Predictive Maintenance In Aviation Panel

Chair, Christopher Teubert, Diagnostics and Prognostics Group Lead, NASA

Justin Sindewald

Team Lead,

Predictive Maintenance,

United Airlines

Darren Macer

Senior Technical Fellow,

Predictive Maintenance and Health Management,

Boeing

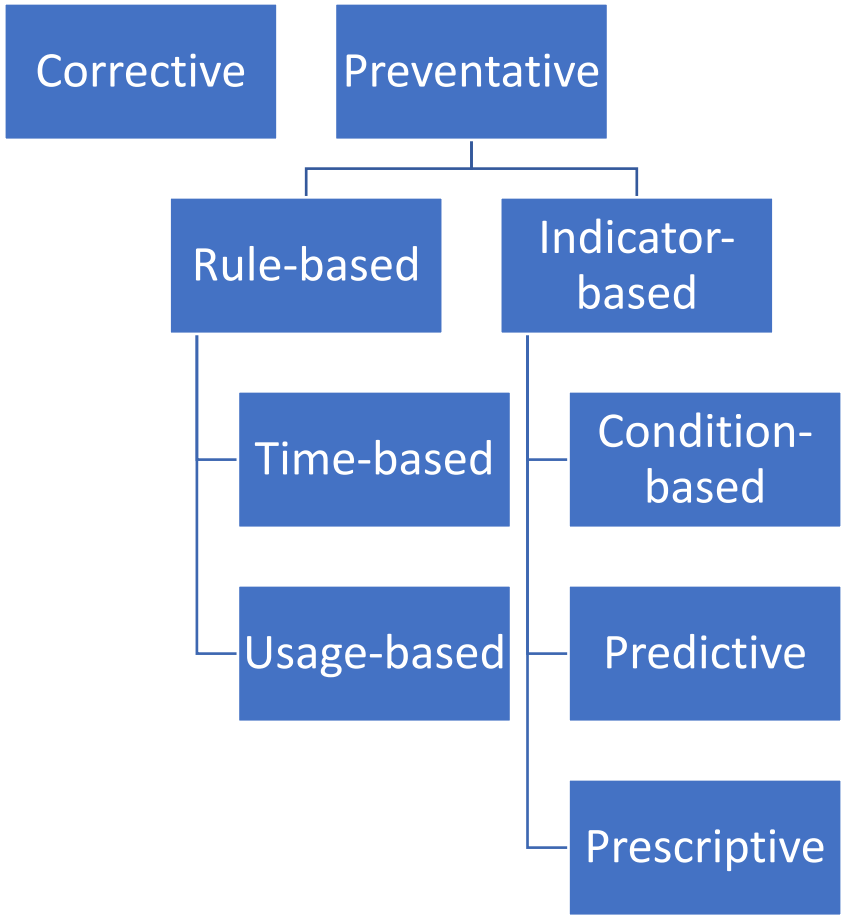
Rhonda Walthall

Technical Fellow,

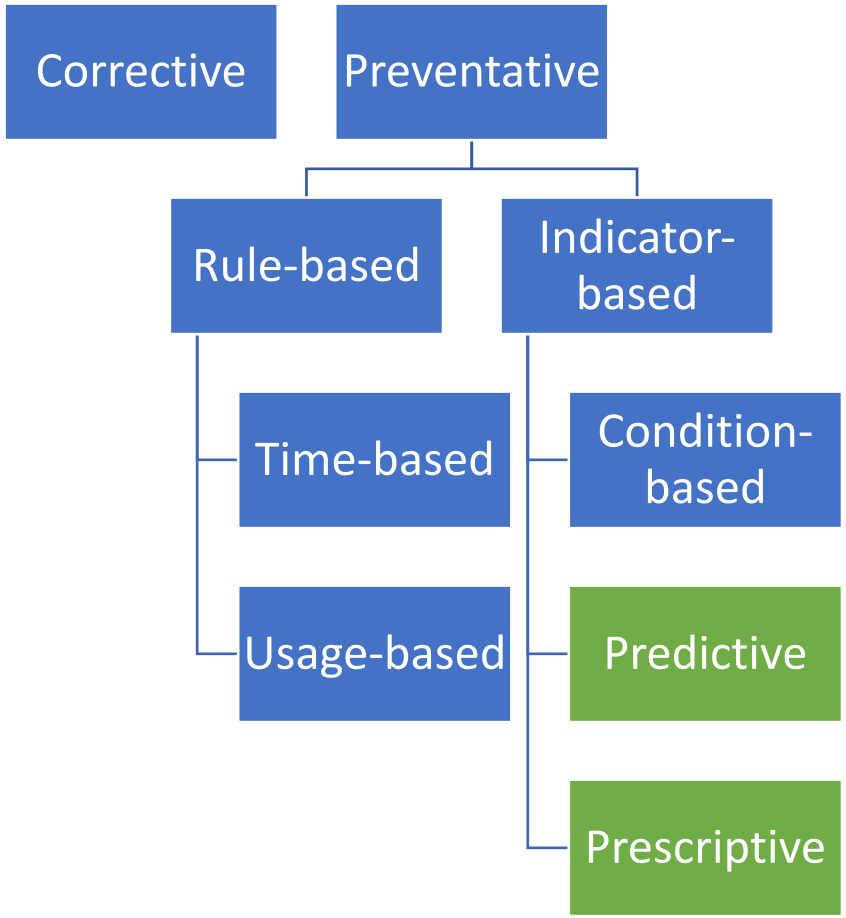
Enterprise Engineering,

Collins Aerospace

Maintenance Strategies



Predictive Maintenance (PdM)

