INTEGRATED VEHICLE HEALTH MANAGEMENT: RELIABILITY, SAFETY AND MAINTENANCE

CREDITS

David Alexander
05.November.2015
The SAE portfolio
a global association of more than 140,000 engineers and related technical experts

PUBLICATIONS
100,000+ collection of technical publications

TECHNICAL STANDARDS
35,000+ aerospace and ground vehicle standards

MEDIA
Magazines, eNewsletters, custom publishing, Tech Briefs Media Group

MEMBERSHIP
140,000 members worldwide, multiple-tiered/benefit model

ENGINEERING EVENTS
Over 30 global technical events annually for the aerospace, automotive, and commercial vehicle sectors

FOUNDATION
Charitable arm of SAE International, supporting STEM for over 30 years; 76,000 K-12 students and over 7,000 college students.

PROFESSIONAL DEVELOPMENT
400 courses portfolio, webinars; in-house, corporate and self-paced learning
...for the aerospace, automotive and commercial vehicle sectors
Major UK, European & Global Aerospace Organizations Develop SAE Standards
New SAE Aerospace Standards for Cutting Edge Technologies

- Composite Materials
- Active RFID Tags
- LED Runway Lighting and EFVS
- Anti-Icing Technology
- Fibre-optic networks
- Additive Manufacturing
- Electronics & Avionics
- Corrosion Protection
- Hydrogen Fuel Cells
- Human Factors & Cockpit Electronics
- Integrated Vehicle Health Management & Prognostics
- Electric & More Electric Aircraft
EASA and FAA are represented on the Aerospace Council

2014 Aerospace Council meetings hosted by FAA and EASA

ICAO – SAE Atlanta Office

FAA – SAE Washington Office

US DoD – SAE Washington Office

EASA – SAE London Office

European National Aviation Authorities – SAE London Office

European Military Agencies – SAE London Office
SAE Aerospace Standards Are Referenced in Global Regulations

- 73 FAA TSOs
- 95 FAA ACs
- 12 ICAO Annex
- 58 EASA ETSOs
- 27 EASA AMCs

Example FAA TSO
Mandatory compliance

Example FAA AC
Guidance material

Example ICAO Annex
Mandatory compliance

Example EASA ETSO
Mandatory compliance

Example EASA AMC
Guidance material
What is Integrated Vehicle Health Management?

“Integrated Vehicle Health Management is an end to end capability that transforms system data into operational support information enabling:

- Optimized maintenance actions
- Improved readiness and availability
- Enhanced Vehicle safety and reliability
- Product life extension
- Product improvement and new design paradigms”

Use of diagnostics and prognostics to monitor, assess “health” or condition and manage assets – parts, systems, or (IVHM) – aircraft and fleets:

**Sense**
**Acquire**
**Transfer**
**Analyse**
**Act**
The History of IVHM at SAE

1975 – Vibration monitoring and E-32

1980s- 2000s TPMS, BTMS, Fault Detection

Integration – IVHM Steering Group and HM-1
The SAE IVHM Steering Group Objectives

IVHM Platform Level – HM-1
  Engine (EHM) – E-32
  Engine Controls – E-36
  Fibre Optic Equipment – AS-3
  Structure (SHM) – G-11SHM
  Landing Gears – A-5
  Flight Controls & Hydraulics – A-6
  Fuel Systems – AE-5

Reliability – G-11R
  Maintainability/Supportability – G-11M
  Probabilistic Methods – G-11PM

RFID – G-18
  Embedded Systems – AS-2
  Fibre Optic Systems – AS-3
  Safety Assessment – S-18
The SAE IVHM Standards Landscape

Organizational Goals
- ARP6275
- Cost benefit analysis

System Requirements
- ARP6883
- ARP6887
- ARP6268
- ARP6290
- Requirements Analysis
- Verification & Validation
- Health Ready Components

System Architecture
- ARP6290
- Architectural design

Detailed System Design
- ARP6883
- ARP6407
- ARP6268
- Detailed design

Verification & Validation
- ARP6883
- ARPxxxx

System Implementation
IVHM, CBM and the Regulatory Landscape

Maintenance Credits?

