

The Importance of Standards

Standards for PHM

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Technical Engineering Standards

- Why should we care about standards?
- The motivation for developing standards, with some examples.
- PHM standards developed by SAE International and other Standards Development Organizations (SDO).
- The new era of digital standards.



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Note: We will talk mainly about the commercial aerospace industry in this presentation

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Weights and Measures

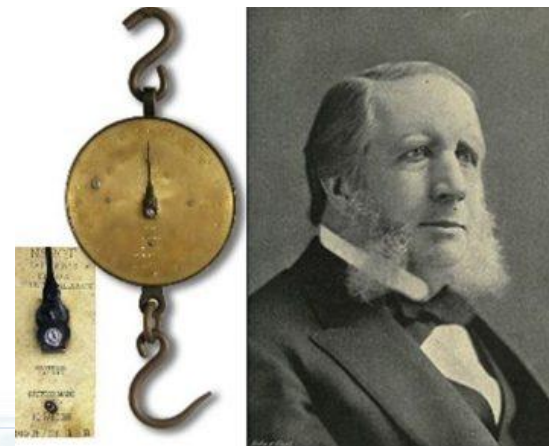
- Weights and measures were essential for trade and governance, and hence they were the first quantities standardized.
- First measures of weight were a quantity of grains of wheat, barley, etc.
- Balance scales have shown up in multiple civilizations, Egypt, China, Indus Valley, etc. dating back to 3rd to 4th millennium BCE.
- Spring loaded scales only came in the 17th century CE. England. Less chances of cheating.



Mohenjo Daro scales, National Museum, Delhi (c 2500 BCE)



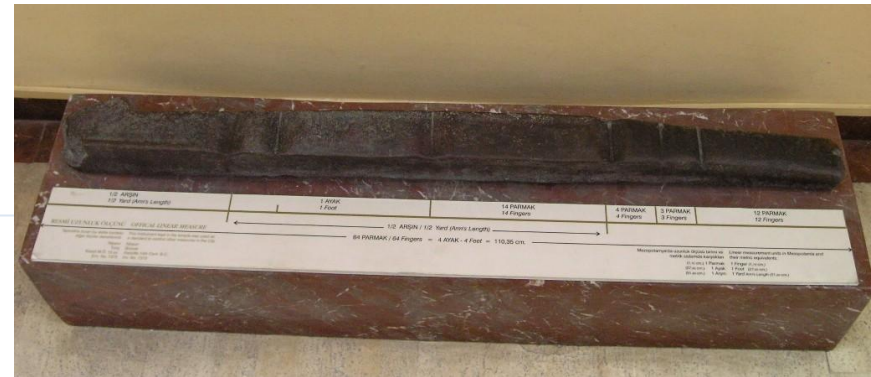
Weighing of the heart ceremony, Papyrus of Ani British Museum, London (c13250 BCE)



Richard Salter, Inventor of balance scale (1770)

Weights and Measures

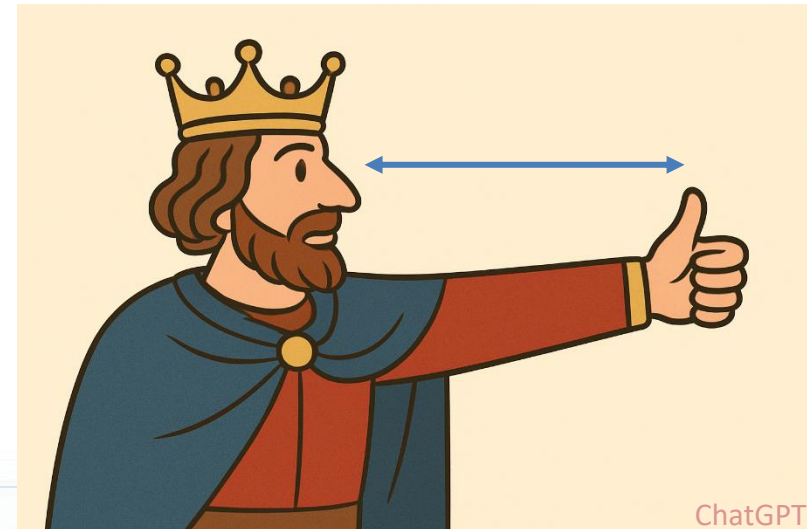
- Weights and measures were essential for trade and governance, and hence they were the first quantities standardized.
- Length measures have been recovered from 3rd and 4th millennium BCE.
- Old standards were arbitrary. E.g., cubit was the distance from the tip of the nose to the elbow. Cubit is derived from the Latin word for elbow: cubitum.
- Many early units may have been derived from royal measurements e.g., the yard from the bodily characteristics of Henry I (c 1120 CE).
- Mesopotamian, Egyptian, Indus Valley, all ancient civilizations had different measures.



Nippur cubit-rod from Archeological Museum Istanbul (c2500 BCE)

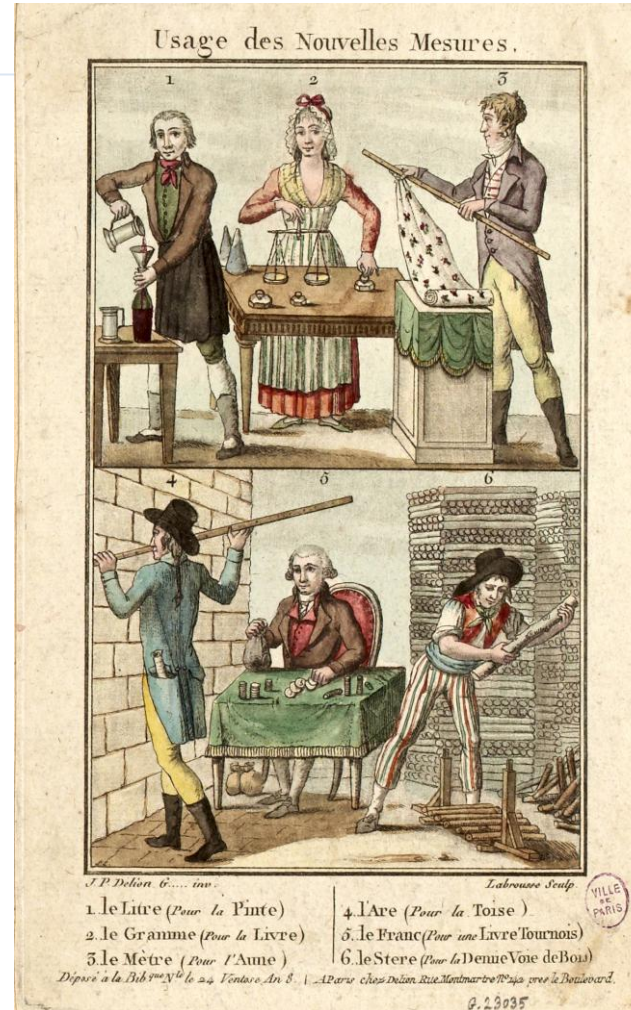


Cubit rod from Egyptian Museum of Turin (c1300 BCE)

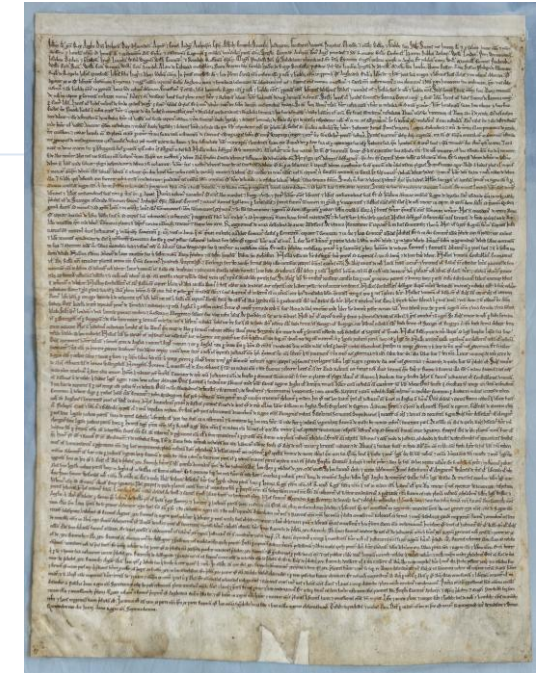


Toward More Modern Times

- In England the Magna Carta (1215 CE) required that measurements be standardized.
- During the French Revolution, the French Academy of Sciences was tasked with creating a standard measurement system. They recommended the metric system to the Government in 1795.
- In 1875 the International Bureau of Weights and Measures (BIPM) was established for global standards.
- Today these standards are based on fundamental physical properties.
 - Meter – Based on the speed of light.
 - Second – Based on the frequency of transition radiation of cesium
 - Kilogram – Derived from fixing the Planck’s constant



Woodcut dated 1800 illustrating the new decimal units which became the legal norm across all France on 4 November 1800 (Wikipedia)



Magna Carta Latin original with Clause 35 (1215). Salisbury Cathedral



But What about Technical Standards?

Historical Note: The Great Baltimore Fire (Feb 7, 1904)

- Burned for 30 hours, engulfed 70 city blocks & 1,526 buildings; resulted in loss of 2,500 businesses.
- Engine companies from Washington, DC, arrived first by train. But could not assist!
- Cities and counties of Altoona, Annapolis, Chester, Harrisburg, New York, Philadelphia, Wilmington, and York sent fire companies.
- Resources used: 1,231 firefighters, 57 engines, 9 trucks, 2 hose companies, 1 fireboat, and 1 police boat.



Momar D. Seck and David D. Evans, "Major U.S. Cities Using National Standard Fire Hydrants, One Century After the Great Baltimore Fire," NISTIR 7158, National Institute of Standards and Technology, Gaithersburg, MD 20899, Aug 2004

The Need for Technical Standards

One of the Consequences of the Baltimore Fire

- *The lack of uniform threads on fire hydrants is commonly cited as a factor in the massive destruction in Baltimore in 1904!*
- The National Fire Protection Association and the National Bureau of Standards (NBS; now NIST) started working on standardizing threads and came out with the first report in 1905.
- However, even today, different cities have different designs. Fire trucks carry adapters to make hoses fit hydrants.
- NST competes with NYCFD, DFD, CFD, BFD, CFD, OFD, PFD, etc. etc.!



City	Hydrant/FDC Thread Standard	Notes
New York City, NY	NYCFD thread (non-NST)	Adapters required for mutual aid
Chicago, IL	Chicago FD thread (non-NST)	City code specifies CFD thread
Seattle, WA	4" STORZ hydrant port; adapters to 4" NST	Engines carry adapters for NST supply
San Francisco, CA	Mix: legacy non-NST + newer NST (per code)	Current SFFD requires NST for new installs
Los Angeles, CA	NST/NH (per code)	Explicitly requires NST
Philadelphia, PA	NST/NH (per code)	Explicitly requires NST
Washington, DC	NST/NH (per code)	Explicitly requires NST
Boston, MA	Legacy Boston FD thread (non-NST)	One of the earliest non-NST cities
Detroit, MI	Detroit FD thread (non-NST)	Legacy local spec
Cleveland, OH	Cleveland FD thread (non-NST)	Legacy local spec
Denver, CO	Denver FD thread (non-NST)	Legacy local spec
Phoenix, AZ	Legacy Phoenix FD thread (non-NST), newer NST	Mix of NST and legacy fittings
Pittsburgh, PA	Pittsburgh FD thread (non-NST)	Legacy local spec
Buffalo, NY	Buffalo FD thread (non-NST)	Legacy local spec
Omaha, NE	Omaha FD thread (non-NST)	Legacy local spec
Cincinnati, OH	Cincinnati FD thread (non-NST)	Legacy local spec

ChatGPT

Lesson: Standards are essential, but they are tough to enforce!

Momar D. Seck and David D. Evans, "Major U.S. Cities Using National Standard Fire Hydrants, One Century After the Great Baltimore Fire," NISTIR 7158, National Institute of Standards and Technology, Gaithersburg, MD 20899, Aug 2004

...Or You Can Be a Cynic (Realist?)