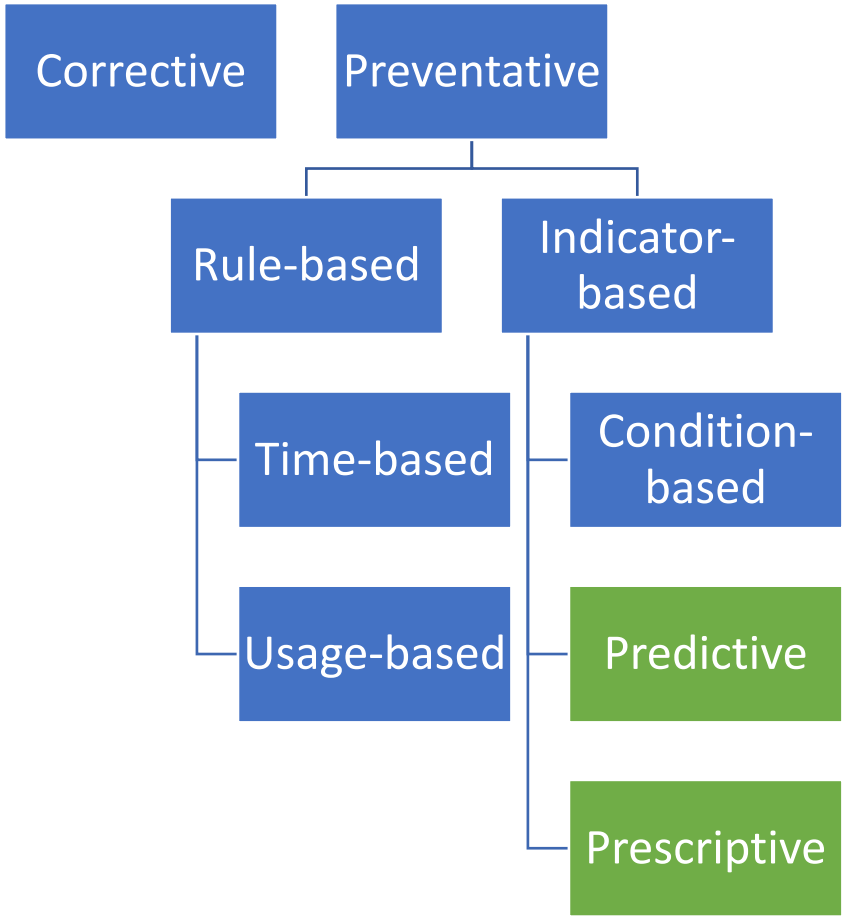


DoE estimates that, if implemented well, PdM could **reduce maintenance costs by 30%**[1]

ICF Aviation reports that savings to airlines could be as much **as $3 Billion**[2]

In 2011, the US Congress indicated that **"predictive maintenance can reduce. . . system downtime, ensure adequate supply of needed parts, and decrease costs."**[3]

Predictive Maintenance - NASA



TTT Project

NASA's Transformational Tools and Technologies project is planning a body of work aimed at helping commercial aviation adopt predictive maintenance technologies. Looking for partners.

Diagnostics and Prognostics Group & PCoE

NASA's Diagnostics and Prognostics group is developing technologies and methods for diagnostics, prognostics, and related technologies in aviation and space.

ProgPy

PCoE Datasets

Predictive Maintenance – PdM Whitepaper

INTELLIGENT SYSTEMS DIVISION

2023 TTT Predictive Maintenance Whitepaper

Teubert, Christopher; Ahmad, Ali Pohya; and Gorospe, George: ***An Analysis of Barriers Preventing the Widespread Adoption of Predictive and Prescriptive Maintenance in Aviation***. NASA, 2023.