EASA recommendation: “before generating new regulations, the IVHM Group should first consider how it can utilise or supplement existing regulations for approval of maintenance processes, with the objective to seamlessly integrate the use of IVHM into existing certification & operational practices.”

New SAE AIR document in development on the regulatory framework and pathways in process:
• CAA/EASA/FAA: CS/Part-, AMC/AC, GM
• MSG-3
A supportive reference to facilitate implementation within the operational maintenance framework: ARP6461 discusses

A4A MSG-3 (revision 2009-1) in which a definition of Scheduled SHM (S-SHM) was added:
‘S-SHM is the act of using/running/reading out a SHM device at an interval set at a fixed schedule.’
The structure section of the A4A MSG-3 document was revised to select S-SHM tasks and interval in lieu of classic inspections.

A proposed further revision to MSG-3 (IP 105) which introduces Automated SHM (A-SHM):
A-SHM: ‘is any SHM technology which does not have a pre-determined interval at which maintenance action must takes place, but instead relies on the system to inform maintenance personnel that action must take place’.
A-SHM technologies have the potential of providing information to operators, OEMs and Authorities to develop ‘on-condition’ or ‘condition-based’ maintenance programs, eliminating several scheduled maintenance inspection tasks.
### SAE/RAeS Maintenance Credits Workshop

<table>
<thead>
<tr>
<th>Date</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nov. 2011</td>
<td>The aircraft that looks after itself</td>
</tr>
<tr>
<td>Nov. 2013</td>
<td>Civil Aircraft Technology Enabled Services</td>
</tr>
<tr>
<td>Oct. 2014</td>
<td>A First Step Towards Achieving Maintenance Credits</td>
</tr>
<tr>
<td>Apr. 2015</td>
<td>Integrated Vehicle Health Management Workshop</td>
</tr>
</tbody>
</table>

- **Three workshops:**
  - Working with the regulators
  - Maintenance Credits
  - Data interoperability

- **Outputs:**
  - Three white papers, becoming
  - Three SAE standards
• Airline Engineering & Maintenance Safety Track: Airlines, Regulatory Authorities and Industry
• SAE presentation delivered by Rolls-Royce Plc
• Outreach to safety management community led to discussions on leveraging & sharing data between safety and maintenance/health monitoring
• Can IVHM actively, or just passively, positively impact aviation safety?
…to determine the potential use of PHM technologies in accident prevention by measuring the health of aircraft systems and preventative and protective defences. PHM technologies would be used to monitor system health and predict component level failures that would impact the operation of the overall system.
System reliability must be at a level acceptable for use

Additional monitoring capability

Safety & operational impacts
IVHM and No Fault Found

No Fault Found:

“Removal of equipment from service for reasons that cannot be verified by the maintenance process (shop or otherwise)”

ARINC 672 Report
Next Steps

- Continued development of SAE IVHM “technology” standards – subsystem and platform levels
- Exploration of regulatory framework
- Interface with MSG-3, MPIG
- Development of guidance for maintenance credits process
- Focus on mitigation of No Fault Found
- Focus on data interoperability and Big Data
- IVHM as an example of IoT
Next SAE HM-1 Meetings

April 12th – 14th 2016
• In conjunction with SAE World Congress (Automotive)
• Special Aero-Auto Prognostics Panel planned

September 7th – 9th 2016
• AVL, Graz, Austria
• Automotive/industrial cross-sector link-up

New members welcome  Committee Website
AND NOW FOR SOMETHING COMPLETELY DIFFERENT
Additive Manufacturing Landscape by Sector

Source: Wohlers Associates, based on a survey of equipment manufacturers and service providers in 2013
Bruce L. Mahone  
SAE International  
1200 G. Street N.W., Suite 800  
Washington, DC 20005

Dear Mr. Mahone:

Additive manufacturing (AM) technology offers many potential benefits, such as reducing material costs, requiring fewer parts for fabrication, and its ability to manufacture complex designs. Therefore, it is expected to rapidly proliferate in the aerospace industry. The Federal Aviation Administration (FAA) Design, Manufacturing, & Airworthiness Division (AIR-100) is aware of various current and forthcoming type certification, production certification, and parts manufacturer approval activities that use AM, as well as the gradual increase in criticality of such applications.