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Different Paths to Developing Standards

Rationale	Examples
To answer industry/public need	Credit card charging, Communications, UPI (India), ...
To enhance public safety	Certification standards, Cybersecurity, ...
By, or at the request of authorities or intergovernmental bodies	Safety standards (ARP4754, e.g.), CODEX-HUMS (US Army) Volcanic ash detection, ...
Driven by new technology	Use of AI in aerospace, EV charging, ...
For cost effectiveness (not necessarily for technical excellence)	Aviation maintenance, VHS vs. Betamax, ...
To foster innovation by standardizing pre- or non-competitive elements	Digital data sharing, ...

We will highlight some specific example.

Basic Principles for Developing Standards (IEEE)

Consensus Driven Process that is highly visible and follows:

- **Openness:** Ensures all interested parties can participate actively in the standards development process.
- **Consensus:** A clearly defined percentage of those in a balloting group vote to approve a draft of a standard. This *does not* mean unanimity!
- **Balance:** Balloting groups include all interested parties and avoid an overwhelming influence by any one party.
- **Right of appeal:** Anyone can appeal a standards development decision at any point, before or after a standard has been approved (with some caveats).

Public review: Some SDOs require public review of the final draft before the balloting process. EUROCAE is one such SDO. SAE and ASTM are not.



Courtesy: Sony Mathew, Schlumberger

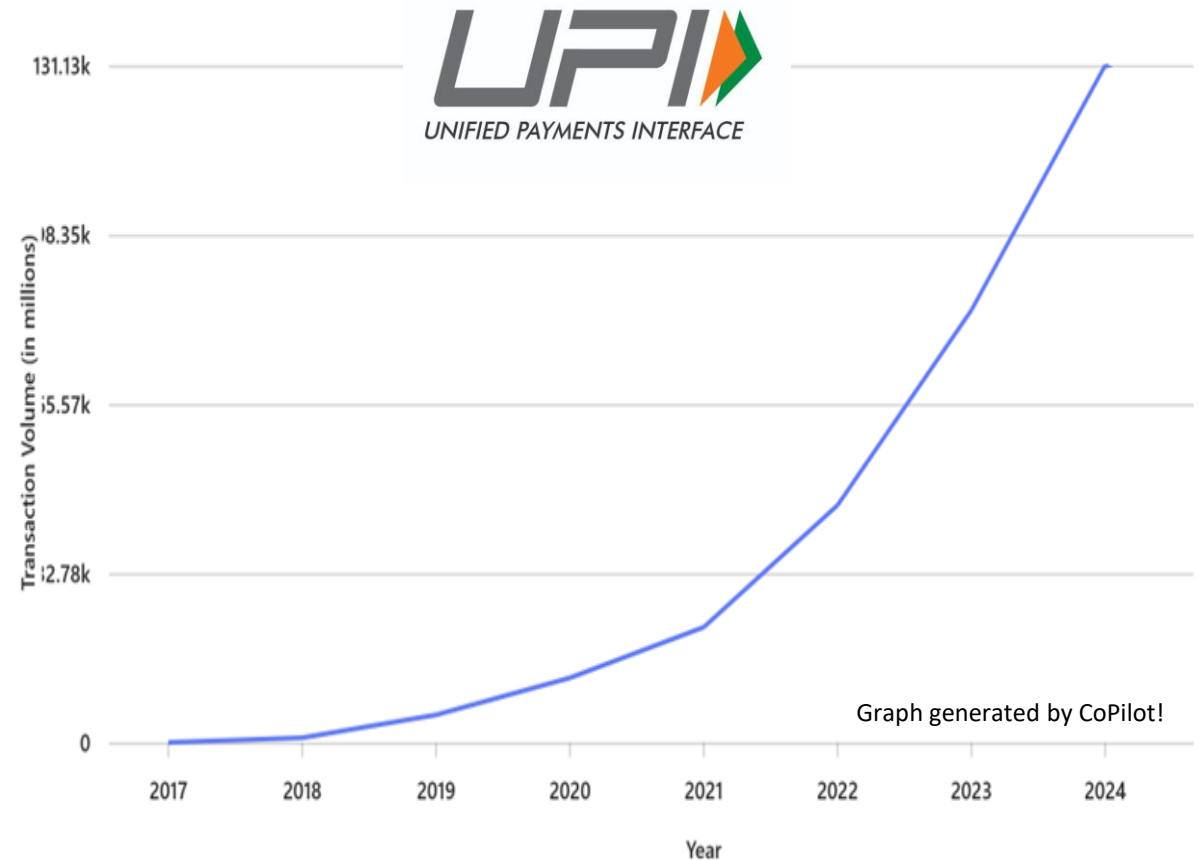
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Unified Payment Interface (UPI)

Driven by the Need to Democratize Financial Transactions in India

- Goals for the UPI
 - Include the common folk in the financial system in India.
 - Reduce the dependence on cash.
 - Remove complexities of digital money transactions.
- Started in 2008-2009 and by 2016 the first transactions were being done.
- Inspired by mobile-based digital transactions in East Africa – M-Pesa in Kenya (by Vodafone) and others around the world such as in China.
- Interface standard developed by the National Payments Corporation of India (NPCI), a public company.
- Implemented on mobile phones via an open-source API. Mainly linked to bank accounts.
- Exponential growth over the years.
- According to the Reserve Bank of India, UPI transactions make up more than 49% of all digital monetary transactions in the world today.

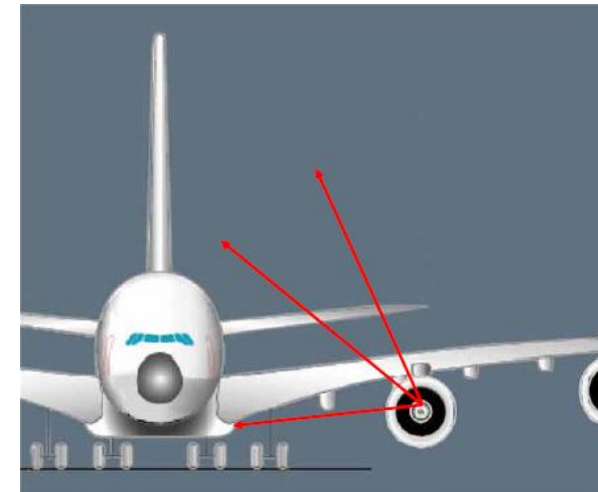


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Engine Vibration Monitoring: Required by Regulators to Enhance Aircraft Safety

- In 1973, FAA decided the risk of rotor unbalance in turbine engines was too high.
- Issued requirement to measure rotor unbalance in CFR 25.1305 (Code of Federal Regulations).
- Engine companies not too happy about this, saying that their engines never experienced harmful vibrations!
- But airframers adopted the guidelines.
- AIR1839 first published in 1986 by SAE E-32.



SAE International, "A Guide to Aircraft Turbine Engine Vibration Monitoring Systems," ARP1839, December 2015.
ATSB, "Final Investigation: In-flight uncontained engine failure Airbus A380-842, VH-OQA, 4 November 2010," June 2013.

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New Data Exchange Standard: AS7140 (CODEX-HUMS)

General

- Data formats proprietary, specific for onboard systems.
- No analysis without dedicated software.
- Limited ability to export data for analysis in 3rd party tools.

Specific

- US Army Future Vertical Lift program and its timeline.



AEROSPACE STANDARD	AS7140™	
	Issued	2025-09
Common, Open Data Exchange Format for Rotorcraft Health and Usage Monitoring Systems (CODEX-HUMS)		

RATIONALE

A Common Open Data Exchange format for rotorcraft Health and Usage Monitoring Systems (CODEX-HUMS) provides for a more affordable, capable, and effective Integrated Vehicle Health Management System. This document provides a standard definition for the CODEX-HUMS open data format produced or used by an onboard or offboard system. The standard format benefits end users (e.g., operators, developers, suppliers, integrators, and maintainers) with the capability to more rapidly operationalize HUMS data. This HUMS open data format meets the intent of a Modular Open System Approach (MOSA) and provides a foundation for rapidly realizing operational benefits from the data at the point of maintenance and exchanging the data with external enterprise systems.

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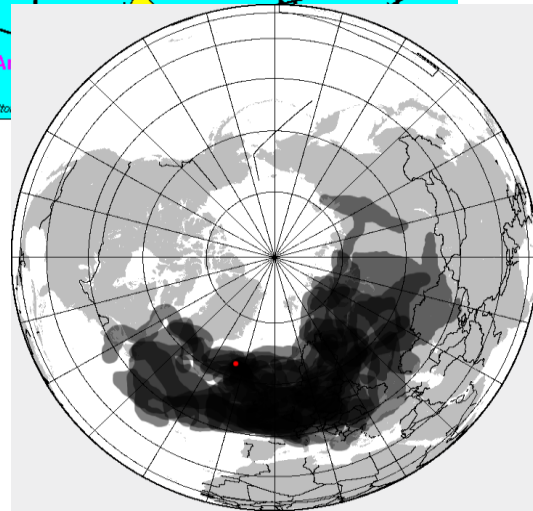
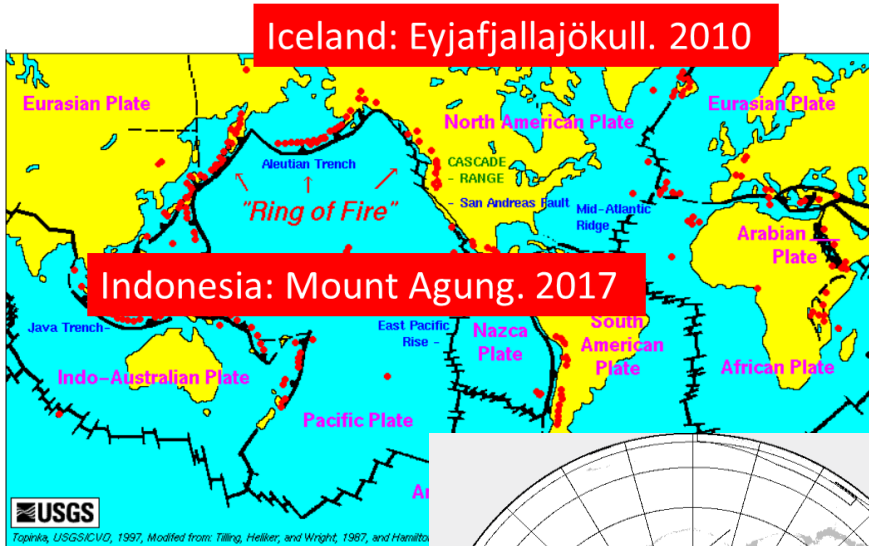
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Volcanic Ash Detection: Requested by the International Civil Aviation Organization (ICAO)



Volcanic Ash coverage after E+15

- Eyjafjallajökull (E+15) in April 2010.
- Disrupted air travel for 6 days and more.
- ICAO reached out to different organizations to develop standards to help with detection / mitigation.
- SAE proposed the use of PHM sensors to detect ash.
- HM-1 TC published “*AIR6212 – Use of Health Monitoring Systems to Detect Aircraft Exposure to Volcanic Events*” in December 2016.



