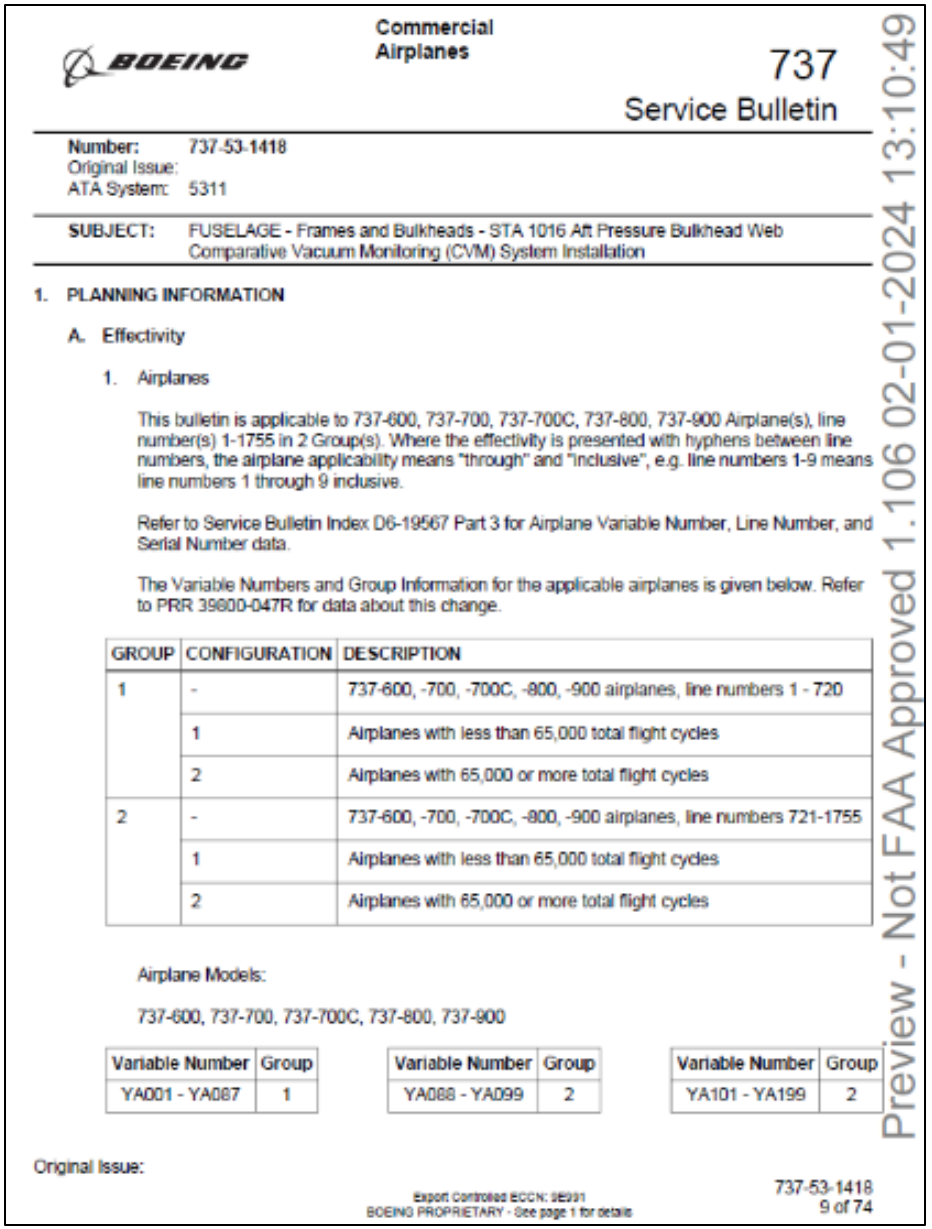
CVM SMART SENSOR SOLUTIONS

Boeing Certification Plan 25464 Output – Service Bulletin

- CVM Performance Assessment
- In-Service Data
- Elec Compliance
- Flammability
- ICA
- Historical Data