1. Problem Complexity
2. Validation, Safety Assurance, and Regulatory Challenges
3. Cost of Adoption
4. Impact Estimation
5. Data Availability, Quality, and Ownership

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United's Growing Fleet

Boeing 737NG

Boeing 737MAX

Airbus A320ceo

Boeing 767-300/400

Boeing 757

Boeing 787

+

Boeing 777-200/300

~890 Aircraft

800+ Orders
(by 2032)

United Airlines Digital Fleet Management Overview

Mission statement:

Develop and deploy innovative predictive alerting and health monitoring solutions to improve United's fleet reliability by turning unexpected system failures into scheduled maintenance

Expertise we deliver:

Aircraft Data Engineering

Innovative predictive alerting & operational integration

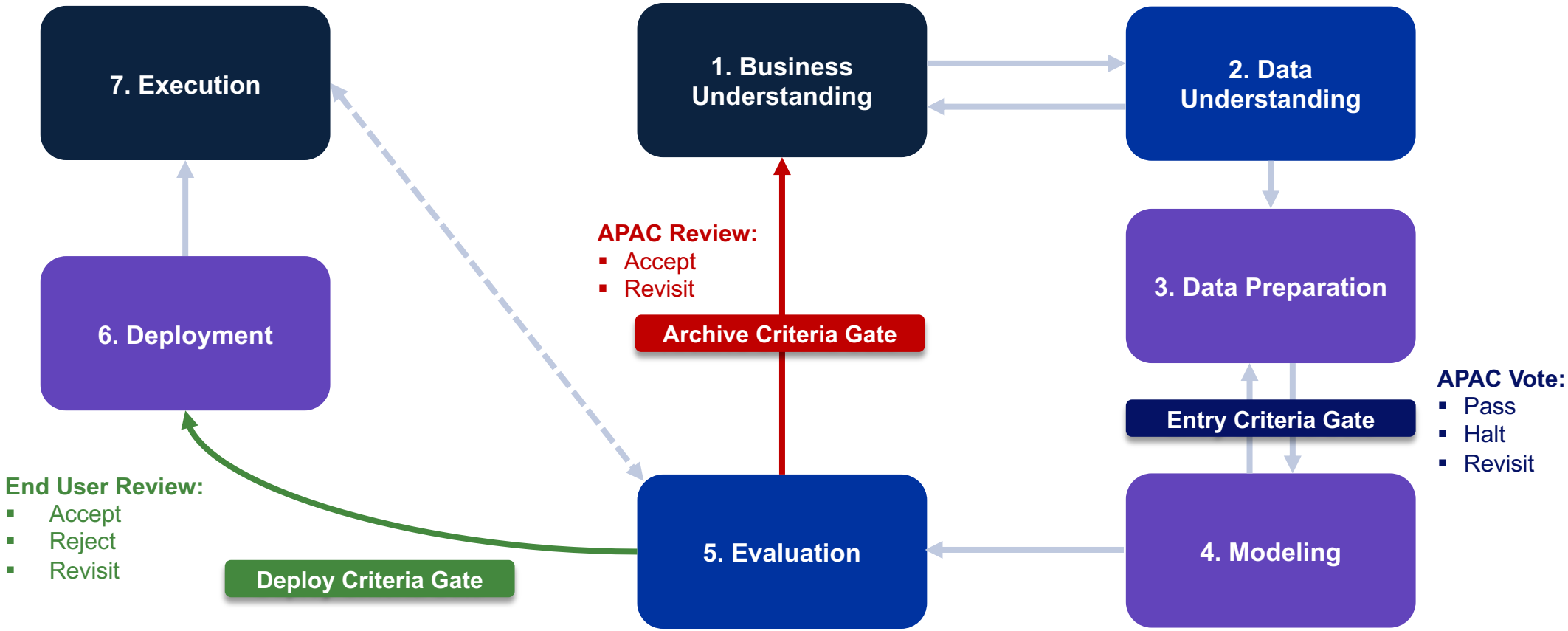
Operational Monitoring & Troubleshooting

Key focus areas:

- ❑ Scaling predictive maintenance use cases and adoption
- ❑ Leveraging full flight data for maintenance purposes
- ❑ Building & managing predictive maintenance and health monitoring products/apps
- ❑ Digital Aircraft Strategy – using sensor data & connectivity to transform operations

Leader-supported innovation and investment in the future of aircraft data utilization

United's Aircraft Predictive Alerting Committee (APAC) Alert Development Life Cycle