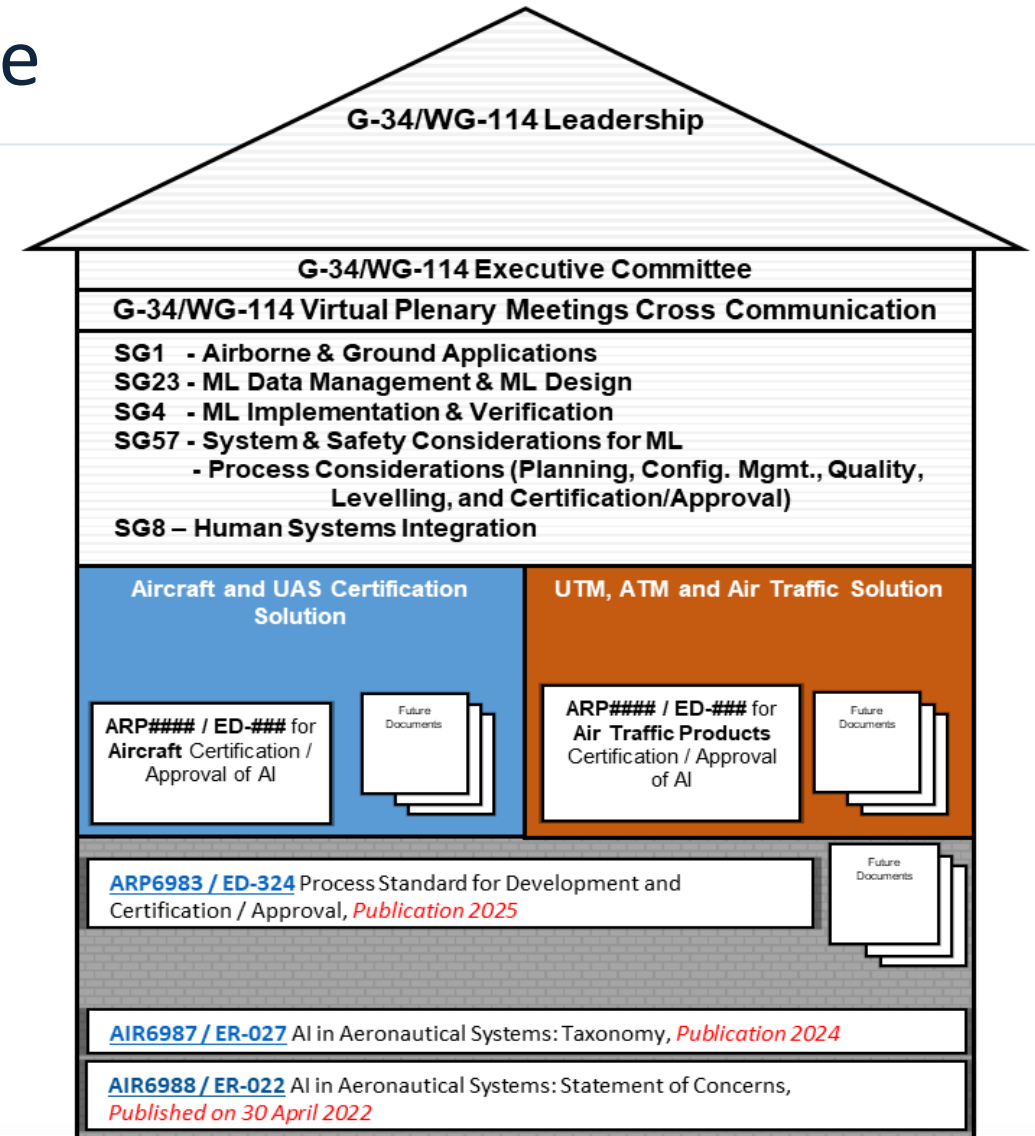
Combustor damage due to VA

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SAE Technical Committee G-34: Responding to the Need for Regulating the Use of AI in Aerospace

- *G-34/WG-114* focuses on implementation and certification related to AI technologies for the safer operation of aerospace systems and aerospace vehicles.
- *G-34/WG-114* (comprised of 600+ members) promotes and standardizes Artificial Intelligence in the entire aviation eco-system (both Airborne and Ground) addressing both manned and UAS.
- Published Standards:
 - AIR6988 / ER-022 Artificial Intelligence in Aeronautical Systems: Statement of Concerns (Published on 30 April 2021)
 - Works In Progress and deliverables:
 - **ARP6983 / ED-324 Process Standard for Development and Certification / Approval of Aeronautical Safety-Related Products Implementing AI**
 - AIR6987 / ER-027 Artificial Intelligence in Aeronautical Systems: Taxonomy
 - AIR6994 / ER-xxx Artificial Intelligence in Aeronautical Systems: Use Cases Considerations



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Maintenance Process Standards Developed by the Industry to Reduce Costs

Douglas DC-8 (1958 – 1972) seating < 200

Cost: ~\$5.5 million (1960) (~8.3M in 1970)

Inspection cost: 4 million MMH for major structural inspections (until 20k hours)



Boeing B-747 (1969 – Present) seating > 400

Cost: ~\$24 million (1970) (**a factor of ~3 more**)

Inspection cost: 66,000 MMH for inspections to reach the same interval (**a factor of ~60 less**)



Different Paths to Developing Standards

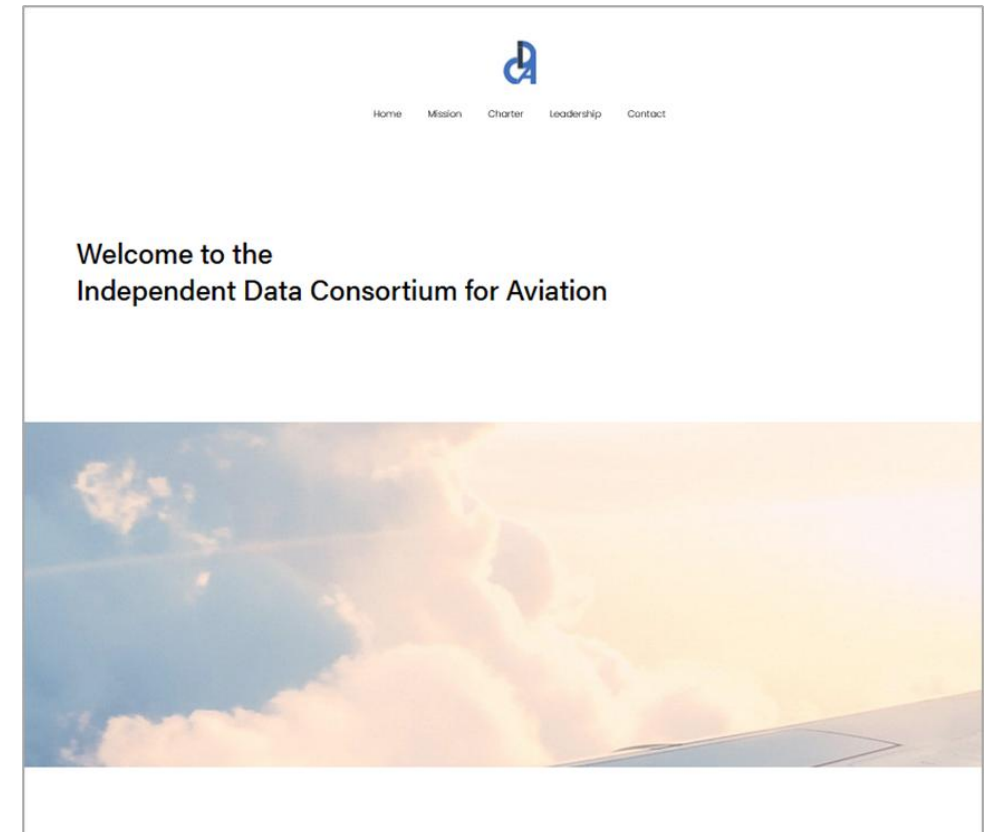
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The Independent Data Consortium for Aviation (IDCA) Created to Address Critical Data Governance Needs

The Independent Data Consortium for Aviation (IDCA) was created in 2022 to address critical governance issues in sharing digital data.

IDCA will develop consensus standards and policies that will allow all industry participants to share relevant data in an efficient and secure manner.

The IDCA is a global (non-profit) consortium of leading aviation companies at all levels of the industry coming together to develop the foundation for allowing data to be shared in a non-competitive manner. Its objective is to create a more efficient marketplace, where both waste and the time required to get to a common solution is minimized.



www.dataforaviation.org

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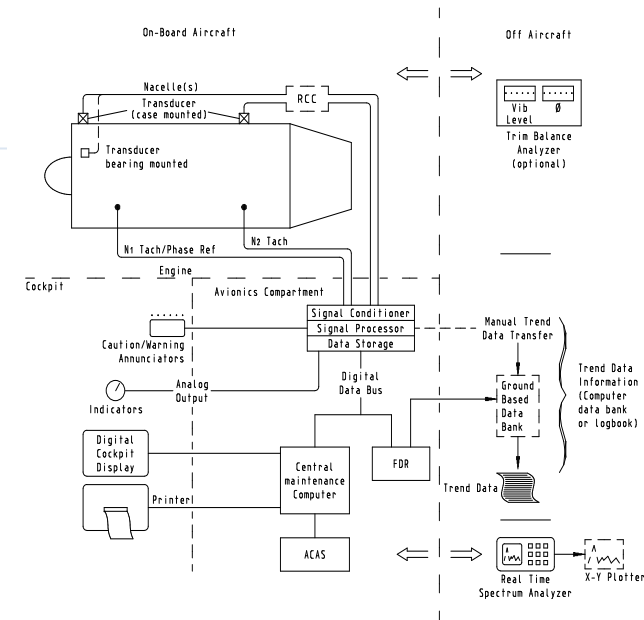
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Standards for PHM

- PHM as a rigorous discipline started with the aerospace industry
- First standards for monitoring engine vibrations were created in the 70s
- Modern automobiles are heavily instrumented machines and with the advent of *emissions controls*, on-board diagnostic (OBD) systems have mandated many standards (Connectors, e.g.: SAE J1962)
- Other industries, such as electronics, manufacturing, nuclear, space, energy, etc., have also developed standards.
- These cover the monitoring of vibrations, temperature, pressure, etc., but not with the rigor of the aerospace industry



J1962 Type A OBD2 Connector

Why Should We Monitor Vibrations?



SAE International Has Played a Pioneering Role in Automotive and Aerospace Standards

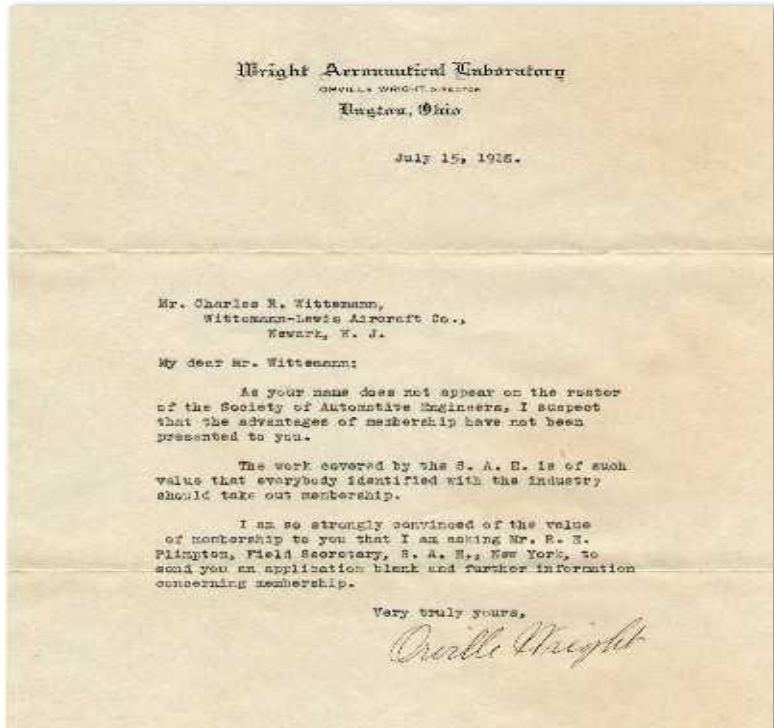
- SAE was established in 1905. It has been developing aerospace standards since 1917 and currently has the largest portfolio of aerospace standards in the world.
- Many rotorcraft Health and Usage Monitoring (HUMS) standards are maintained by SAE.
- Modern automobiles are heavily instrumented machines and with the advent of emissions controls, on-board diagnostic systems have mandated many standards. SAE was a pioneer in this area.
- SAE has published more than 10,000 standards (7,600+ aerospace)
- SAE acquired TechAmerica in 2013. TechAmerica developed many standards related to systems engineering, config mgt, info/comm
- ARINC's standards division was sold to SAE in 2014, when the company was acquired by Rockwell, now part of Raytheon.
- Many MIL standards have now being transitioned to SAE as well.



Standards and Regulations (SAE Example)



SAE and PHM History



To Charles Wittemann:

“The work covered by the S.A.E. is of such value that everybody identified with the industry should take out membership.”

