

IVHM – And the Path Forward

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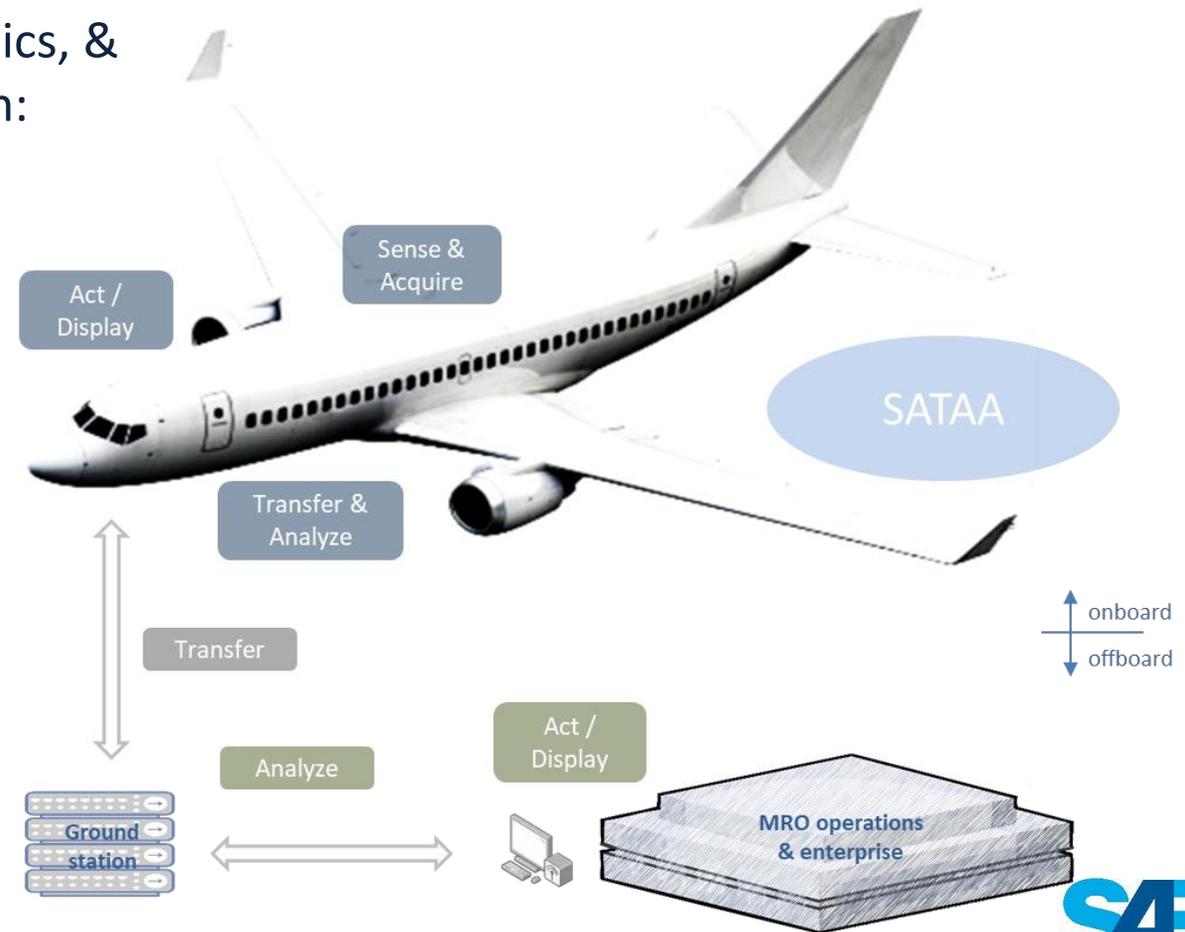
May 2021

Outline

- Brief introduction to IVHM
- History of SAE's involvement in aerospace and IVHM standards
- Spotlight on ARP5987
- Example of the use of IVHM in an aircraft
- Path forward