Predictive Maintenance In Aviation Panel

Darren Macer

Senior Technical Fellow,

Predictive Maintenance and Health Management,

Boeing

PHM Society Salt Lake 2023

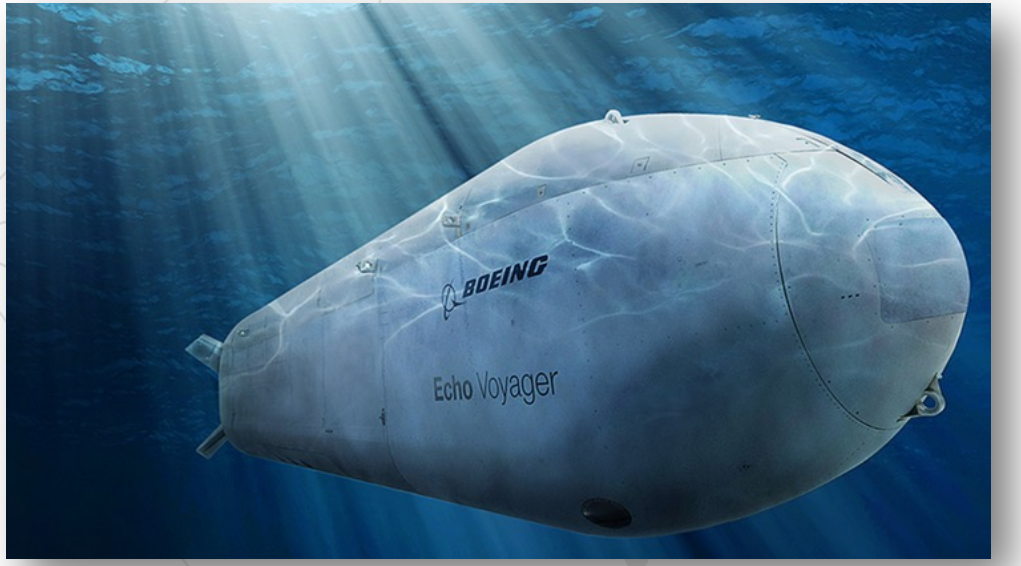
“Predictive Maintenance In Aviation”

Abstract:

The aviation industry has long recognized the potential benefits of predictive maintenance, a maintenance strategy that leverages sensor and operational data to predict the degradation of components and leverages those predictions for optimal maintenance scheduling. With the ability to reduce maintenance costs by up to 30%, as reported by the Department of Energy, these maintenance strategies have been identified to be an important investment to reduce aviation operational costs. Technological advances in areas such as diagnostics, prognostics, sensing, computation, and machine learning have created the foundation to support these technologies. However, with a few exceptions, predictive maintenance has not been widely applied in aviation. This panel will focus on the current state of adoption of predictive maintenance technologies in aviation, the barriers and challenges limiting more widespread adoption, and what technologies are needed to address those barriers.

Darren Macer – Senior Technical Fellow
Predictive Maintenance and Health Management

Boeing



Boeing

Darren Macer

Senior Technical Fellow specializing in Predictive Maintenance and Health Management for both commercial and military platforms

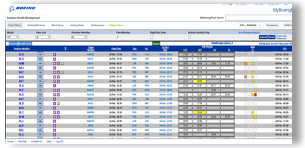
Lead the **research**, **development** and **implementation** of capabilities utilizing engineering knowledge, big data techniques and Model Based Engineering techniques and applying them to operational and maintenance data enable **predictive maintenance and health management**.

Lead the enterprise effort defining the Product Support **Digital Thread/Digital Twin**, by collaborating across the enterprise in defining the strategy, providing technical oversight and guidance to enabling capabilities that meet business and customer needs

Reduce Operational Disruption

Boeing predictive maintenance evolution and future

2004



What Has Happened

Real Time Fault Notification

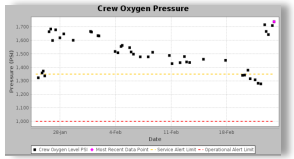
ACMF/CMCF and AHM enables real time understanding of onboard faults

Custom Alerting

ACMF data allows for offboard processing and alerting

Enabled by
- Onboard Data
- Engineering Logic

2010



What Is Happening

Fix Effectiveness

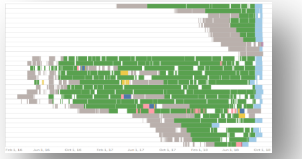
How to more efficiently trouble shoot issues

System/Fleet-wide monitoring

Understand the current state of your fleet through data

Enabled by
- Onboard Data
- Maintenance Data
- Engineering Logic
- Machine Learning

2017



What Will Happen

Predictive Maintenance

Understand remaining useful life or detect degradation that will require action

Condition Based Maintenance

Complete maintenance only when it is required, based on the condition of the system

Reliability or Cost Optimization

Improve reliability or costs based on turning unscheduled into scheduled maintenance

Enabled by
- Onboard Data
- Maintenance Data
- Full Flight Data
- Engineering Logic
- Machine Learning
- Digital Twins/Data Science