Orville Wright, 1916

1905



2025

- SAE established: 1905
- First SAE standard published (Spark-plug threads): 1915 (stabilized 2013!)
- SAE charter expanded to incorporate aeronautics: 1916
- 1st SAE Aerospace Standard (Interchangeable spark plugs): 1917
- SAE E-32 – EHM committee: 1975
- G-11 SHM (now AISC-SHM) formed and work on ARP6461 begun: 2008
- IVHM Steering Group and HM-1 committee: 2010
- SAE AeroTech with IVHM track and first SAE IVHM book: 2011
- ARP6461 Published: 2013
- Reliability Maintainability and Health Management Systems Group: 2016
- DDSG and G31 committees. Standards for digital transactions: 2018
- ARP5987 Published: 2018 (rev A: 2022)
- G34 committee on AI in aviation: 2019
- G35 committee on modeling and simulation and training: 2021
- More than 12 books on IVHM and related topics published to date
- HM-1R established: 2022
- ARP7122 published: 2025

Examples of SAE Health Management Standards

E-32

- **ARP5120** *Aircraft Gas Turbine Engine Health Management System Development and Integration Guide*
- **ARP1839** *A Guide to Aircraft Turbine Engine Vibration Monitoring Systems*
- **AIR7999** *Diagnostic and Prognostic Metrics for Aerospace Propulsion Health Management Systems*
- **AIR1871C** *Lessons Learned from Developing, Implementing, and Operating a Health Management System for Propulsion and Drive Train Systems*
- **ARP5987A** *A Process for Utilizing Aerospace Propulsion Health Management Systems for Airworthiness Credit*

HM-1

- **ARP6803** *IVHM Concepts, Technology and Implementation Overview*
- **ARP6275** *Determination of Cost Benefits from Implementing an Integrated Vehicle Health Management System*
- *Train Transmissions Using Monitoring Data*
- **JA6268** *Design & Run-Time Information Exchange for Health-Ready Components*
- **ARP7122** *Utilizing Integrated Vehicle Health Management Systems for Airworthiness Credit*

HM-1R

- **AS7140** *Common, Open Data Exchange Format for Rotorcraft Health and Usage Monitoring Systems (CODEX-HUMS)*

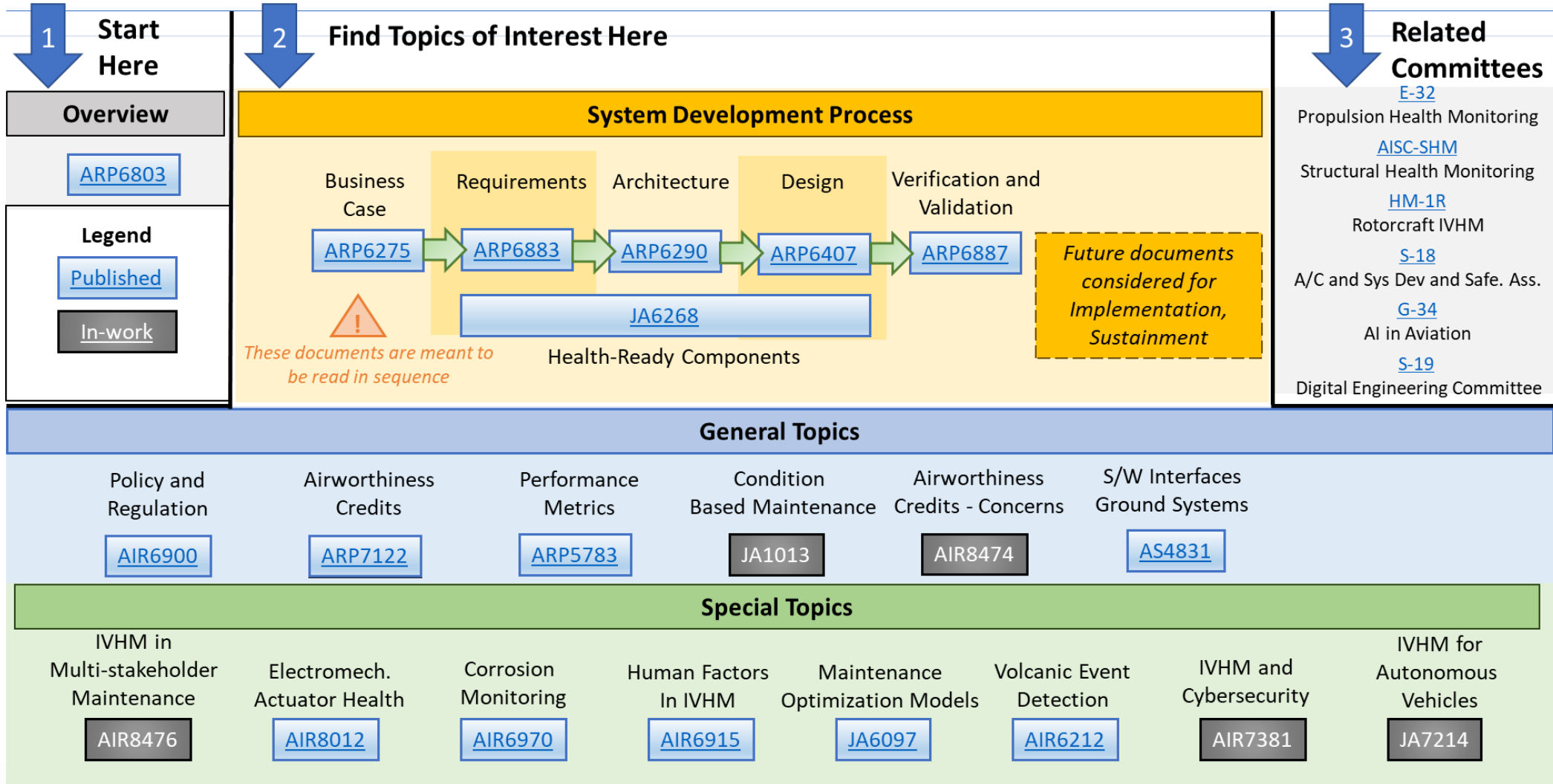
AISC-SHM

- **ARP6461A** *Guidelines for Implementation of Structural Health Monitoring on Fixed Wing Aircraft*
- **AIR6892** *Structural Health Monitoring Considerations and Guidance Specific to Rotorcraft*
- **ARP6821** *Guidance for Assessing the Damage Detection Capability of Structural Health Monitoring Systems*

Others

- **A1012** *A Guide to the RCM Standard (G11/M)*
- **ARP6137** *Tire Pressure Monitoring Systems (TPMS) for Aircraft (A-5C)*
- **AIR6168A** *Landing Gear Structural Health Monitoring (A-5)*
- **AIR5273** *Actuation System Failure Detection Methods (A-6A3)*

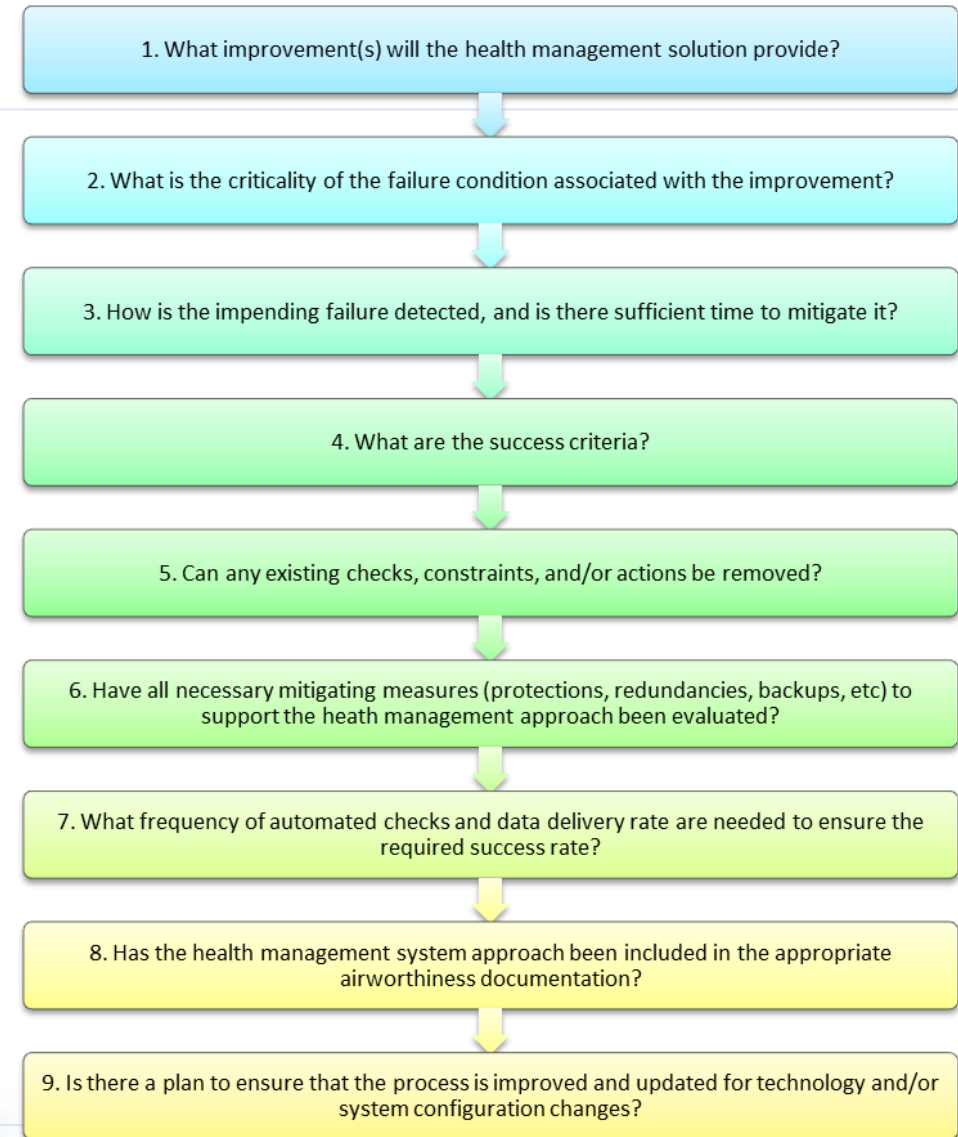
PHM Standards Developed by HM-1, the IVHM Committee



ARP7122 Utilizing Integrated Vehicle Health Management Systems for Airworthiness Credit (HM-1)

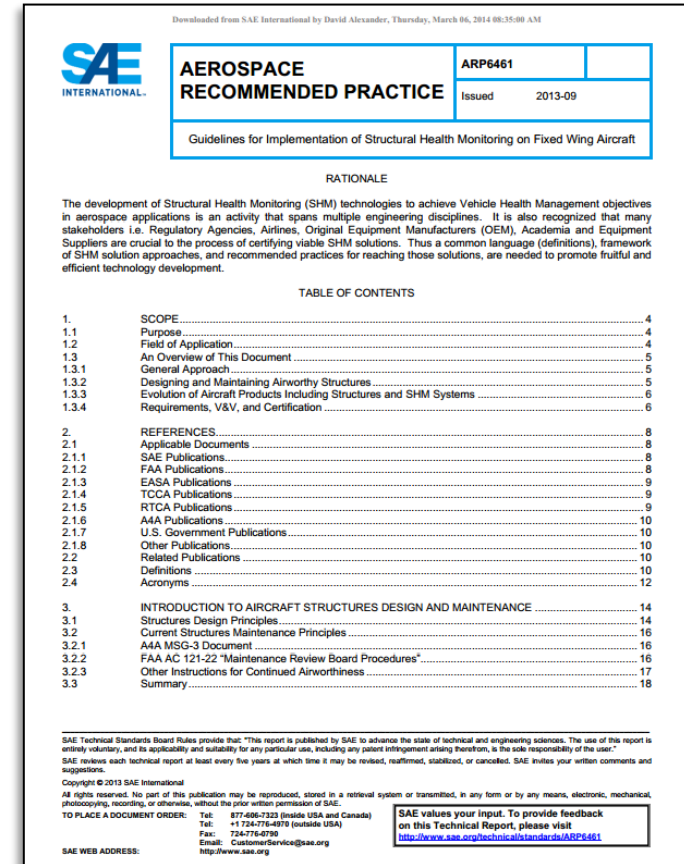
- Derived from ARP5987A (*A Process for Utilizing Aerospace Propulsion Health Management Systems for Airworthiness Credit*) from E-32.
- Lays out a simple 9-step process for helping get approval from regulators on certifying IVHM functionality in aircraft systems when they are applied for obtaining airworthiness credit.
- Includes guidance on how to incorporate ground-based systems as part of IVHM.
- The ARP includes five examples of fielded IVHM systems (or those awaiting approval from the authorities) in civil and military aviation.