Integrated Vehicle Health Management

- An end-to-end capability that uses sensors, electronics, & analytics both on-board and off-board to accomplish:
 - Diagnostics: Determining the **current** health condition
 - Prognostics: Predicting the **future** state
 - Health management: **Managing** the asset based on this (and related) information
- IVHM systems comprise of:
 - Sense, Acquire, Transfer, Analyze, Act/Display (**The SATAA Model**)
- IVHM systems manage assets while
 - Delivering guaranteed performance
 - Increasing availability
 - Lowering life-cycle costs
 - And without compromising system safety

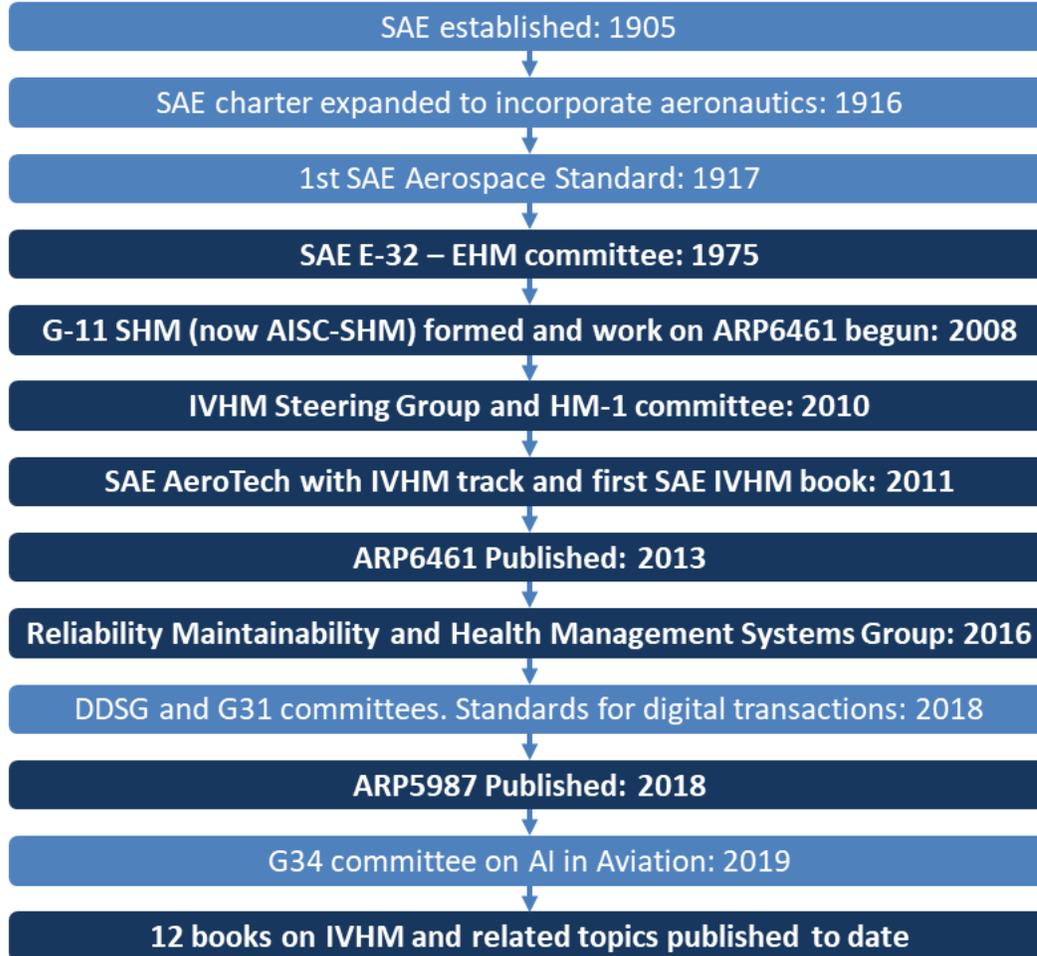


SAE's History with Aerospace and Involvement in IVHM

1905



2021



- In addition to aerospace SAE covers spacecraft, automobiles, commercial vehicles, multi-modality, infrastructure, power needs, access, smart grids, data sharing, data ownership.
- Has produced over **8,500 standards** for ground vehicles and over **32,000 standards** for aerospace.

“The work covered by the SAE is of such value that everybody identified with the industry should take out membership.”
Orville Wright, 1918

Current Work Across Different SAE Committees Related to the Broad Area of Continued Airworthiness

IVHM Steering Group

- Steering group initiative on Maintenance Credits
- Liaisons with FAA / EASA / MPIG / etc.