Research with industry and academic partners

Continuous Improvement

Continuous Improvement

MSG-3 and Airworthiness Credits

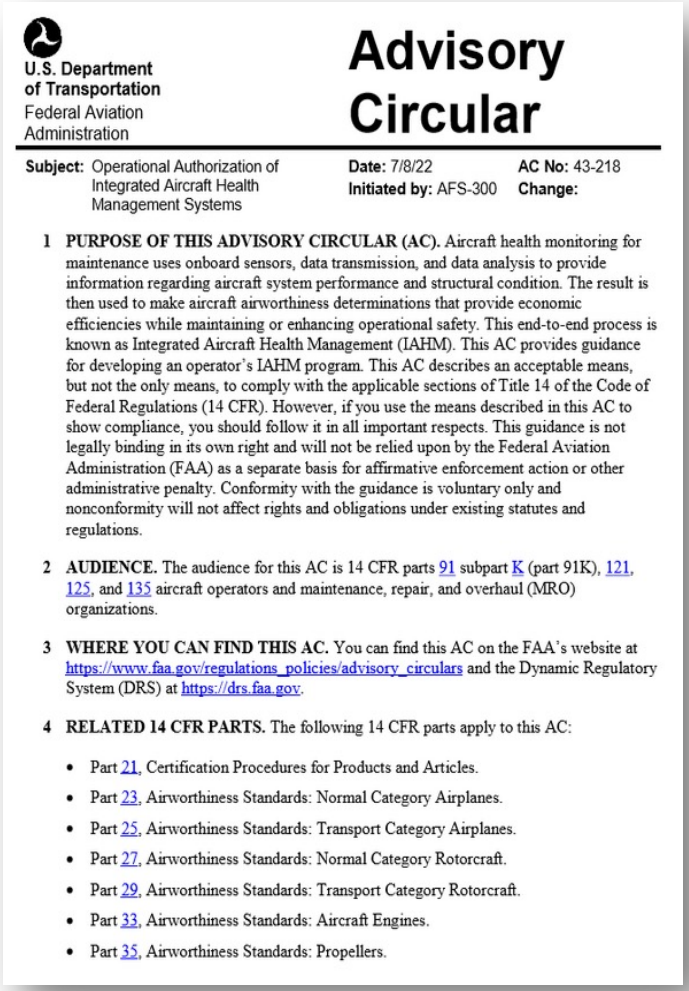
Maintenance Review Board Report (MRBR) contains the minimum scheduled maintenance requirements to be used in developing a continued airworthiness maintenance program.

- Task – What needs to be done (Detailed Inspection, Operational Check, etc.)
- Interval – When to do it (3YR, 18000FH, 6000FC, etc.)

Developed though the Maintenance Steering Group (MSG-3) Process

Prior to IP-180 and AC43-218, all actions of MSG-3 had to be accomplished by a mechanic at the aircraft.

We are now developing the process to accomplish these tasks using data



U.S. Department of Transportation
Federal Aviation Administration

Advisory Circular

Subject: Operational Authorization of Integrated Aircraft Health Management Systems
Date: 7/8/22 **Initiated by:** AFS-300 **AC No:** 43-218 **Change:**

1 **PURPOSE OF THIS ADVISORY CIRCULAR (AC).** Aircraft health monitoring for maintenance uses onboard sensors, data transmission, and data analysis to provide information regarding aircraft system performance and structural condition. The result is then used to make aircraft airworthiness determinations that provide economic efficiencies while maintaining or enhancing operational safety. This end-to-end process is known as Integrated Aircraft Health Management (IAHM). This AC provides guidance for developing an operator's IAHM program. This AC describes an acceptable means, but not the only means, to comply with the applicable sections of Title 14 of the Code of Federal Regulations (14 CFR). However, if you use the means described in this AC to show compliance, you should follow it in all important respects. This guidance is not legally binding in its own right and will not be relied upon by the Federal Aviation Administration (FAA) as a separate basis for affirmative enforcement action or other administrative penalty. Conformity with the guidance is voluntary only and nonconformity will not affect rights and obligations under existing statutes and regulations.

2 **AUDIENCE.** The audience for this AC is 14 CFR parts 91 subpart K (part 91K), 121, 125, and 135 aircraft operators and maintenance, repair, and overhaul (MRO) organizations.

3 **WHERE YOU CAN FIND THIS AC.** You can find this AC on the FAA's website at https://www.faa.gov/regulations_policies/advisory_circulars and the Dynamic Regulatory System (DRS) at https://drs.faa.gov.

4 **RELATED 14 CFR PARTS.** The following 14 CFR parts apply to this AC:

- Part 21, Certification Procedures for Products and Articles.
- Part 23, Airworthiness Standards: Normal Category Airplanes.
- Part 25, Airworthiness Standards: Transport Category Airplanes.
- Part 27, Airworthiness Standards: Normal Category Rotorcraft.
- Part 29, Airworthiness Standards: Transport Category Rotorcraft.
- Part 33, Airworthiness Standards: Aircraft Engines.
- Part 35, Airworthiness Standards: Propellers.

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<610>FEG  787-9        BRAKE AND TIRE STATUS REPORT          COPY 5

 ACID    FLT          FM  FLTCT    DATE      TIME     DPT   DST
 N29978  UAL760       ES  797    12/06/23 02:18:07  KDEN  EDDM

  SFC       AMI-SWID        GWT    TAT     PAMB
  0      BSM59-7000-0013   486900  17.9    835.9

                BRAKES AND TIRES MEASUREMENTS
 ENGINE START:
   PERCENT BRAKE WEAR REMAINING
---- MAIN WHL FWD ----   ---- MAIN WHL AFT ----
LO/1  LI/2  RI/3  RO/4  LO/5  LI/6  RI/7  RO/8
21    28    28    27    27     31    35    34