To address this issue, the FAA is requesting that SAE International form a committee to develop Aerospace Materials Specifications, process standards, Aerospace Recommended Practices, and other related standards. This action will assist the FAA in developing guidance material for AM certification.

If you have any questions, please contact Jim Kabbara, Electrical and Mechanical Equipment Section, AIR-133, at (202) 267-1575.

Sincerely,

Susan J. M. Cabler  
Acting Manager, Design, Manufacturing, & Airworthiness Division  
Aircraft Certification Service
SAE AMS-AM Committee Objectives

- ...develop Aerospace Material Specifications (AMS) for the procurement of additive precursor and manufactured materials ... When applicable, ensure the material specification is tied to the appropriate shared material property database.
- Publish recommended practices and/or specifications for processing and fabrication of end products from AM materials.
- Provide a forum for the exchange of technical information related to additive manufacturing.
- Further the adaptation of industry sponsored material specifications through coordination with MMPDS, ASTM, AWS, Nadcap, other AMS committees and associated organizations.
- Coordinate requirements for publishing data in shared material property databases with MMPDS Emerging Technology Working Group for new metallic materials and CMH-17 for new composite materials.
- Establish a system to ensure material specifications are controlled and traceable.
Inaugural meeting July 21-22, 2015 in Atlanta, GA
- 65+ in attendance, 20+ online. Industry plus EASA/FAA
- Selected Laser Powder Bed 625 as pilot project
- 3 sponsored specifications
  - LPB 625 Finished Product
  - LPB 625 Powder Feedstock
  - LPB Process
- 1 proposed specification
  - Feedstock process spec
- FAA tasking request
- Nadcap Checklist in development (Welding TG)
Upcoming Meetings

**Autumn 2015:**
October 26 - 27, 2015
GE Aviation Learning Centre
Cincinnati, USA

**Spring 2016:**
May 10 – 12, 2016
Airbus Pegasus House
Filton Bristol, UK

Register online at [www.sae.org](http://www.sae.org).
THANK YOU FOR YOUR ATTENTION

David Alexander
Aerospace Standards Manager Europe
SAE International
1 York Street
London W1U 6PA UK

o +44 (0) 208 291 3231
m +44 (0) 7525 687909
david.alexander@sae.org
The Aerospace Standards Landscape: SAE Global Leadership

- **8500+** standards
- **150+** committees, subcommittees, and task groups
- **11000+** global participants

**Civil and Military applications addressed**
SAE Aerospace Council – Global Oversight and Strategy

- Agusta Westland
- Airbus
- Airbus Group
- All Nippon Airways
- A4A
- AVIC
- BAE Systems
- The Boeing Company
- Bombardier Aerospace
- CAPE
- CIRA
- COMAC
- European Aviation Safety Agency
- Embraer
- Federal Aviation Administration
- Fed Ex
- GE Aviation
- Honeywell Aerospace
- Lockheed Martin
- Lufthansa Technik
- NASA
- Northrop Grumman
- Pratt & Whitney
- Rolls-Royce
- United Aircraft Corporation
- U.S. Department of Defense
- Wichita State University
### SAE History - and Future....

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>1905</td>
<td>SAE charter expanded to incorporate aeronautics, 1916</td>
</tr>
<tr>
<td>1916</td>
<td>1&lt;sup&gt;st&lt;/sup&gt; SAE Aerospace Standard, 1917</td>
</tr>
<tr>
<td>1917</td>
<td>SAE E-32 – EHM committee established, 1975</td>
</tr>
<tr>
<td>1975</td>
<td>G-11 SHM is formed – work begins on the SHM guidebook (ARP6461), 2008</td>
</tr>
<tr>
<td>2008</td>
<td>IVHM Steering Group established in June, HM-1 Committee in October, 2010</td>
</tr>
<tr>
<td>2010</td>
<td>SAE AeroTech, first SAE IVHM Book, 2011</td>
</tr>
<tr>
<td>2012</td>
<td>SAE AeroTech, IVHM and SHM Panel Session @ LHT, 2013</td>
</tr>
<tr>
<td>2013</td>
<td>10 HM-1 documents in progress, 7 HUMS/IVHM standards published</td>
</tr>
</tbody>
</table>