Service Bulletin 737-53A1248 (AD 2005-21-06 & 2016-18-15) requires inspection of web at "Y" chord: LFEC inspection (aft side) - outside of a regular maintenance schedule

Service Bulletin 737-53-1418 as AMOC: CVM inspection (fwd side) every 1,200 flight cycles



BOEING Commercial Airplanes

737 Service Bulletin

Number: 737-53-1418
Original Issue:
ATA System: 5311

SUBJECT: FUSELAGE - Frames and Bulkheads - STA 1016 Aft Pressure Bulkhead Web Comparative Vacuum Monitoring (CVM) System Installation

1. PLANNING INFORMATION

A. Effectivity

1. Airplanes

This bulletin is applicable to 737-600, 737-700, 737-700C, 737-800, 737-900 Airplane(s), line number(s) 1-1755 in 2 Group(s). Where the effectivity is presented with hyphens between line numbers, the airplane applicability means "through" and "inclusive", e.g. line numbers 1-9 means line numbers 1 through 9 inclusive.

Refer to Service Bulletin Index D6-19567 Part 3 for Airplane Variable Number, Line Number, and Serial Number data.

The Variable Numbers and Group Information for the applicable airplanes is given below. Refer to PRR 39800-047R for data about this change.

GROUP	CONFIGURATION	DESCRIPTION
1	-	737-600, -700, -700C, -800, -900 airplanes, line numbers 1 - 720
	1	Airplanes with less than 65,000 total flight cycles
	2	Airplanes with 65,000 or more total flight cycles
2	-	737-600, -700, -700C, -800, -900 airplanes, line numbers 721-1755
	1	Airplanes with less than 65,000 total flight cycles
	2	Airplanes with 65,000 or more total flight cycles

Airplane Models:

737-600, 737-700, 737-700C, 737-800, 737-900

Variable Number	Group
YA001 - YA087	1

Variable Number	Group
YA088 - YA099	2

Variable Number	Group
YA101 - YA199	2

Original Issue:

Export Controlled ECCN: 9E991
BOEING PROPRIETARY - See page 1 for details

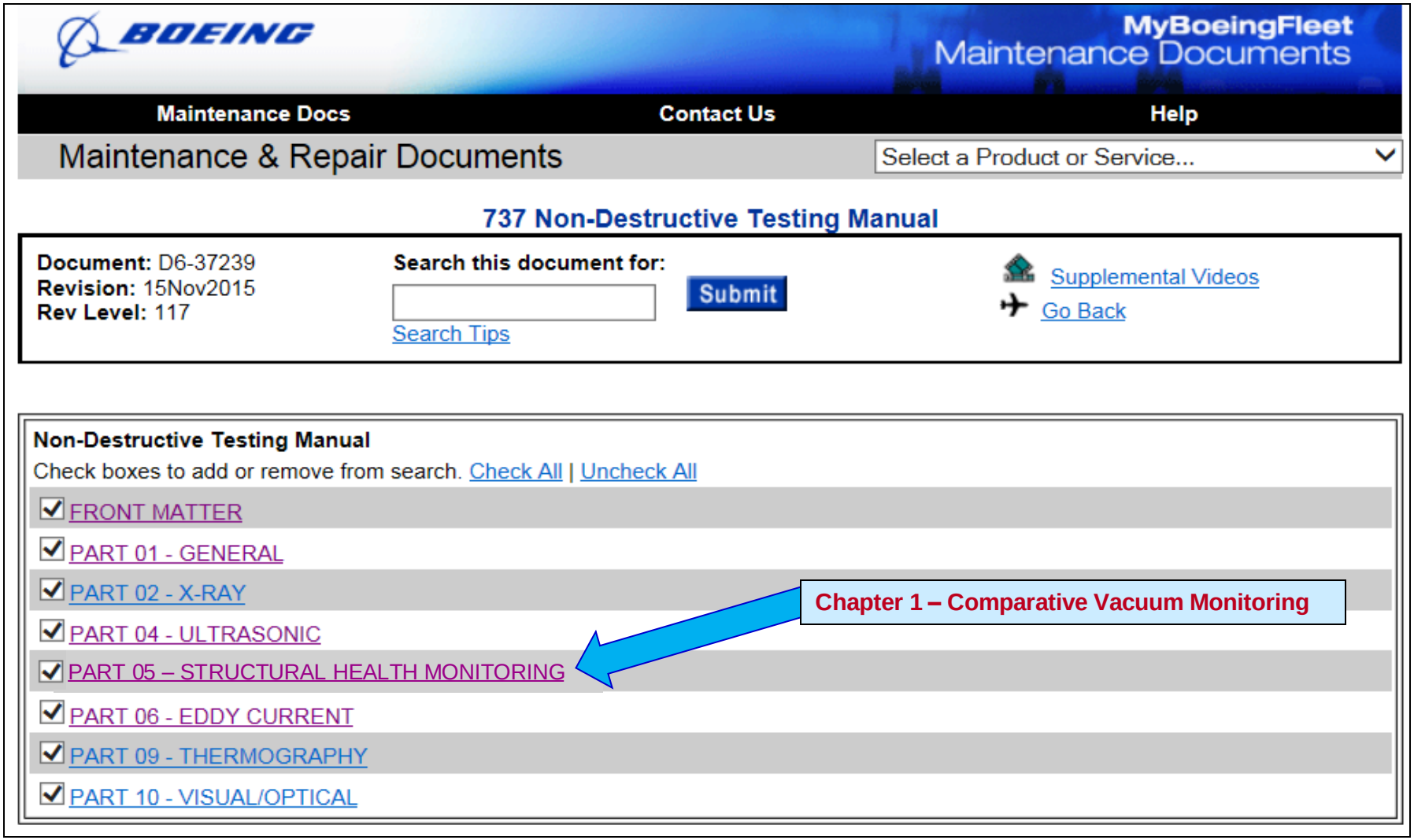
737-53-1418
9 of 74

Preview - Not FAA Approved 1.106 02-01-2024 13:10:49

CVM SMART SENSOR SOLUTIONS

737 NDT Manual - New SHM Chapter Published (Nov 2015)

Building Block to Approval for Routine Use of SHM



SMART SENSOR SOLUTIONS

Certification to Allow for Routine Use of CVM Solutions

Wing Box Fitting: Boeing Service Bulletin (June 2016)

BOEING SERVICE BULLETIN 737-57-1309

BOEING — Commercial Airplanes

737 Service Bulletin

Number:	737-57-1309
Original Issue:	January 28, 2011
Revision 1:	June 27, 2016
ATA System:	5714

Revision Transmittal Sheet

SUBJECT: WINGS - Center Wing Box - Front Spar Shear Fitting - Inspection, Repair and Preventive Modification

This revision includes all pages of the service bulletin.

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.

United States of America
Department of Transportation
Federal Aviation Administration
Supplemental Type Certificate
Number: ST04103NY

Description of Type Design Change:

Installation of Structural Monitoring Systems Comparative Vacuum Monitor (CVM) Sensors in accordance with Delta Engineering Master Data List 0106-10998-2499 Revision A dated Mar. 2, 2022 or later FAA approved revisions to Delta Engineering Master Data List previously listed. The Instructions for Continued Airworthiness as listed on the Master Data List is required with this installation.

WiFi Monitoring: Supplemental Type Certificate (Mar 2022)

CVM SMART SENSOR SOLUTIONS

FAA Issue Papers – Generic and Specific (2019, 2021)

FAA IP on SHM represents the first formal set of guidelines from the FAA for certification of Structural Health Monitoring (SHM) systems in routine maintenance activities.