E-32: Propulsion Health Management

- ARP5987A: A Process for Utilizing Aerospace Propulsion Health Management Systems for Maintenance Credit (being updated)

AISC-SHM: Aerospace Industry Steering Committee on Structural Health

- ARP6461A: Guidelines for Implementation of Structural Health Monitoring on Fixed Wing Aircraft (recently balloted)

HM-1: Integrated Vehicle Health Management

- **JA6268: Design & Run-Time Information Exchange for Health-Ready Components**
- ARP7122: Utilizing Aircraft IVHM Systems for Maintenance Credit
- JA1013: Condition Based Maintenance (CBM) Recommended Practices

G11: Probabilistic Methods / Maintainability

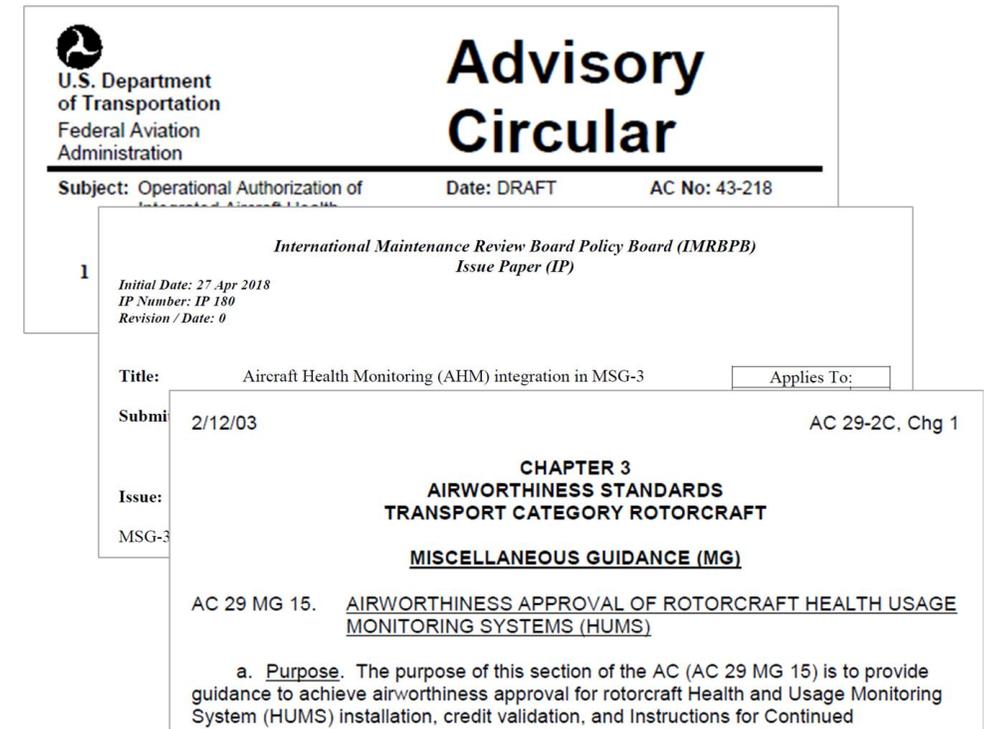
- **JA1010: Maintainability Program Standard**
- **JA1011: Evaluation Criteria for RCM Processes**
- **JA1012: A Guide to the RCM Standard**

Documents in bold already published

In addition, many documents discuss requirements, design, V&V, etc., related to IVHM systems

Other Developments

- FAA AC29-2C / MG15 (2003)
 - Related to rotorcraft health & usage monitoring systems (HUMS).
 - Restricted to DAL B or lower.
 - Discusses COTS systems as well.
- MPIG Modified MSG-3.2009
 - Mention of scheduled structural health management systems (S-SHM).
- MPIG IP-180 (2018)
 - Introduces the concept of Level 3 maintenance where AHM can be used.
 - Has a very clearly laid out flowchart.
 - Will be incorporated into MSG-3 guidance soon.
- FAA AC43-218
 - Guidance for the certification of IAHM systems for fixed wing.
 - Currently being reviewed by FAA legal.



