From NDT to SHM
A Practical Approach

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NDT - SHM

Use in Service – MSG3

Applications & Solutions

Testia support along the process chain
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What is NDT?

**Nondestructive testing or non-destructive testing (NDT)** is a wide group of analysis techniques used in science and technology industry to evaluate the properties of a material, component or system **without causing damage**  

- Equipment (sensors) cover a **wide range of different applications**
- **Active system** (usually excitation/measurement in one unit/equipment)
- Usually **time consuming**
- Damages in hidden structures can only be **inspected through other structures**
- Detectable **damage size often increase with the thickness** of the structure
- **Human interaction** necessary
- Only **scheduled inspection** possible
- Mainly **single**, separated **locations**
- To get access, **removing of installations** sometimes necessary

*Source: Wikipedia*
Sections of the NDT Process

NDT/NDI 'Non Destructive Testing / Investigation of materials and compounds with regard to defects, physical & chemical properties'

Principle

**Excitation**
- Probe X
- Thermal
- Mechanical
- Magnetic
- Electric
- Electro-magnetic
- Radiative (+ VIS)

**Material, Compound**
- Interaction
  - Matter
  - Defects
  - Boundary Layers

**Response**
- Detected Signal
  - Thermal
  - Mechanical
  - Magnetic
  - Electric
  - Electro-magnetic
  - Radiative (+ VIS)

**Evaluation**
- Information on
  - Defects
  - Properties

- ! Coupling
- ! Access
- ! Complex Interaction
- ! Coupling
- ! Access
- ! Parasitic Effects
- ! Processing
- ! Modelling
What is SHM?

SHM is the **continuous, autonomous** in-service monitoring of the **physical condition** of a **structure** by means of **embedded or attached sensors** with a minimum manual intervention, to monitor the **structural integrity** of the aircraft.

Human nervous system: detection of intensity and location of pain and doctor visit judgement

**Evaluation**

**SHM system:** monitoring of airframe and evaluation of the follow up maintenance actions
The Global Approach

- Use of real-time diagnostics (On-Condition maintenance)
- Prognostics will avoid unnecessary unscheduled maintenance
- No physical access required
- Shorter inspection time

Less scheduled and unscheduled maintenance
SHM = Complexity

SHM is not only a sensor
SHM – Transdisciplinary Approach

Material+ Structure

Effects of defects (EOD)
Failures/Properties to be monitored
Determination of SHM method

Failures/Properties to be monitored
Sensors

Application of sensors:
Modelling of optimised sensors placement
Simulation: -Bonding -Embedding

Reliability:
Probability of Detection (POD)
Durability

Application of sensors:
Modelling of optimised sensors placement
Simulation: -Bonding -Embedding

Benefits: DMC reduction Increase availability Postpone repairs

Use for Maintenance optimisation
Use for Design optimisation

Benefits: Reduction of Weight Detection of Loads/Overloads

Implementation Manufacturing

Prognostic

Data analysis

Data Transfer

Sensor/SHM Unit

Power Supply

SHM equipment:
Offboard Onboard

Metals:
Corrosion Fatigue

Composites:
Impacts Overloads

BVID (Barely visible impact damage) Debondings

Holger Speckmann, CoC Structure, M&P - Testing Technology
What to detect or measure?

- **Measurement** of in flight real A/C constrains
  - Analysis of repercussion (ex: hard landing, tail bumper)
  - Recording of exceptional, aerodynamic loads/strains
  - Recording of loads in hot spot areas
  - Customisation of A/C life cycle
  - Flight control coupling for limitation of in flight constraints

- **Detection** of damages
  - Inspection in hazardous areas without direct access
  - Weight saving through sizing cases deletion (e.g. broken stringer)

- **Monitoring** of damage propagation:
  - Postpone repairs to planned checks
  - Reduction of downtime – Increased availability

**Approach:**

- **Multi Disciplinary approach:**
  - System compatibility, Cabin, Costumer support, Maintainability
Benefits of SHM

**SHM**

Continuous and autonomous monitoring of defects, stress/strain, environmental and flight parameters by means of permanently attached or embedded sensor systems in order to ensure the structural integrity.