More details about this and related topics during **Paper Session 3B** (13:45 / Tuesday / Evergreen 1): **Digital Twins and Aviation**



ARP6461A Guidelines for Implementation of Structural Health Monitoring on Fixed Wing Aircraft (AISC-SHM)

- SAE published ARP6461 in September 2013, and updated it to version A in August 2021.
- AISC-SHM has OEMs, Regulators, DoD personnel, University researchers.
- MSG-3 2009.1 allows S(cheduled)-SHM to be used for damage detection but it does not allow automated SHM.
- ARP6461A includes guidance for specifying requirements, validation, verification and certification for A(utomated)-SHM.
- Calls attention to relevant regulatory statutes that would allow SHM to be used today as an alternate means of compliance for inspection (MSG-3).



SAE International, "Guidelines for Implementation of Structural Health Monitoring on Fixed Wing Aircraft," ARP6461, September 2013.

Other Standard Development Organizations in the PHM Space

- ASME (established in 1880 as the American Society of Mechanical Engineers)
- Institute for Electrical and Electronics Engineering (IEEE; established in 1884)
- RTCA (founded in 1935 as the Radio Technical Commission for Aeronautics)
- International Organization for Standards (ISO; established in 1947 as an intergovernmental agency)
- EUROCAE (founded in 1963 as the European Organisation for Civil Aviation Electronics)
- Maintenance Programs Industry Group (MPIG; founded in 1968 as the ATA Maintenance Steering Group, by Boeing and managed by Air Transport Assoc. now Airlines for America)



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International MRB Policy Board

Other Standard Development Organizations in the PHM Space

- ASME (established in 1880 as the American Society of Mechanical Engineers)
- Institute for Electrical and Electronics Engineering (IEEE; established in 1884)
- RTCA (founded in 1935 as the Radio Technical Commission for Aeronautics)
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International MRB Policy Board

International Organization for Standards (ISO)

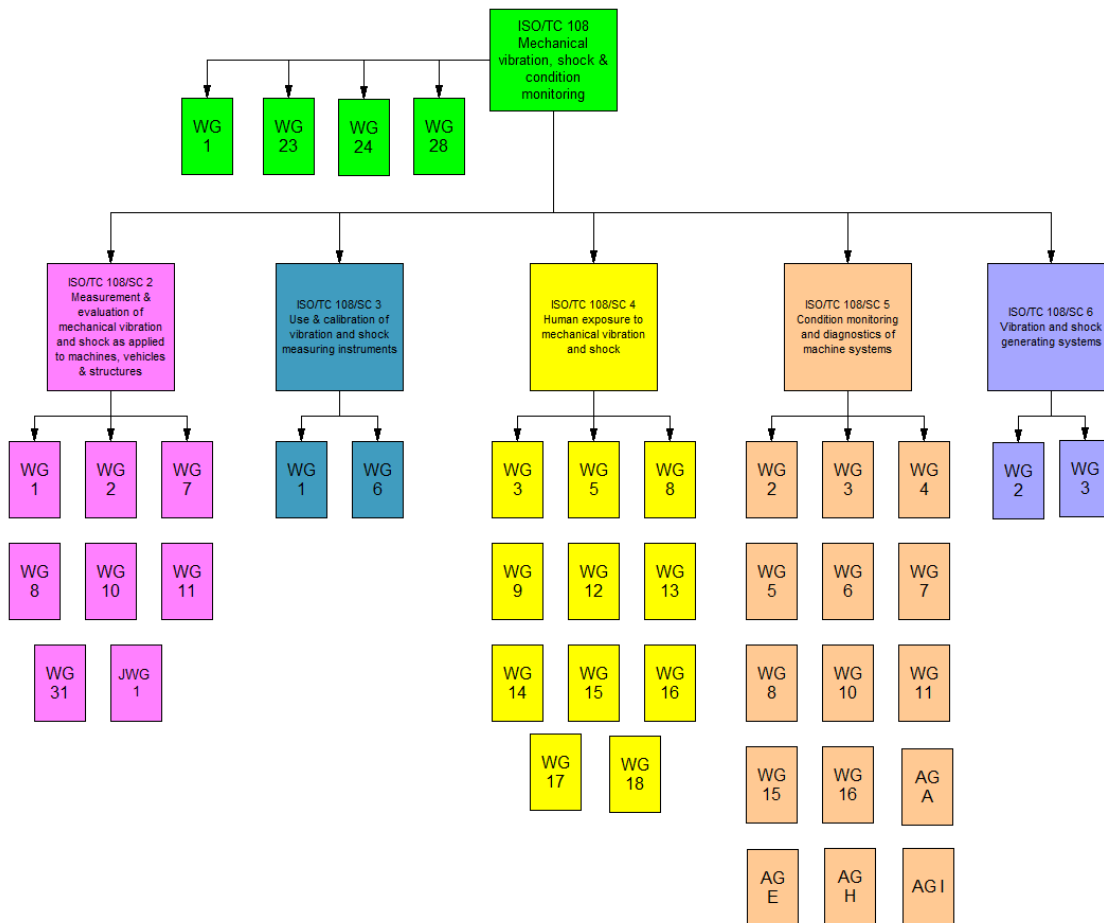
- ISO founded in 1947.
- Central Secretariat in Geneva, SW.
- 174 member countries.
- World's largest developer of voluntary standards.
- PHM Society is full member of the US Technical Advisory Group for TC108.

Portfolio of published ISO deliverables and work programme by technical sector at the end of 2024

Breakdown by technical sectors

Technical Sectors ¹	New registered in 2024	%	Total active work items	%	New published ISO deliverables ²	%	Number of pages	Total published ISO deliverables	%	Total number of pages
Building and construction	114	5.6%	266	6.1%	76	5.0%	5138	1412	5.5%	64257
Business management and innovation	18	0.9%	44	1.0%	19	1.2%	1636	116	0.5%	7103
Chemicals	41	2.0%	112	2.6%	42	2.7%	1354	942	3.7%	23961
Energy	86	4.3%	214	4.9%	66	4.3%	2862	888	3.5%	39704
Food and agriculture	107	5.3%	191	4.4%	46	3.0%	1910	1296	5.0%	39007
Freight, packaging and distribution	14	0.7%	30	0.7%	10	0.7%	344	225	0.9%	6332
Health, medicine and laboratory equipment	215	10.6%	480	11.0%	165	10.8%	9536	1884	7.3%	109424
Horizontal subjects	52	2.6%	142	3.3%	50	3.3%	2689	746	2.9%	37777
Information technology, graphics and photography	437	21.6%	734	16.8%	342	22.3%	28880	5460	21.2%	416914
Mechanical engineering	202	10.0%	488	11.2%	158	10.3%	9297	3587	14.0%	171743
Non-metallic materials	176	8.7%	311	7.1%	107	7.0%	3440	2163	8.4%	59775
Ores and metals	74	3.7%	180	4.1%	53	3.5%	1643	1171	4.5%	34527
Security, safety and risk	17	0.8%	25	0.6%	14	0.9%	632	79	0.3%	4548
Services	21	1.0%	67	1.5%	31	2.0%	1322	199	0.8%	8756
Special technologies	99	4.9%	262	6.0%	106	6.9%	5210	1098	4.3%	47131
Sustainability and environment	64	3.2%	181	4.1%	63	4.1%	3326	939	3.6%	49718
Transport	255	12.6%	596	13.7%	169	11.0%	8780	3246	12.6%	134989
Unassigned sector ³	30	1.5%	40	0.9%	16	1.0%	740	252	1.0%	10913
Grand Total	2022		4 363		1533		88739	25 703		1 266 579

ISO/TC 108 and Relationship to the PHM Society



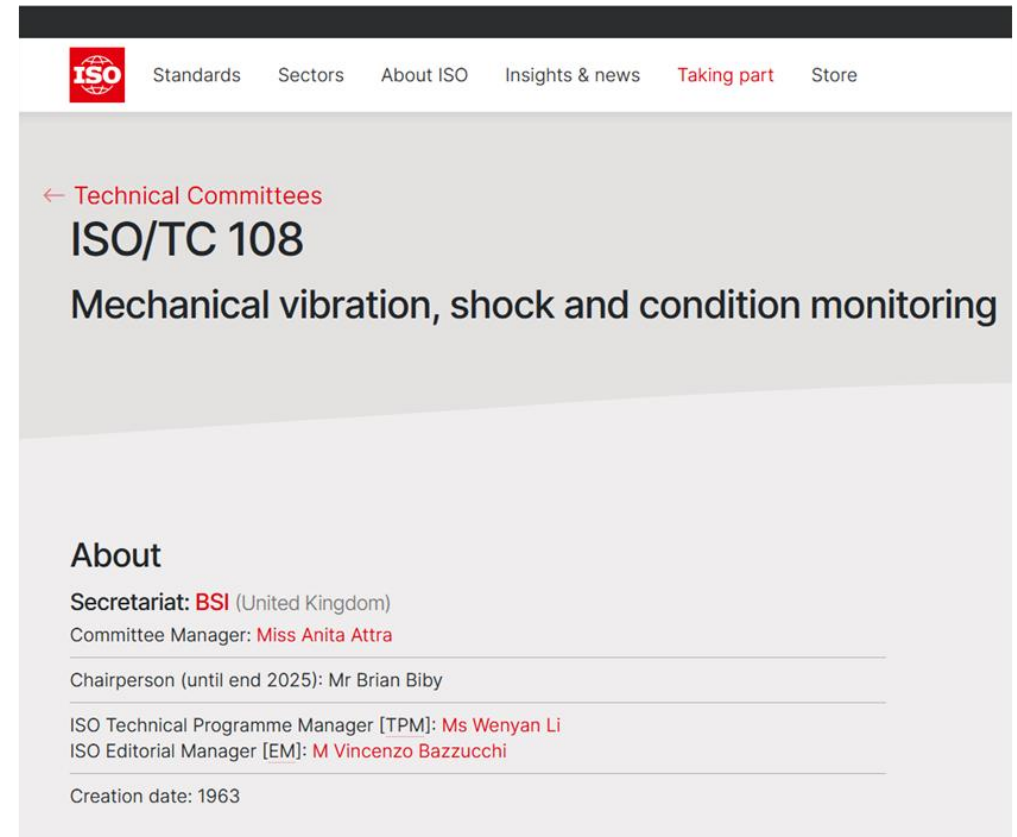
Courtesy: Susan Blaeser, Acoustical Society

- PHM Society is a paying member of the US Technical Advisory Group for TC108.
- We review draft documents and provide comments.
- We recruit experts and technical leads as requested
- In return: Access for the society, and associated small companies and academia to
 - Participate in standards development process.
 - Network with international experts in multi-disciplinary domains.
 - Be cognizant of developments global PHM standards
- The relationship is managed by Greg Vogl and Jeff Bird from our board's Standards and Education and Professional Development Committees.

Active Subject Areas of TC108

Domain: Condition monitoring and diagnostics of machines

1. Data interpretation and diagnostics techniques
2. Tribology-based monitoring of machines
3. Prognostics: Performance based approaches, Cyclic-driven life usage techniques, Useful-life-remaining prediction models
4. Data processing, communication and presentation
5. Requirements for qualification and assessment of personnel
6. Parameter selection and set-up
7. Power transformers
8. Thermography: Guidelines, Image interpretation and diagnostics, Power transformers
9. Ultrasound: Procedures and validation
10. Wind turbines: Guidelines, Monitoring the drive train
11. Hydro-electric generating units



The screenshot shows the ISO/TC 108 website page. At the top, there is a navigation bar with the ISO logo and links for Standards, Sectors, About ISO, Insights & news, Taking part, and Store. Below the navigation bar, the page title is "ISO/TC 108" with a sub-header "Mechanical vibration, shock and condition monitoring". A breadcrumb trail shows "← Technical Committees". Under the "About" section, the following information is provided: Secretariat: BSI (United Kingdom), Committee Manager: Miss Anita Attra, Chairperson (until end 2025): Mr Brian Biby, ISO Technical Programme Manager [TPM]: Ms Wenyan Li, and ISO Editorial Manager [EM]: M Vincenzo Bazzucchi. The creation date is listed as 1963.