U.S. Department of Transportation
Federal Aviation Administration

Advisory Circular

Subject: Operational Authorization of Integrated Aircraft Health Monitoring Systems (IAHM) Date: DRAFT AC No: 43-218

1 *International Maintenance Review Board Policy Board (IMRBPB) Issue Paper (IP)*

Initial Date: 27 Apr 2018
IP Number: IP 180
Revision / Date: 0

Title: Aircraft Health Monitoring (AHM) integration in MSG-3 Applies To: AC 29-2C, Chg 1

Submittal Date: 2/12/03

Issue: MSG-3

**CHAPTER 3
AIRWORTHINESS STANDARDS
TRANSPORT CATEGORY ROTORCRAFT
MISCELLANEOUS GUIDANCE (MG)**

AC 29 MG 15. AIRWORTHINESS APPROVAL OF ROTORCRAFT HEALTH USAGE MONITORING SYSTEMS (HUMS)

a. Purpose. The purpose of this section of the AC (AC 29 MG 15) is to provide guidance to achieve airworthiness approval for rotorcraft Health and Usage Monitoring System (HUMS) installation, credit validation, and Instructions for Continued Operation (ICO) for the installation of the HUMS.

ARP5987

A Process for Utilizing Aerospace Propulsion Health Management (HM) Systems for Maintenance Credit (MC)

- Started in 2008 and published in 2018.
- Has input from major engine OEMs and regulators.
- Is being updated right now, for a new ballot end of the year.
- Will be the basis for ARP7122, which will discuss vehicle level health management for maintenance credit.
- Emphasizes the end-to-end nature of the HM function involving onboard and offboard elements.

Health Management & Maintenance Credits

Retrofit design (modify existing ICA)

Examples

- Replace a manual task with automated one.
- Reduce/remove a scheduled task.
- Make tasks condition-based.
- Support in-service issue with monitoring instead of mandated inspections.
- AMOC for an airworthiness directive (AD).

New design (develop novel ICA)

Examples

- Reduce design conservatism with health management.
- Use data to drive new maintenance procedures.

A Key Part of ARP5987: The PHM Checklist

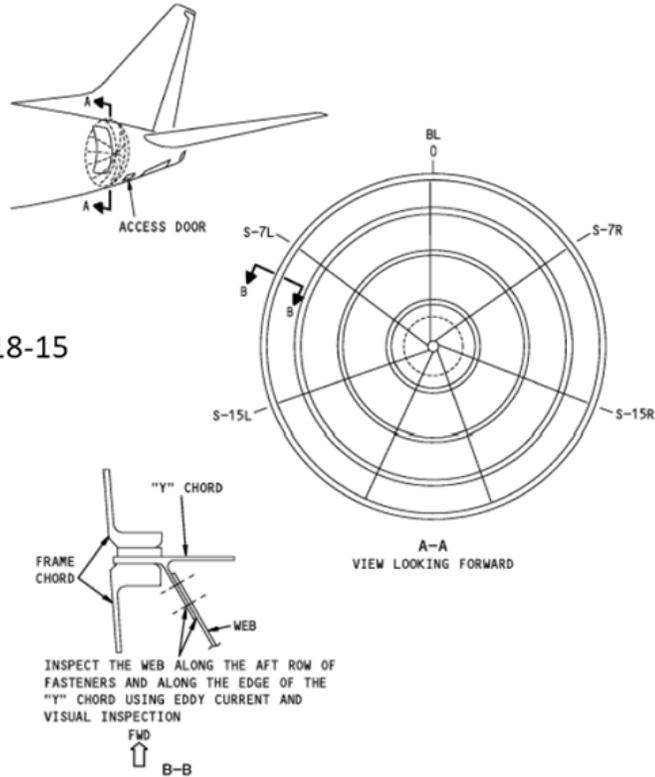
	Checklist question	Explanation
1	What protection or benefit will the system provide?	Articulate the benefit that the HM system provides over and above conventional methodology.
2	What is the limitation of the current state or criticality of the failure effect?	Determine the criticality of the failure. This is to ensure that the new system will be developed with the appropriate criticality level.
3	How is the impending failure detected, and is there sufficient time to mitigate it?	Ensure that sufficient time is allowed for maintenance action to be taken once an alert is given.
4	What is the required detection success rate?	Use standard processes (e.g. AIR7999) to document the relevant metrics such as prob. det., false alarm rate, etc. This can be done with test and operational data or with models.
5	What frequency of automated checks is needed to ensure the required success rate?	Ensure that the rate of data capture is higher than the rate of failure progression so that sufficient time can be set aside for mitigation action. Also, make sure that the data can be validated during operation.
6	Can any existing checks, constraints, and/or actions be removed?	Determine, in detail, the existing procedures that are made redundant by the proposed HM solution. This will lead to changes in the ICA. It may also require a change to the MMEL.
7	Have all mitigations to support the credit been evaluated?	Make sure that the HM system is robust. There should be mitigations in place so that the vehicle can work with a degraded HM system. One way is to fall back on the old procedures.
8	What is the cost versus benefits?	Articulate the costs and the benefits (e.g. using ARP4176) of the new system because with this, no system can be creditably fielded. Most HM systems today exist for economic benefit alone, not for safety.
9	Should the maintenance credit process proceed?	Only proceed if you are completely satisfied that all the steps in this checklist have been completely successfully. Engage in early and constant dialog with all stakeholders to ensure wide support.
10	Is there a plan to ensure that the credit is improved and updated for technology and/or system configuration changes?	Ensure that there is a way to monitor the HM system so that the metrics from step no. 4 above are validated over the life of the system. A plan for maturation, recalibration, and redesign should be in place so that improvements (with recertification, if necessary) can be carried out continuously.