**Maintenance / Operatability**
- Reduction of inspection time
- Deferred maintenance / repair
- Maintenance on demand
  - **Reduced DOC, DMC**
  - **Increased Availability**

**Design**
- Optimised structural efficiency
- New design philosophies
  - **Weight saving**
Benefit of SHM

Scheduled Maintenance Process

- EASA/FAA rules
- Maintenance Plan Document (MPD)
- Aircraft Maintenance Manual (AMM)
- Non-destructive Testing Manual (NTM)
- Visual

Possible Benefits on

- Performance of inspection tasks
- Inspection time & procedures process

Unscheduled Maintenance Process

- Damage

Possible Benefits on

- Structure Repair Manual (SRM) – Service Bulletin
- Repair Approval Sheet (RAS) – Additional damage

For Service Bulletins (Inspection and Mod), the process is similar

Damage assessment tasks & Repair decision

Inspection time of temporary repairs
3rd Option for Service Bulletins

• Damage detection in metal and composite structures to replace ISBs by SHM

Benefits:

→ Avoiding development of complex NDT technology and complex description in NTM
  benefit for OEM

→ Avoiding of penalizing inspections and opening areas with difficult access (100% of aircraft to be inspected, number of expected damages is only a few %)
  benefit for operator

→ Use of SHM standard equipment, to be performed by non-specialist
  benefit for operator
New, SHM enabled Design

SHM can provide a design benefit (weight saving) or a maintenance benefit.
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Basic Maintenance Definitions & History

Maintenance as defined by World Airlines Technical Operations Glossary (WATOG*)
*today replaced by ATA Common Support Data Dictionary

Scheduled or Preventive Maintenance
That maintenance performed at defined intervals to retain an item in a serviceable condition by systematic inspection, detection, replacement of wear-out items, adjustment, calibration, cleaning, etc.

Unscheduled or Corrective Maintenance
That maintenance performed to restore an item to a satisfactory condition by providing correction of a known or suspected malfunction and/or defect
MSG-3 Document Evolution

- **MSG-1**
  - Maintenance Evaluation and Program Development
  - Prepared by: 747 Maintenance Steering Group
  - Date: July 10, 1968
    - Aug. 1, 1968
    - June 1, 1969
  - Boeing 747

- **MSG-2**
  - Airline / Manufacturer Maintenance Program Planning Document
  - Prepared by: R&M Subcommittee, Air Transport Association
  - Date: March 25, 1970
  - Douglas DC-10
    - Lockheed L-1011

- **EMSG**
  - European Maintenance System Guide
  - Prepared by: Association of European Airlines
  - Date: July 1972
    - August 1972
    - Sept. 1972
    - February 1973
  - Airbus A300B2/B4
    - AS/BAe Concorde
    - VFW 614

- **MSG-3**
  - Airline / Manufacturer Maintenance Program Development Document
  - Prepared by: MSG-3 Task Force, Air Transport Association
  - Date: September 30, 1980
    - March 31, 1988 - Rev.1
    - Sept. 12, 1993 - Rev.2
  - A310/A300-600
  - A319/320/A321
  - A330/A340
  - B757/767/777/787
MSG3 preparation process

The MPIG delegates the preparation of Issue Papers associated with extensive MSG-3 revision proposal to dedicated working groups (i.e. L/HIRF, SHM...)

Diagram:
- Draft IP
- Candidate IP
- Rework Loop (if needed)
- Preparation Loop
MSG-3 Document Revision Process

who is the “ATA MSG-3 SHM WG?”

Supporting the IP draft process with their advise
MSG-3 Document Revision Process

who is the “MPIG”?
MSG-3 Document Revision Process

who is the “IMRBPB?”

The Regulators!

Civil Aviation Bureau
MSG 3 Revision

The term **S-SHM** is introduced as a maintenance task level in MSG-3:

**Scheduled SHM (S-SHM):**
S-SHM is the act to use/run/read out a SHM device at an interval set at a fixed schedule

The structure section is revised to select **S-SHM** tasks and interval **in lieu of classic inspections**

Structure inspection tasks for Accidental Damage (AD), Environmental Deterioration (ED) and/or Fatigue Damage (FD) can be replaced by a scheduled interaction with a SHM device where demonstrated to be applicable and effective
Inpection level according to MSG3, as of today

1. Visual Inspection
   GVI (General Visual)
   DET (Detailed)
   Steered by MPD
   Performed in according to AMM, etc.

2. NDT (Non Destructive Testing)
   SDET (Special Detailed)
   Using of Tools and equipment
   Procedures mainly in NTM
   Steered by MPD, SB, etc.