WiFi SPECIFIC IP

For use in conjunction with Memo No. AIR600-18-AIR-6C0-DM119
Electronic means of capturing the below data can be used in lieu of this grid.
Remove Grid Before Transmitting Externally

ISSUE PAPER

PROJECT:	Delta Engineering ODA Boeing 737-600/-700/-700C/-800/-900/-900ER Project No. ODA-2499-01	**ITEM:** A-1 **STAGE: 2**
REG. REF.:	§ 21.50, § 25.571, §25.1529, Appendix H,	**DATE:** 11/21/19
		ISSUE STATUS: OPEN
NATIONAL POLICY REF:	AC 25.571-1D	**BRANCH ACTION: AIR-7H1, AIR-7H2, AIR-675, AEG**
SUBJECT:	Comparative Vacuum Monitoring (CVM) for Damage Detection in Structure of Antenna Installations	**COMPLIANCE TARGET:** Pre-STC

Method of Compliance

STATEMENT OF ISSUE:

Delta Engineering seeks a supplemental type certificate (STC) to install a Structural Health Monitoring (SHM) system—Comparative Vacuum Monitoring (CVM)—on a Boeing 737 model airplane. An SHM system such as CVM, evaluates the integrity of certain structure by acquiring data from on-board sensors that interface with handheld carry on electronic device. This approach for detecting structural damage (e.g., fatigue cracking) eliminates the need for an inspector to physically access and assess structure. Over the past 35 years, industry has used nondestructive inspection (NDI) techniques, such as visual and eddy current inspections, to detect structural damage and ensure the continued airworthiness of transport category airplanes. Industry incorporates procedures and timing for implementing NDI techniques & in the Instructions for Continued Airworthiness (ICA) manuals as part of their data for showing compliance with Title 14, Code of Federal Regulations (14 CFR) 25.571 and 25.1529.

Physical accessibility of structure has been an important aspect of inspection programs used to ensure the continued operational safety of transport airplanes. The FAA has not previously approved an SHM system as an inspection technique for compliance with §§ 25.571 and 25.1529. The current industry practice and guidance used to validate conventional NDI techniques may not be adequate for an SHM system. The purpose of this issue paper is to ensure the proposed SHM system can adequately & reliably detect damage for compliance with §§ 25.571 and 25.1529.

This issue paper specifies key elements and criteria the applicant must address to demonstrate that their proposed SHM system adequately replaces existing ICA that are necessary for compliance with §§ 25.1529 and 25.571. The primary intent of §§ 25.1529 and 25.571 is to ensure an airplane's structural maintenance program will prevent catastrophic failure due to fatigue damage over the operational life of the airplane. The elements and criteria identified in this IP (FAA Position) will guide the applicant's comprehensive assessment of the functionality, reliability, durability, and maintainability of the proposed SHM system.

Generic SHM Certification IP

ISSUE PAPER

PROJECT:	*[Applicant]* Model *[make & model]* Project No. *[project number]*	**ITEM:** A-# **STAGE:**
REG. REF.:	14 CFR § 21.50, § 25.571, §25.1529, Appendix H	**DATE:**
NATIONAL POLICY REF:	AC 25.571-1D	**ISSUE STATUS:** Open
SUBJECT:	Qualification of a Structural Health Monitoring System for Detection of Damage in Structure	**OFFICE ACTION:** AIR-621, AED **COMPLIANCE TARGET:**