Boeing B737 application – Aft Pressure Bulkhead (APB)

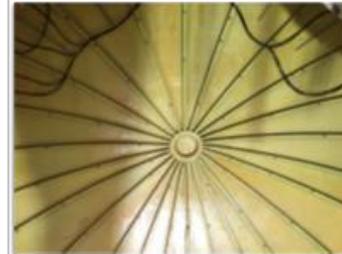
Inspection complicated due to aft galley covering inspection area

Courtesy: David Piotrowski

- SB 737-53A1248
 - Threshold 25,000 FC
- Repeat Intervals
 - LFEC 1,200 FC
 - HFEC 3,800 FC
- Airworthiness Directive AD2016-18-15
- Airplane Models: 737-600, 737-700, 737-700C, 737-800, 737-900



- 20 aircraft equipped with Structural Monitoring Systems' CVM sensors SMS.
- AMOC, which is in progress at Boeing.
- Two aircraft have Acellent PZT Sensors installed in addition.
- Two technologies can be compared.
- CVM is specific, but PZT is widespread.



Airworthiness Directive (AD) requires crack inspections which the operator is replacing with S-SHM systems: Comparative Vacuum Monitoring (CVM) and Piezoelectric Transducers (PZT)-based.

Applying 5987 Process to Delta's B737 APB Application

Courtesy: **David Piotrowski**

	Checklist question	Explanation
1	What protection or benefit will the system provide?	Will provide crack detection without onerous access requirements (3-5 days out of service Special Schedule reduced down to ~1 hour).
2	What is the limitation of the current state or criticality of the failure effect?	AD 2016-18-15 (SB 737-53A1248) is mandated for crack detection via eddy current on certain fasteners of the APB; Structural Health Monitoring will be an AMOC to the required inspections
3	How is the impending failure detected, and is there sufficient time to mitigate it?	Sensor is designed (ring around fastener) and placed to intercept crack with the same (or better) probability of detection (POD) crack length as Eddy Current.
4	What is the required detection success rate?	Same (or better) probability of detection (POD) crack length as Eddy Current.
5	What frequency of automated checks is needed to ensure the required success rate?	Same as the scheduled task; Threshold and repetitive intervals were determined by OEM SB. Frequent interval (1200 cycles) means Special Scheduling of aircraft to Hangar
6	Can any existing checks, constraints, and/or actions be removed?	SHM will be used to replace the eddy current inspection; Access requirements (and possible associated damage) avoided
7	Have all mitigations to support the credit been evaluated?	Yes; Implemented into Boeing manuals and previous economic SB
8	What is the cost versus benefits?	Going from 3-5 days out of service annually to ~1 hour translates into annual benefit of \$600K per aircraft
9	Should the maintenance credit process proceed?	Yes; However, requires AMOC to AD 2016-18-15
10	Is there a plan to ensure that the credit is improved and updated for technology and/or system configuration changes?	Yes, fully supported by Structural Monitoring Systems. Improving the credit (i.e., increasing intervals) is unlikely near-term, but possible with additional acceptance into fatigue & damage tolerance community. <i>This would lead to tangible maintenance credits.</i>