   BRAKE TEMPERATURES
---- MAIN WHL FWD ----   ---- MAIN WHL AFT ----
LO/1  LI/2  RI/3  RO/4  LO/5  LI/6  RI/7  RO/8
.0    .0    .0    .0    .0     .0    .0    .0

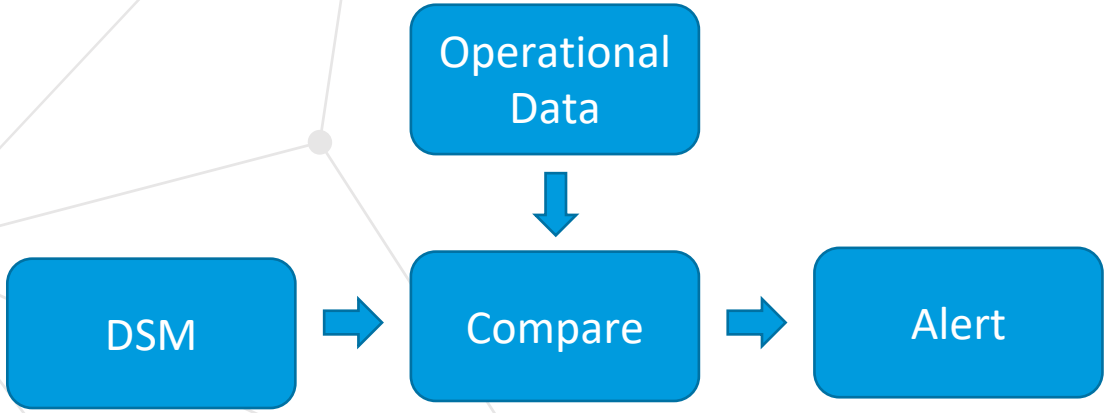
   TIRE PRESSURES
   -- MAIN WHL FWD --      -- MAIN WHL AFT --      - NSE WHL -
LO/1  LI/2  RI/3  RO/4   LO/5  LI/6  RI/7  RO/8   L/9  R/10
236   237   236   231    235   238   236   236    188   190
```

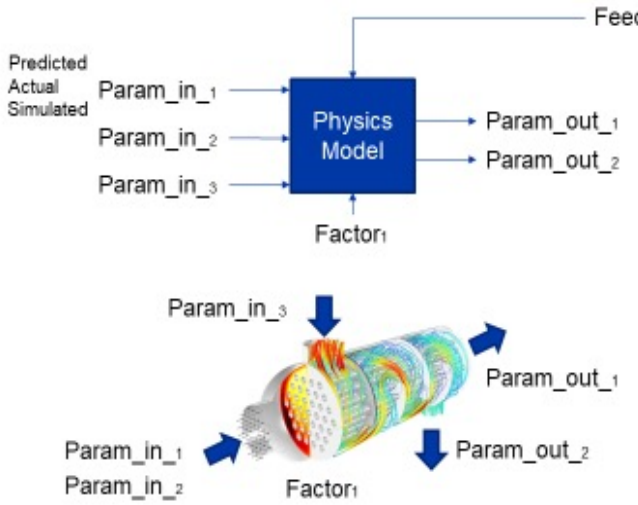
First tasks on any commercial aircraft model in the world have been approved using this new analysis method

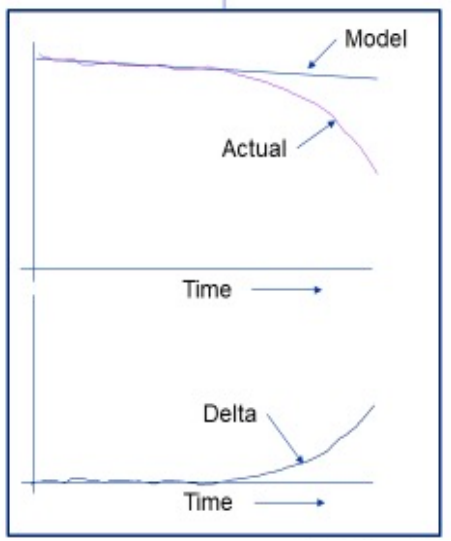
DSM's and Digital twins for Predictive Maintenance

Model Based Engineering to Enable Monitoring

- Digital System Model (DSM) defines what should happen.
- Operational Data tells us what is happening
- The difference between two can be used to understand health
- Digital Twins allow us to more deeply understand the nuance





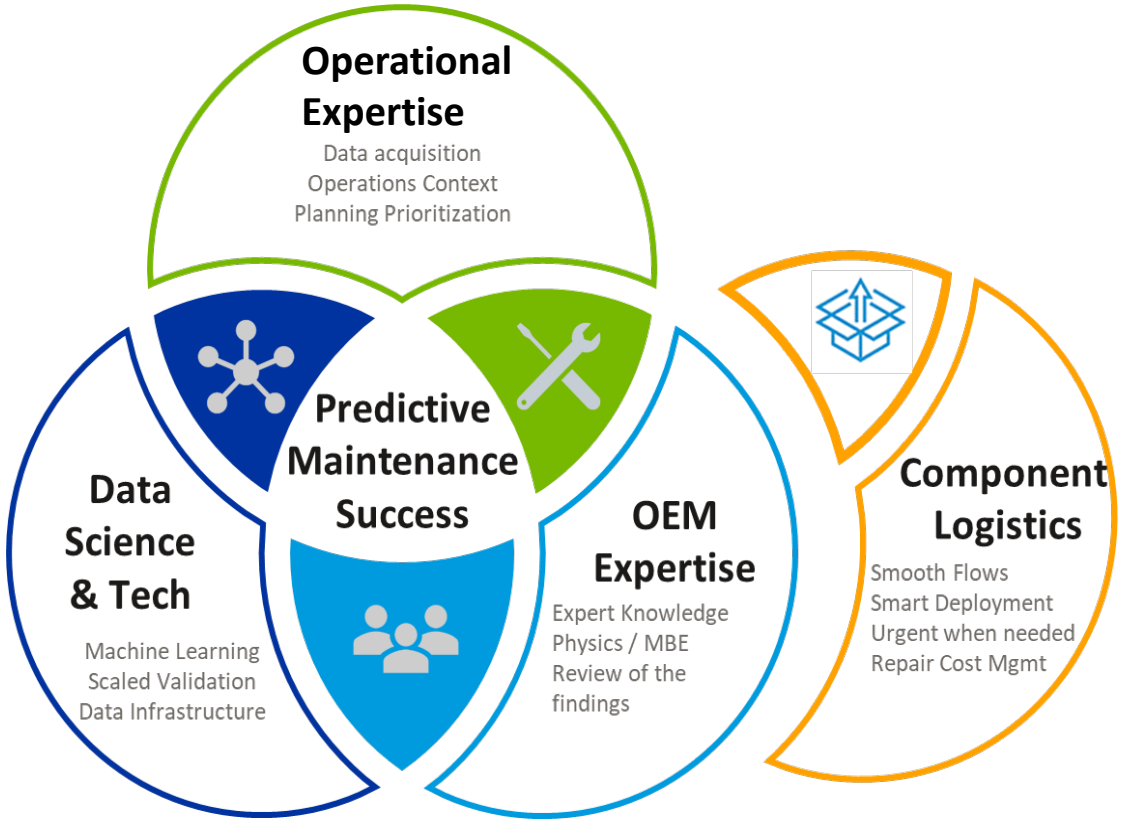


17

Predictive Maintenance is a team sport

Global Services

- There are many issues to be solved
- There are many approaches that can be used
- They look a little different from each perspective
- We need to right size each one



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Collins Aerospace
An RTX Business

RTX

Collins Aerospace
An RTX Business

Pratt & Whitney
An RTX Business