Method of Compliance

STATEMENT OF ISSUE:
The applicant proposes to install a Structural Health Monitoring (SHM) system on a model <Enter TCDS Model(s)> airplane. An SHM system evaluates the integrity of structure by acquiring and analyzing data from on-board sensors that interface with an electronic device (either on-board or off-board) that processes the data and provides an indication of the health of structure in terms of the existence of damage (e.g., fatigue damage). A SHM technology capable of reliably detecting damage of a specific nature and size over a specific line, area or volume is a candidate alternative to conventional non-destructive inspections (NDI) such as visual, eddy current, ultrasonic and X-ray inspections methods. This approach for detecting structural damage may supplement or eliminate the need for an inspector to physically access and assess structure. Over the past 30 plus years, industry has relied on accessing structure to assess its overall integrity and, as part of that assessment, perform NDI such as visual and eddy current inspections, to detect structural damage. The current industry practice and guidance used to validate conventional NDI techniques may not be adequate as a method of compliance with title 14, Code of Federal Regulations (14 CFR) 25.571 and 25.1529 for an SHM system. Therefore, this issue paper is necessary to establish an acceptable method of compliance.

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Training to Support Adoption of SHM

- Classes established to support education of engineers, maintenance managers, installers and SHM system monitors (airlines, OEMs, regulators, SHM developers)
- EASA SHM class (Oct 2023) and two FAA on-line classes (Part 1; Part 2)

SHM Training Overview

Module 1 – Introduction to SHM Technology and SHM Implementation

Module 2 – SHM Validation, Performance Assessment & Prep for Routine Use

Module 3 – Integration of SHM into Airline Maintenance Programs

Module 4 – SHM Certification & Approval: Regulatory & Industry Guidance

Module 5 – Installation and Monitoring of SHM Systems

Module 6 – Personnel Qualification for SHM Usage

- SHM General Training – Technique Independent
- SHM Specific Training – Technique Dependent (qualification)
- Qualification Levels
    1) Level I – Inspector
    2) Level II – Installer
    3) Level III – Trainer
        - Level III (Expert) – Instructor

Certified training for specific applications

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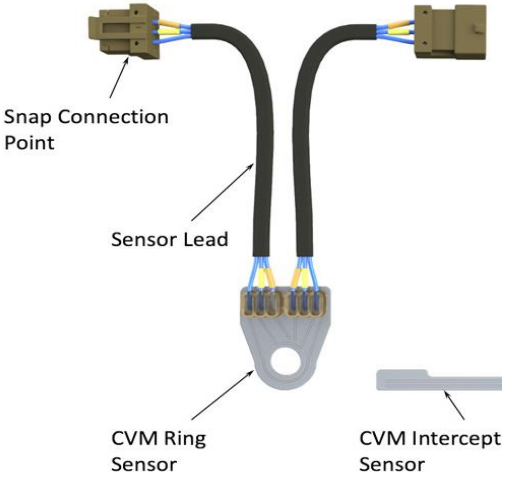
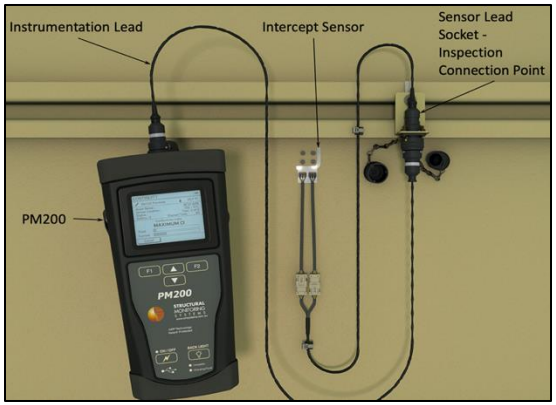
Inspections Using CVM System – Training for CVM Monitoring