Next Steps for SAE IVHM-SG and Its TCs

Event	Date
ARP6461 Rev A (Guidelines for Implementation of Structural Health Monitoring on Fixed Wing Aircraft)	Ballot closed 5/18
ARP5987 Rev A (A Process for Utilizing Aerospace Propulsion Health Management Systems for Maintenance Credit)	Fall 2021
JA1013 (Condition Based Maintenance (CBM) Recommended Practices)	Nov 2021
ARP7122 (Utilizing Aircraft IVHM Systems for Maintenance Credit)	Dec 2021
Develop plans to create specific IPs related to vehicle health management	Ongoing

SAE INTERNATIONAL
AEROSPACE RECOMMENDED PRACTICE
ARP6461
 Issued 2013-09
 Guidelines for Implementation of Structural Health Monitoring on Fixed Wing Aircraft

RATIONALE
 The development of Structural Health Monitoring (SHM) technologies to achieve Vehicle Health Management objectives in aerospace applications is an activity that spans multiple engineering disciplines. It is also recognized that many stakeholders (i.e., Regulatory Agencies, Airlines, Original Equipment Manufacturers (OEM), Academia and Equipment Suppliers) are crucial to the process of certifying viable SHM solutions. Thus a common language (definitions), framework of SHM solution approaches, and recommended practices for reaching those solutions, are needed to promote fruitful and efficient technology development.

TABLE OF CONTENTS

1.	SCOPE	4
1.1	Purpose	4
1.2	Field of Application	4
1.3	An Overview	4
1.3.1	General App	4
1.3.2	Designing an	4
1.3.3	Evolution of a	4
1.3.4	Requirement	4
2.	REFERENCE	4
2.1	Applicable D	4
2.1.1	SAE Publicat	4
2.1.2	FAA Publicat	4
2.1.3	EASA Public	4
2.1.4	TCCA Public	4
2.1.5	RTCA Public	4
2.1.6	ATA Publicat	4
2.1.7	U.S. Govern	4
2.1.8	Other Public	4
2.2	Related Publ	4
2.3	Definitions	4
2.4	Acronyms	4

SAE INTERNATIONAL
AEROSPACE RECOMMENDED PRACTICE
ARP5987™
 Issued 2018-12
 A Process for Utilizing Aerospace Propulsion Health Management Systems for Maintenance Credit