Raytheon
An RTX Business

Collins Aerospace is a leader in technologically advanced, intelligent solutions that help redefine the aerospace and defense industry.

We dedicate our capabilities, comprehensive portfolio and expertise to solving customers' toughest challenges and meeting the demands of the global market.

STRATEGIC BUSINESS UNITS

ADVANCED STRUCTURES

Based in Charlotte, North Carolina

- Actuation
- Landing systems
- Nacelle systems
- Flight controls
- Pilot controls
- Propellers
- Naval composites
- Other highly engineered aerospace structures

AVIONICS

Based in Cedar Rapids, Iowa

- Aircraft sensors
- Avionics systems
- Cabin management systems
- Fire protection
- Hoist and winch systems

CONNECTED AVIATION SOLUTIONS

Based in Annapolis, Maryland

- Airport systems
- Applications, analytics & data products
- Business aviation flight support services
- Connectivity & network services
- Passenger & freight rail control systems

STRATEGIC BUSINESS UNITS

INTERIORS

Based in Winston-Salem, North Carolina

- Aircraft seating
- Cargo systems
- De-icing products
- Evacuation systems
- Galleys and galley inserts
- Interior systems
- Lavatories
- Life rafts
- Lighting
- Potable water systems
- Veneers

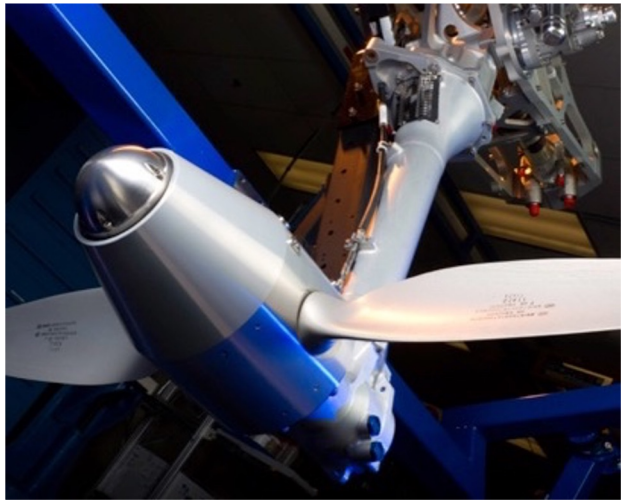
MISSION SYSTEMS

Based in Cedar Rapids, Iowa

- Communication, navigation and guidance
- Electronic warfare