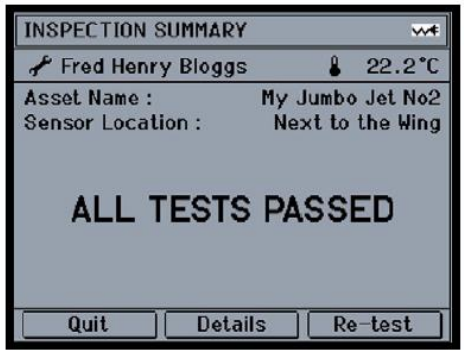
CVM™ INSPECTOR TRAINING

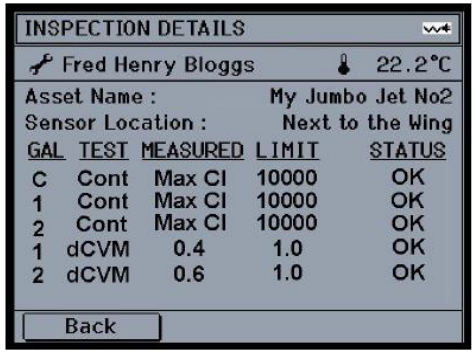
STRUCTURAL MONITORING SYSTEMS plc

TRAINING PACKAGE FOR CVM™ INSPECTORS









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737APB-S5LS7L-IKCVM

Comparative Vacuum Monitoring Installation Kit

Technique Cover Sheet

737APB-S5LS7L-IKCVM-536-0 Rev. 1.40

December 14, 2023

COVER SHEET FOR DOCUMENTATION PURPOSES ONLY
DO NOT PRINT THIS PAGE.

Prepared By:	Checked By:	Approved By:
Bifan Structural Designer 14-Dec-2023	Darin Ingram Designer 14-Dec-2023	

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Conclusions on Routine Use of SHM Solutions

- **Strong industry interest in SHM – multitude of applications**
- **CVM for monitoring fatigue damage, especially in hard to access locations, has been found to be a common use-case across OEMs**
- **"Out-of-cycle," time-consuming inspections are first candidates for CVM**
- **Goal: maximize fleet utilization by reducing hangar-based downtime**
- **Adoption of CVM replaces time-consuming, costly and potentially destructive manual inspections on aircraft**
- **Quantitative performance analysis methods have been evolved along with corresponding regulatory guidance on certification**
- **General lab performance (POD, durability) & flight test data is accumulating - OEM and regulator approvals are supported by years of cumulative testing**
- **Airline operator adoption of CVM has occurred & routine use is underway**
- **Certification & regulatory framework has evolved to streamline applications for use (AMOC for SBs and ADs or STCs)**
- **Safe use of SHM and associated benefits to airlines is a joint effort of maintenance management, engineering, A&P and inspection depts.**

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Integration of SHM and NDI for Optimized Monitoring of Commercial Aircraft

Special Thanks:

Walt Jarecki and Zeb Tidwell, Boeing

David Piotrowski, Delta Air Lines

Brian Shaigec and Derrick Formosa, AEM/SMS

SMART SENSOR SOLUTIONS

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Historical CVM Partners for Integration into Routine Maintenance

Integration of SHM and NDI for Optimized Monitoring of Commercial Aircraft

Dennis Roach
Trevor Lynch-Staunton
Structural Monitoring Systems
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Reliable Structural Health Monitoring (SHM) systems can automatically process data, assess structural condition and signal the need for human intervention. The use of in-situ sensors, coupled with remote interrogation, can be employed to overcome a myriad of inspection impediments stemming from accessibility limitations, complex geometries, and the location and depth of hidden damage. Recent efforts by regulators, OEMs, airlines and SHM developers have moved SHM into routine use for aircraft maintenance. Specifically, as the use of Comparative Vacuum Monitoring (CVM) technology increases, it is important to recognize the need to properly integrate SHM with NDI tasks. An array of SHM integration programs have addressed formal SHM technology validation and certification issues so that the full spectrum of concerns, including design, performance, deployment, and continued airworthiness were appropriately considered. This paper will provide an update on CVM deployment and certification in several aircraft applications, streamlined processes for airline adoption, prospects for SHM to compliment NDI, and FAA training initiatives to assist the safe integration of SHM with ongoing NDI activities. Formal documents have been modified by aircraft manufacturers to accommodate SHM usage. The FAA and industry standards organizations have also published essential guidelines for SHM deployment and procedures for assessing the performance of SHM systems. These efforts are allowing SHM solutions to efficiently and safely support maintenance activities by working in concert with related NDI tasks.