Business plan and information at <https://www.iso.org/committee/51402.html>.

Courtesy, Jeff Bird

Other Standard Development Organizations in the PHM Space

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International MRB Policy Board

Benefits of Standardizing Maintenance Practices

Douglas DC-8 (1958 – 1972) seating < 200

Cost: ~\$5.5 million (1960) (~8.3M in 1970)

Inspection cost: 4 million MMH for major structural inspections (until 20k hours)



Boeing B-747 (1969 – Present) seating > 400

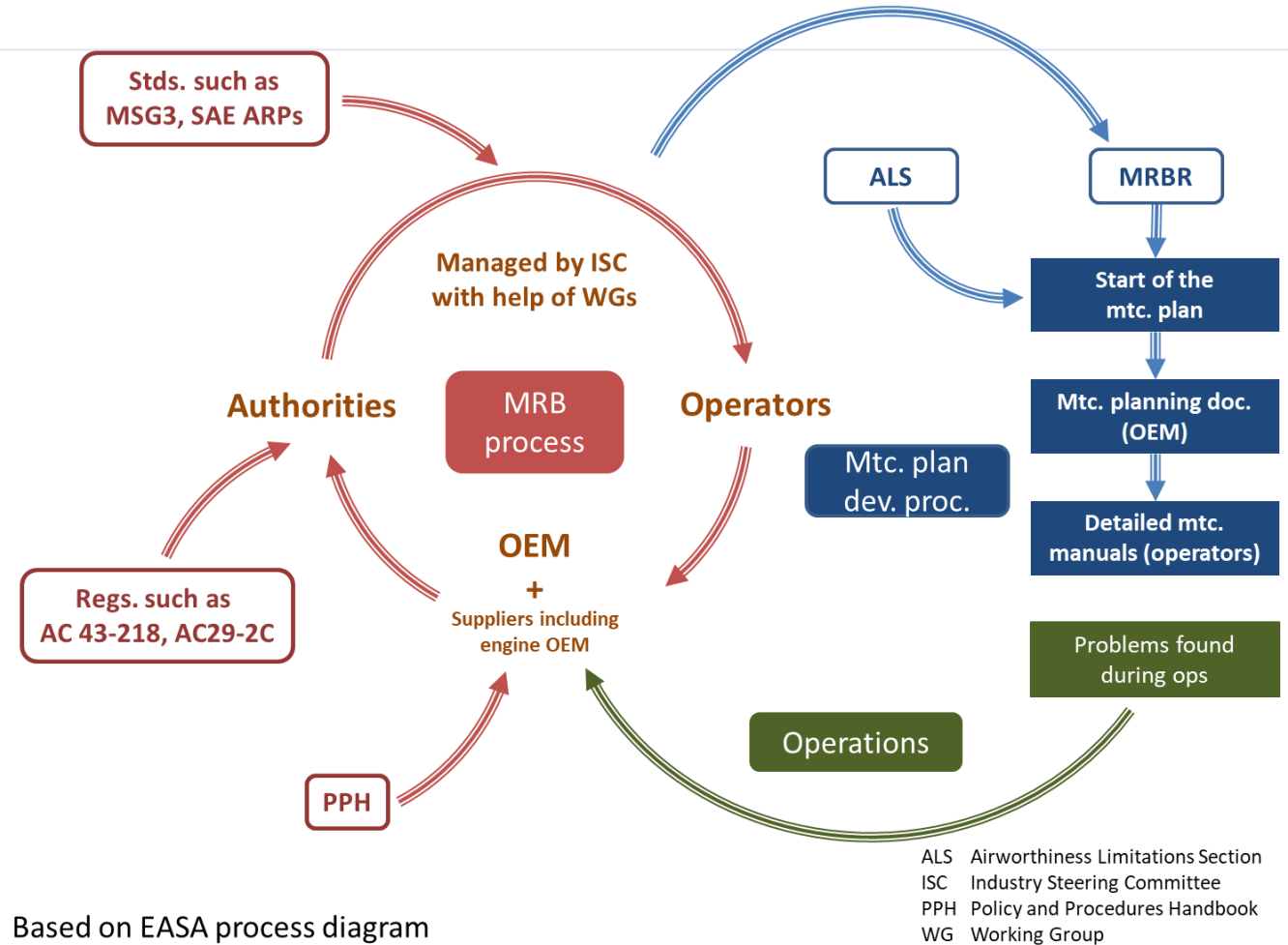
Cost: ~\$24 million (1970) **(a factor of ~3 more)**

Inspection cost: 66,000 MMH for inspections to reach the same interval **(a factor of ~60 less)**



What Changed in About a Decade?

- One factor was the formation of MSG (now called MPIG).
- Originally MSG consisted of
 - Airframers and engine OEMs
 - Airlines foreign and domestic (with United a significant player)
 - FAA and CAA (UK) and the US Navy
- Now there is a very rigorous process for developing the maintenance program for a specific aircraft operated by a specific airlines in member countries.
- The MPIG is managed by A4A and works closely with the International Maintenance Review Board Policy Board (IMRBPB) consisting of 11 global CAAs.



History of Standards for Maintenance Practices



Boeing B-747-100 (1969)



McDonnell Douglas DC-10 (1970)



Lockheed L-1011 TriStar (1970)



Airbus A300 (1972)

Maintenance Steering Group formed by the Air Transport Association (ATA) in mid 1960s

MSG-1 published in 1968

MSG-2 published in 1975

MSG3 published in 1980

- High maintenance cost, resource usage, and time spent.
- Many safety escapes.
- Mostly scheduled or reactive.
- Beginnings of Reliability Centered Maintenance (RCM).

- Main motivation was to develop a cost-effective maintenance program for the B747.
- Some RCM principles used.

- Adding new wide-body aircraft like the L-1011 and DC-10.
- More use of on-condition maintenance and condition monitoring.

- A more systematic top-down approach beginning with a 2-level analysis of all items that need maintenance.
- Zonal, Structural, Systems, L/HIRF
- Fully based on principles of RCM.
- Closer involvement of global CAAs, establishment of the MRB and development of the MFBR.

Honorable Mention: OSA-CBM (MIMOSA)

- The Open Systems Architecture for CBM (OSA-CBM) was developed in 2001 by an industry led team partially funded by the US Navy through a Dual Use Science and Technology (DUST) program.
- Industrial, commercial, and military applications of CBM technology
- Boeing, Caterpillar, Rockwell Automation, Rockwell Science Center, Newport News, Oceana Sensor, Penn State, MIMOSA were initial partners. Then GE joined.
- It is hosted by MIMOSA today.

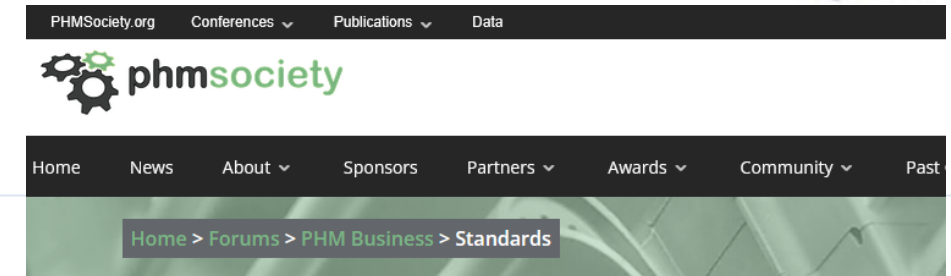
OSA-CBM Architecture	Description	IVHM Process Stages
Data Acquisition (DA)	Collects sensor data and health state information from the equipment internal monitors, the system data bus or data recorder.	Sense
Data Manipulation (DM)	Processes and transforms the sensor data and health state information collected by the DA.	Acquire
State Detection (SD)	Evaluates equipment state conditions against normal operating profiles and generates normal or abnormal condition indicators.	Transfer
Health Assessment (HA)	Provides information to determine the current state of health of equipment.	Analyze
Prognostics Assessment (PA)	Provides future state of health, performance life remaining, or remaining useful life (usage) indicators.	
Advisory Generation (AG)	Provides actionable information to operational and maintenance personnel or external systems.	Act


The SATAA process model adopted by HM-1 / IVHM











PHM Society and Standards

- Annual panel sessions at the PHM Society conferences
- Community (free forum) at <https://phmsociety.org/phm-forums/phm-forum/phm-business/standards/>
- Organizational Member of ISO/TC 108/SC 5
 - Gives free access to all to evolving standards to comment/influence
- Long-standing partnership with SAE and its technical committees: Several PHM Society board members are active TC members, current and past chairs, and steering group chair.
- Technical paper: Jeff Bird and Ginger Shao, “A View of Standards for Prognostics and Health Management,” IJPHM, ISSN 2153-2648, 2013-033. (Contains a summary of the 2012 panel.) www.phmsociety.org/node/1151



This forum has 14 topics, 1 reply, and was last updated 8 years ago by  jeff bird.

Viewing 14 topics - 1 through 14 (of 14 total)

Topic
PHM Standards in the Machine Learning Domain- Panel July 28 at the PHME20 Virtual Event Started by:  jeff bird
Standards Panel proceedings from Diigital transformation Started by:  jeff bird
PHM15 Panel- Evolving standards for Adaptive PHM Started by:  jeff bird
PHME16 Debate on The Internet of Things needs Standards Started by:  jeff bird
PHM18 Standards panel report Started by:  jeff bird
PHM18 Standards Panel Introduction- How do we track the standards world? Started by:  jeff bird
Education and Standards Panel Background and Challenges for PHM17 Started by:  jeff bird
Standards article from MFPT Started by:  jeff bird



Technical Engineering Standards

- Why should we care about standards?
- The motivation for developing standards, with some examples.
- PHM standards developed by SAE International and other Standards Development Organizations (SDO).
- **The new era of digital standards.**



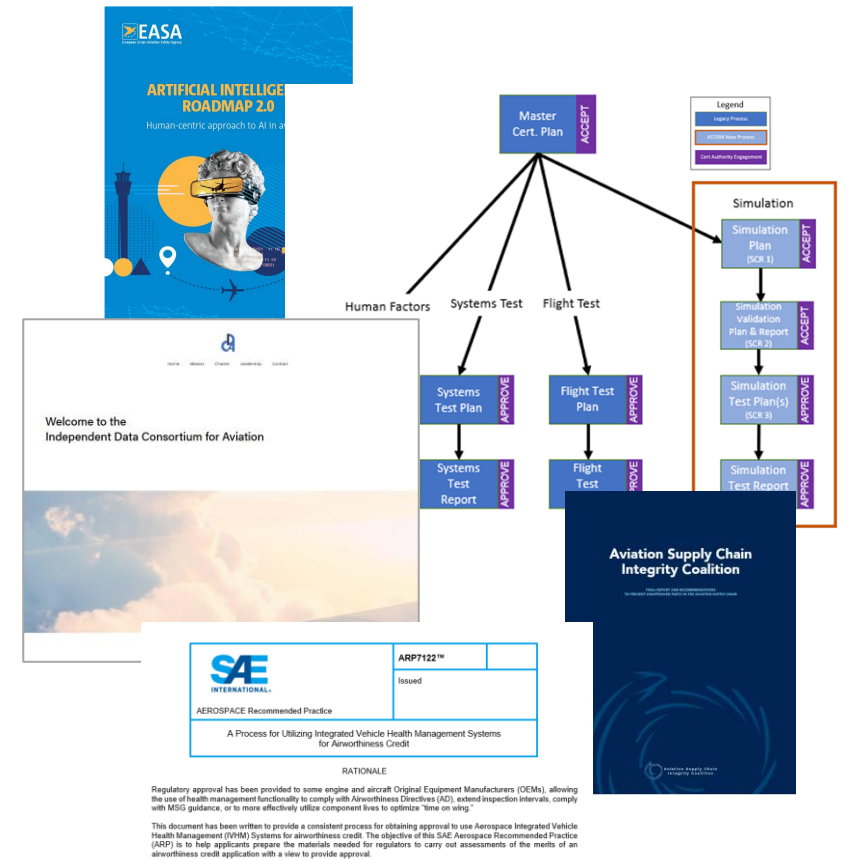
ATA e-BUSINESS PROGRAM



Note: We will talk mainly about the commercial aerospace industry in this presentation