- Ejection seats
- Intelligence, surveillance and reconnaissance
- Missile actuation
- Simulation and training
- Space solutions
- Strategic command and control
- Unmanned aircraft systems

POWER & CONTROLS

Based in Windsor Locks, Connecticut



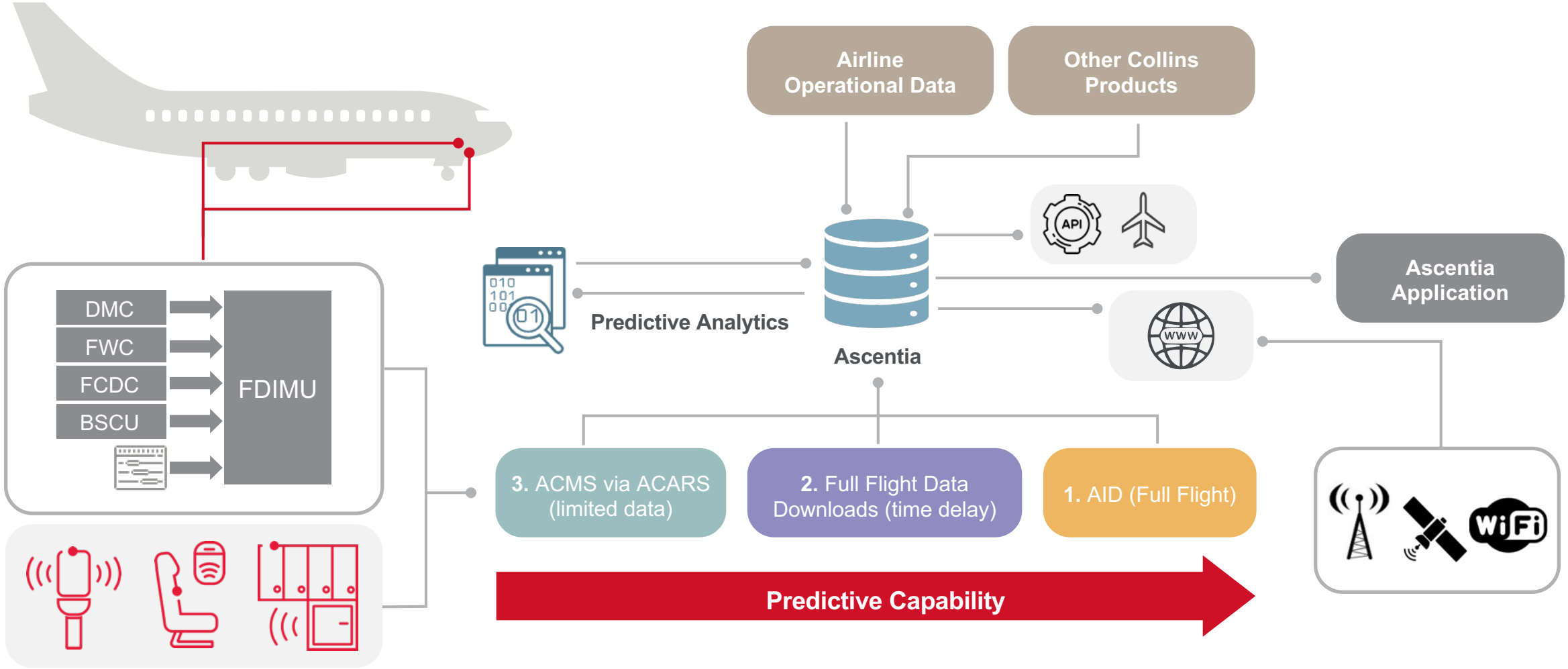
- Air management
- Airframe controls
- Electric systems
- Engine controls

COLLINS SMART PRODUCTS & ENABLERS

- PDM enablement
  - Health Ready components
  - Data visualization, tools
  - Data movement
- IAHM enablement
  - Data as an alternative means of compliance to scheduled and unscheduled maintenance
- Digital Thread / Digital Twin enablement
  - Modeling, digital data, single source of truth
- Airline / Airport operational / sustainment enablement
  - High value data providing insights into operational efficiencies and sustainability

Offering solutions that enable PDM

ASCENTIA® DATA OPTIONS



Collins Aerospace
An RTX Business

ISSUES / BARRIERS TO ADOPTING PDM

- Procurement and installation of hardware
- Contractual issues pertaining to ownership and sharing of data
  - Raw data ownership
  - Intelligent data ownership
- Algorithm development for components that fail randomly or infrequently
- Warranty concerns related to early removals
- No Fault Found results for early removals

THANK YOU

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