3. SHM
   SDET (alternative to NDT)
   Permanent installed sensors
   Procedures for Off-Board use in NTM
   On-Board and/or On-Line use via IVHM architecture
   “Automated SHM”
SHM in MSG-3 IP105 (pending since 2010)

The MSG-3 principle concept avoids reference to specific (SHM) technology details as it should cater for the full range of application scenarios.

In this respect two further scheduled maintenance SHM classification categories have been defined:

**SHM Operation Mode**

- **Scheduled SHM (S-SHM)** – from IP92, no change
- **Automated SHM** - SHM technology which does not have a pre-determined interval at which maintenance action much takes place, but instead relies on the system to inform maintenance personnel that action must take place.

**SHM Technology Type**

- **Damage Monitoring System** – SHM technology that uses sensors to *directly* monitor structure for deterioration conditions
- **Operation Monitoring System** – SHM technology that uses sensors which do *not directly* check the structure for damage, but instead correlate various measurements (e.g. environment conditions, loads) to make an inference to the probability or likelihood of damage.
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Application at In-Service – some examples

**Structural Health Monitoring (SHM)**
- Sensors permanently applied on the structure
- Fast automated inspection
- No "physical" access necessary
- Continuously monitoring of known flaws
- Inspection outside the maintenance schedule

**COMPOSITES**
- Impact detection and localisation
- Repair monitoring
- Delamination detection
- Debonding

**METALS**
- Crack detection
- Crack growth monitoring
- Corrosion detection

Example: CVM

Example: Acousto Ultrasonics
Maintenance Application

- Damages caused by corrosion
- Fatigue Cracks
- Inspection of Hidden areas without removal of installations
Examples of damage and load sensing technologies

- A large scope of sensing technologies:
  - CVM (Comparative Vacuum Sensors)
  - Acoustic Emission
  - Foil eddy current sensors
  - Acousto Ultrasonic
  - Fibre Bragg Gratings (FBG)
  - ...
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Documents
- Develop and prepare documents for installation, instrumentation and protection
- Work in close cooperation with OEM, operators and authorities

Consultancy
- Act as focal point for all involved parties
- Make the link between OEM, system integrator and operator
- Expert in SHM Toolbox application

Installation
- Install sensors, cables, connectors, etc.
- All kind of sensors to be installed
- Worldwide service
- Service for all industries & all customers

‘SHM Toolbox’
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Protection
- Protect all SHM elements according to OEM needs

Functional Check
- Perform functional checks of the system
- Certify performance
- Calibration & recalibration of systems

System Operation
- Being in-situ to perform the measurements
- Using tools to remote analyze areas with sensors
- Frequently reporting to customers
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Analysis
- Collect and store data (if requested)
- Evaluate data
- Diagnostic of data
- Simulation

Predictive Maintenance
- Use analyzed data to support prediction of failures
- Provide predictive maintenance solutions (Big Data analysis)
- End-to-End Life-Time-Monitoring

Repair & Maintenance
- Repair sensors, cables, connectors, etc.
- Reinstall sensors and protect
- Periodically check of sensor and equipment function
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**Training**
- Perform trainings for installation and operation of sensor systems
- eLearning for remote training & education
- Hands-On trainings for all sensor types

**Supplier & Partner**
- Provide the "Tool Box" with the right technology for the right application
- Be a partner for SHM technology developer

**Customer**
- All Aerospace OEM
- Airlines, MRO, ……
- Other industries (construction, automotive, wind, ……)
Testia could be your enabler of your regional policy

- Perform \textit{locally} all SHM relevant Services
- Analyze and evaluate data in selected data analytic centers

→ Your local SHM workforce
→ Engineer & deliver your regional innovation initiatives & services
Thank you for your attention
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WE...


...THANK YOU