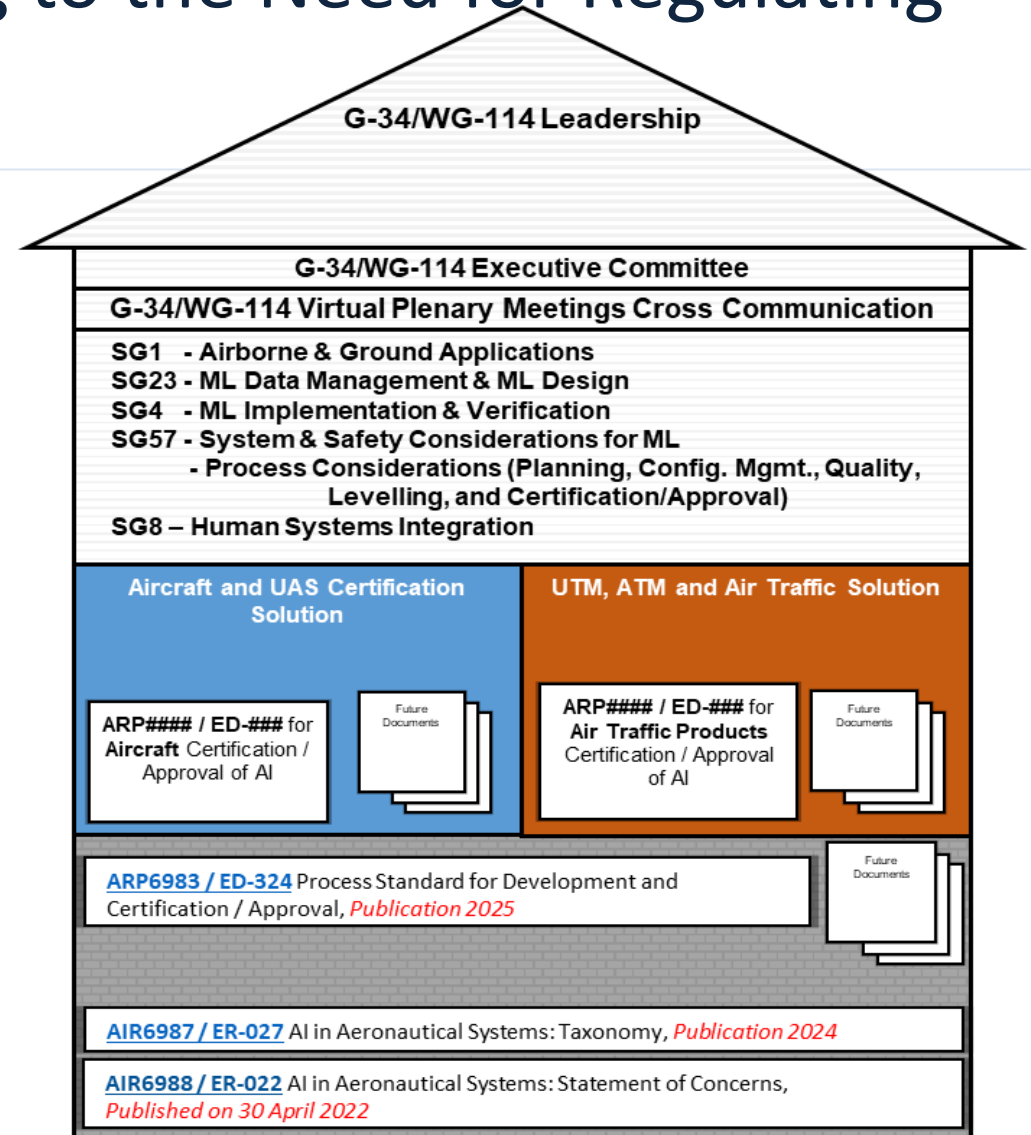
New Standards Related Initiatives to Address New Concepts

- **Artificial Intelligence**
 - Roadmaps from EASA, FAA, CAA
 - Establishment of G-34 (SAE)
- **Model-Based Processes**
 - Academic research initiatives (e.g. GATech)
 - Establishment of G-31, G-35 (SAE)
- **Data Governance**
 - Establishment of IDCA
 - ASCIC report on fake parts
- **Certified Health Management**
 - IP-180 / IP-170 and discussions on MSG4 (A4A-MPIG)
 - ARP5987 / ARP7122 (SAE)
 - AC43-218 recognizing end-top-end process (FAA)



Establishment of G-34: Responding to the Need for Regulating the Use of AI in Aerospace

- *G-34/WG-114* focuses on implementation and certification related to AI technologies for the safer operation of aerospace systems and aerospace vehicles.
- *G-34/WG-114* (comprised of 600+ members) promotes and standardizes Artificial Intelligence in the entire aviation eco-system (both Airborne and Ground) addressing both manned and UAS.
- Published Standards:
 - AIR6988 / ER-022 Artificial Intelligence in Aeronautical Systems: Statement of Concerns (Published on 30 April 2021)
 - Works In Progress and deliverables:
 - **ARP6983 / ED-324 Process Standard for Development and Certification / Approval of Aeronautical Safety-Related Products Implementing AI**
 - AIR6987 / ER-027 Artificial Intelligence in Aeronautical Systems: Taxonomy
 - AIR6994 / ER-xxx Artificial Intelligence in Aeronautical Systems: Use Cases Considerations



Guidance on AI From Regulators

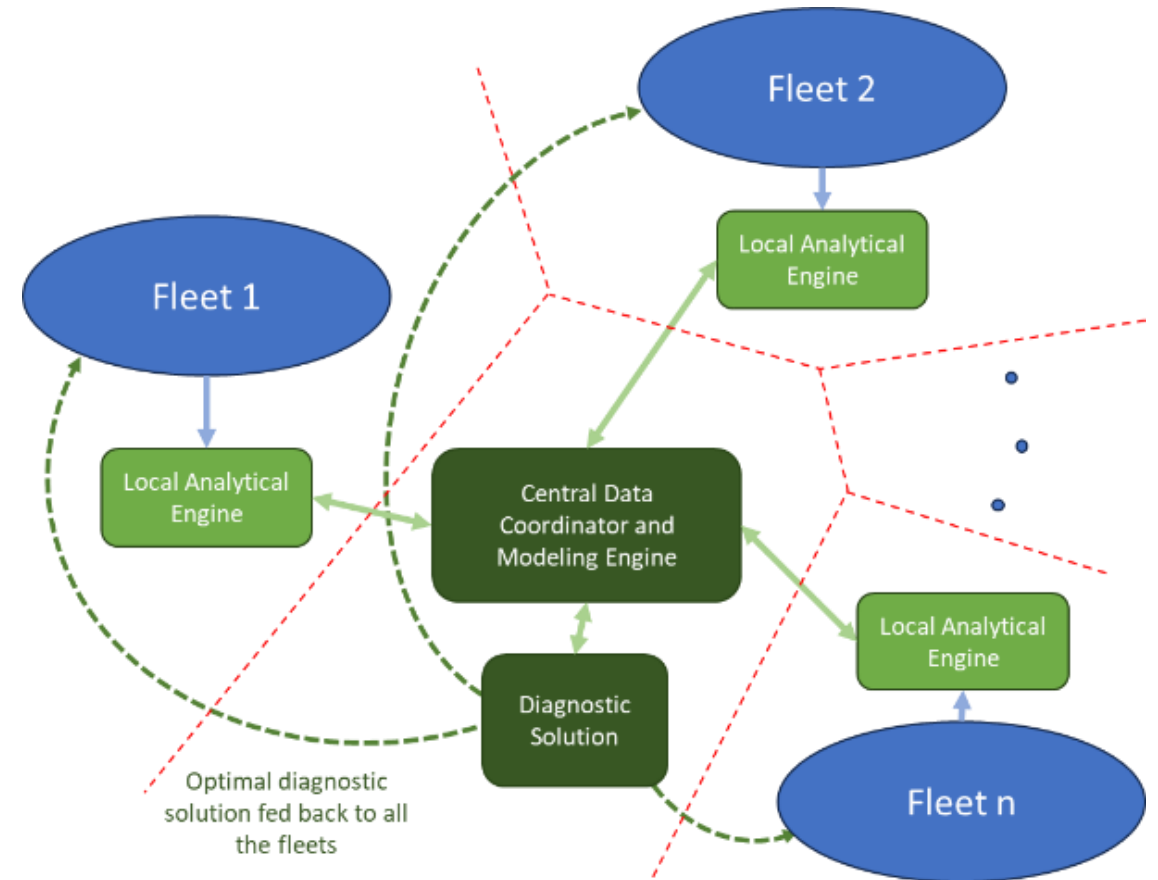
- EASA was the first to publish guidance via an AI roadmap
 - Level 1 ('assistance to human').
 - Level 2 ('human-machine teaming').
 - Level 3 ('more autonomous machine').
 - No adaptation on the fly.
- UK CAA has published a strategy document for AI assurance and automation in 2024
 - CAP3064: A plan for the next three years.
- FAA published its roadmap in 2024
 - Learned systems (fixed) very hard.
 - Learning systems considered research topics.
 - Take an incremental approach based on the safety continuum.



AI Learning Under Sovereign Governance Rules: Federated Learning

- IDCA is developing rules for using data across sovereign governance jurisdictions
- Use of AI and ML is growing in commercial aviation.
- Standards are needed for ensuring that data is reliable, accurate, and usable.
- Governance rules are needed for legal and appropriate data use.
- Team consisting of
 - University of Amsterdam
 - Technical University, Delft
 - KLM
 - Airbus / Embraer
 - IDCA

is developing a proposal to the Dutch government to fund graduate student to support this work called *Trust4Data*



Digital Data Standards: The Three-Layer Model

Governance Layer

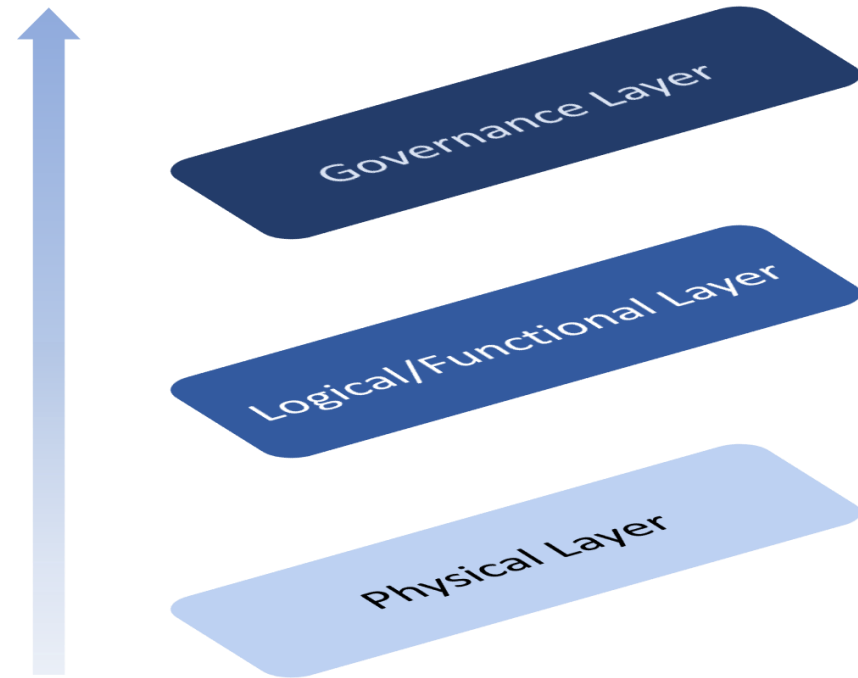
- Rules for how data is managed
- Standards and laws related to data ownership and sharing, airworthiness, export, cyber security, government policy, etc.