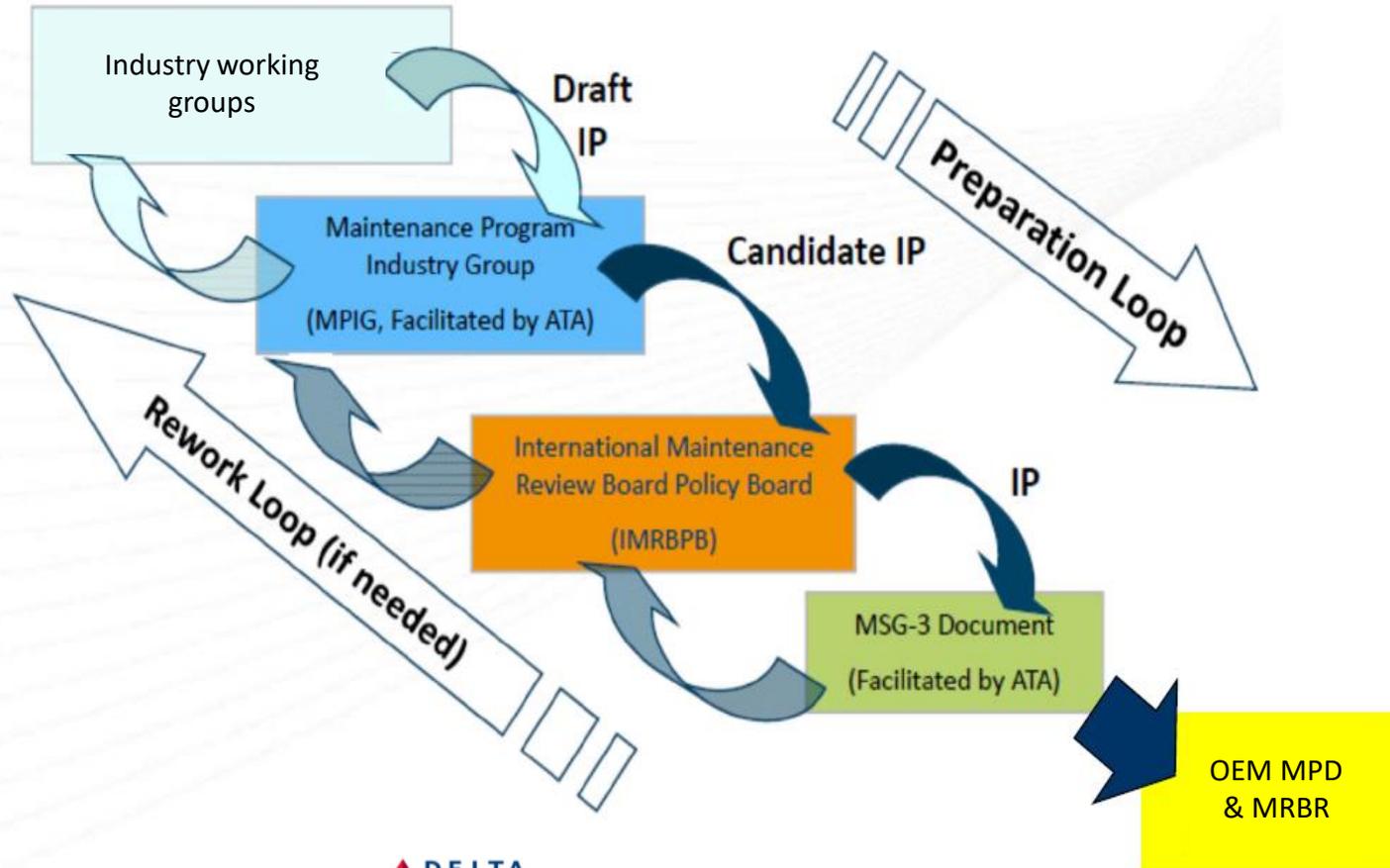
RATIONALE
 This document has been written to provide a process to achieve Maintenance Credits using Aerospace Propulsion Health Management Systems in a consistent way. This will help Regulators carry out assessments of the merits of a Maintenance Credit application with a view to provide approval.

This document reflects the fact that regulatory approval has been provided to multiple engine and aircraft Original Equipment Manufacturers (OEMs), allowing the use of Propulsion Health Management functionality in the mitigation of Airworthiness Directives, extending inspection intervals, compliance with Maintenance Steering Group-3 (MSG-3) and more effective utilization of component lives to increase 'time on wing'.

TABLE OF CONTENTS

1.	SCOPE	2
2.	REFERENCES	2
2.1	Applicable Documents	2
2.1.1	SAE Publications	2
2.2	Related Publications	2
2.3	Definitions	3
2.4	Glossary	3
3.	INTRODUCTION	4
4.	MAINTENANCE and DESIGN CREDITS	5
4.1	Maintenance Credits Process Questions	5
5.	NOTES	7
5.1	Revision Indicator	7
APPENDIX A	MAINTENANCE CREDIT CHECKLIST	8
APPENDIX B	MAINTENANCE CREDIT EXAMPLES	10

Path Forward With Respect to the MPIG and IMRBPB



- The member TCs will continue to develop standards and processes to prepare specific IPs related to different aspects of health management.
- This will be coordinated with the IMRBPB / MPIG / SAE via cognizant partners (currently Heliker, Labay, Piotrowski, Walthall, Hickenbottom, Budeneau)
- *The IVHM-SG will only act as an advisory body. The work will be done by the TCs and industry experts.*

Courtesy: David Piotrowski

Courtesy: Holger Speckmann

THANKS!

Questions?