Logical/Functional Layer

- Functional use of data
- Digital thread and digital twin
- Enterprise systems and standards related to lifecycle management

Physical Layer

- Actual physical flow of information
- Governed by network and data exchange standards



This data model is inspired by the work done in the G31 Technical Committee of SAE International

G31: SAE's Technical Committee (TC) on Digital Transactions for Aerospace.

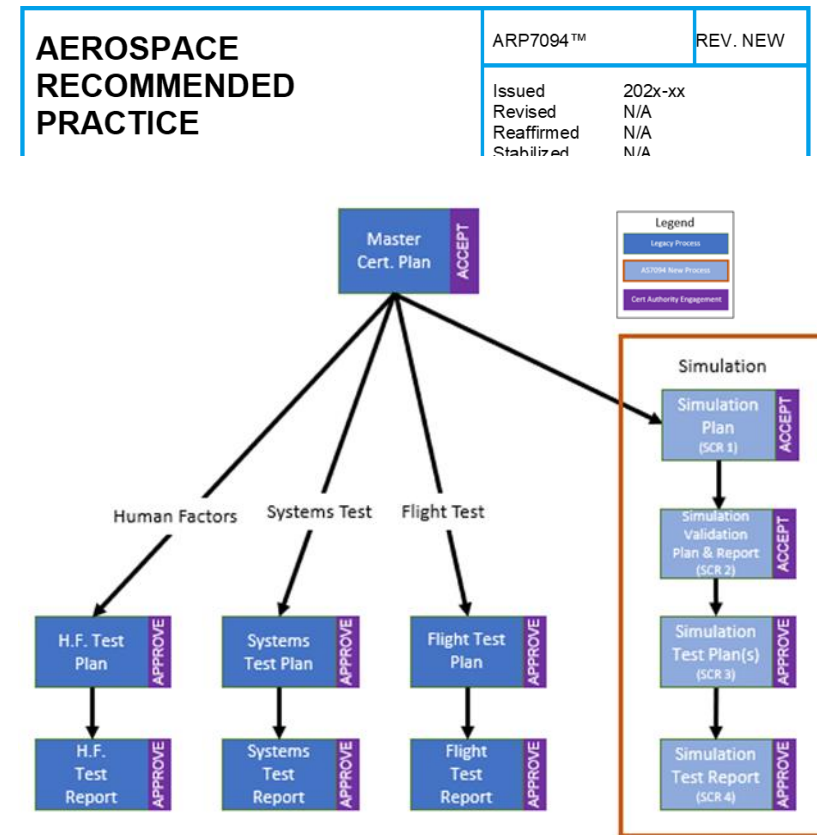
AIR 7161: Guidance in Digital Thread data standards Enablement, Monitoring and Quantification.

Use of Models and Simulation Will Become Essential in Certification of PHM Functionality

- G-35: Modeling, Simulation, Training for Emerging Aviation Technologies
- The committee was set up in 2021 to develop standards for the use of modeling and simulation to assist with
 - Type certification of aircraft
 - Training devices
 - Pilot education and certification

The initial emphasis is on new generation of aircraft, but the guidance can be used for all aircraft.

- Documents on pilot licensing and on type certification have been balloted in 2024.



The new steps using models and simulation
In comparison to the old process

New Data Exchange Standard: AS7140 (CODEX-HUMS)

General

- Data formats proprietary, specific for onboard systems.
- No analysis without dedicated software.
- Limited ability to export data for analysis in 3rd party tools.

Specific

- US Army Future Vertical Lift program and its timeline.



AEROSPACE STANDARD	AS7140™	
	Issued	2025-09
Common, Open Data Exchange Format for Rotorcraft Health and Usage Monitoring Systems (CODEX-HUMS)		

RATIONALE

A Common Open Data Exchange format for rotorcraft Health and Usage Monitoring Systems (CODEX-HUMS) provides for a more affordable, capable, and effective Integrated Vehicle Health Management System. This document provides a standard definition for the CODEX-HUMS open data format produced or used by an onboard or offboard system. The standard format benefits end users (e.g., operators, developers, suppliers, integrators, and maintainers) with the capability to more rapidly operationalize HUMS data. This HUMS open data format meets the intent of a Modular Open System Approach (MOSA) and provides a foundation for rapidly realizing operational benefits from the data at the point of maintenance and exchanging the data with external enterprise systems.

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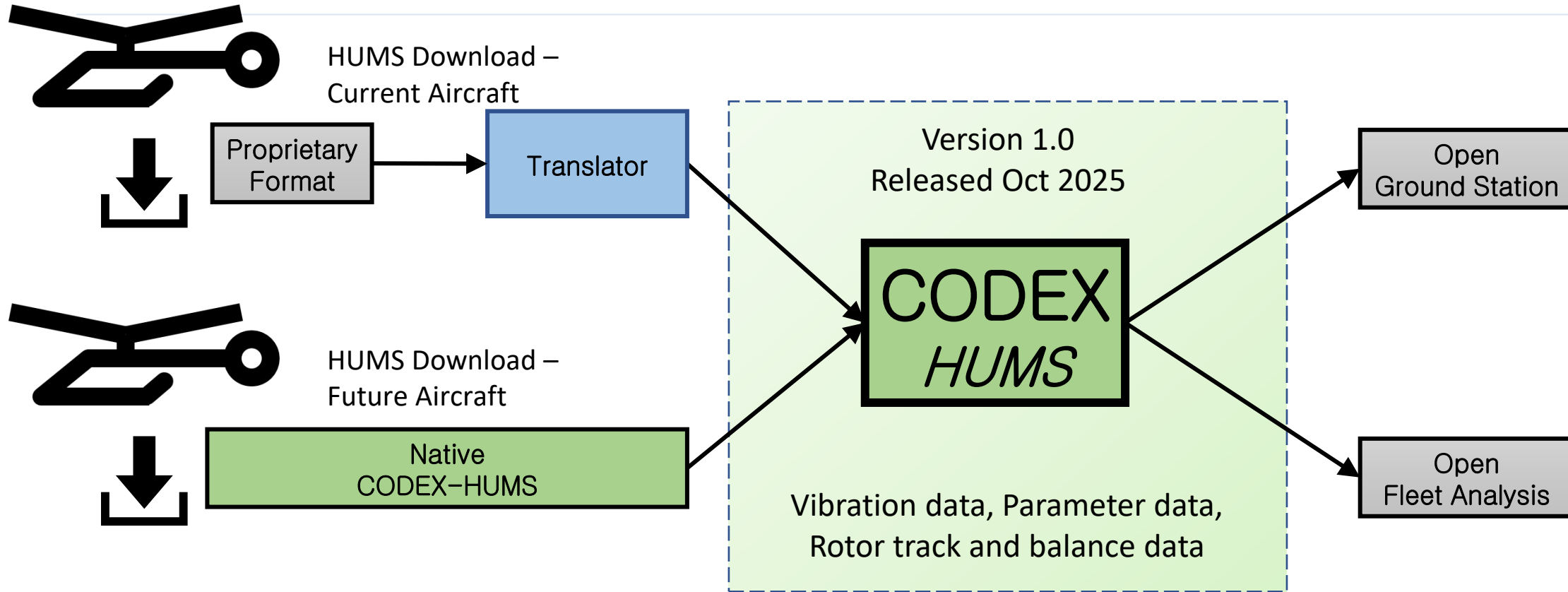
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http://www.sae.org

SAE WEB ADDRESS:

For more information on this standard, visit
<https://www.sae.org/standards/content/AS7140/>

What Does the AS7140 Data Standard Enable?



Open Ground Station and Open Fleet Analysis aren't covered by the standard, but the data standard is a pre-requisite for those capabilities (potential future work for the committee)

Digital Transformation

- Automation
- Digital Standards
- Digital Thread
- Digital Twin
- Modelling & Simulation for Certification

AEROSPACE COUNCIL

SAE G-38 Automation of Aircraft Inspection

Proposal for an SAE Technical Committee to develop aerospace industry information reports, recommended practices, and standards for the use of automation for aircraft inspection(s)

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G-31 Digital Transactions for Aerospace

Discuss

Overview | WIPs | Ballots | Published | Participants | Work Area | Meetings

The ETA committee is responsible for creating and maintaining SAE technical reports focusing on secure digital solutions to store, move, and access product lifecycle data and to streamline technical supply chain data to track, trace, and authenticate critical aircraft parts and materials.

[New Project Request](#)

Public Resources

- G-31 Fact Sheet.pptx
- G31 Charter

Leadership

- RR** Robert Rencher
Chairperson - User
- RU** Ravi Udali
Secretary
- CM** Chris Markou
Vice Chairperson - User

Committee Manager

- JS** James N Steele
Staff Representative



New Dedicated Committees / Steering Groups (SG) / Consortia

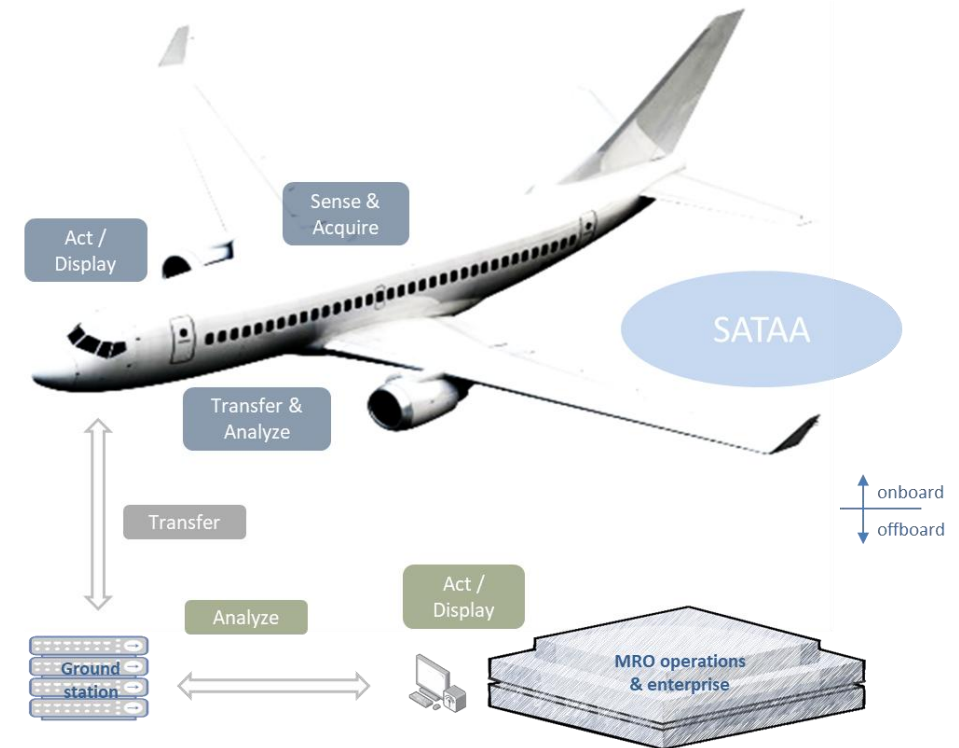
- DDSG – Digital & Data SG
- G31 – Digital Transactions in Aero
- G32 - Cybersecurity
- G35 – Modeling and Simulation
- G34 – AI/ML in Aero
- Digital Standards Alliance



A Consortium of SAE ITC

Concluding Remarks

- Standards are essential for a civilized society to function effectively!
- Consensus standards are a convenient and efficient way for industry to agree upon shared guidelines for design, analysis, and certification.
- These standards avoid the use of proprietary elements.
- PHM functionality is increasingly finding its way into the aviation sector and the need to certify it is essential. SAE is helping develop the guidelines along with organizations like MPIG.
- The digital revolution and new kinds of aircraft have made this even need even more important.



...or You Can be a Cynic

Monday April 11, 1994



Technical Engineering Standards



ATA e-BUSINESS PROGRAM

- Why should we care about standards?
- The motivation for developing standards, with some examples.
- PHM standards developed by SAE International and other Standards Development Organizations (SDO).
- The new era of digital standards.



THANKS! ANY MORE QUESTIONS?



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