Manhattan University

A.E.R.I.S.

Aircraft Enhanced Resilience and Intelligence Systems

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Meet The Team

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Operational Challenge & System Solution

Operational Challenge: Create a novel maintenance advancement to improve efficiency, safety, and/or costs for the aviation industry.

System Solution: Bridge the predictive maintenance technology gap for legacy commercial aircraft through retrofittable sensor networks and unified data integration with the goal of maintenance efficiency and life extension.

Quick Overview

Two-part system utilizing current sensor technology, along with newer AI advances.

- Layer 1will focus on retrofitting the A320ceo platforms.
- Layer 2 will integrate AI prediction technologies into a solution matrix.

Layer 1: Sensor Network & Data Integration

Layer 1: Sensor Network

A Hybrid - Wireless Sensor Network (H-WSN) across high-risk A320ceo subsystems.

- Micro-Electro-Mechanical Systems (**MEMS**) and Fiber Bragg Grating (**FBG**) sensors tailored to each subsystem failure mode.
- Self-power harvesting modification. Minimal wiring or batteries.
- Semi-wireless transmission to onboard IoT gateway.

Sensor monitoring application:

Four critical subsystems selected for high-stress exposure, fatigue risk, or wear-sensitive mechanics.

- Landing Gear & Brake Assembly
- Wings & Fuselage Structure
- High-Lift Systems: Flaps & Slats
- ECS Packs & APU

Open architecture design: old sensor system and emerging updates can be incorporated.

Layer 1: Data Integration

IoT Gateway Module

- Edge processing on each node. Only anomaly-tagged data is transmitted.
- ARINC 429 passive bus tap adaptors unify QAR, DAU, ACMS, and CMMS into one standard format.
- Data concentrators bring multiple data streams to one unit and organizes it.
- Gateway modules package and transmit the data off the aircraft.

Data Mapping

- Ground based software that receives aircraft data and makes it usable for the CMMS (Computer Maintenance Management System).
- Standardizes parameter names.
- Maps the legacy data into the CMMS schema ready for our ISM integration.

Layer 2: Intelligence Solution Matrix

Layer 2: Intelligence Solution Matrix

- Data mirroring architecture synchronizes the mapped dataset and CMMS ground analytics server to the ISM.
- Based on the sensor data, values will be entered into one of the variables.
- Provides a score based on collected data.

Variable:	Weight:	Score:	Comment:
Problem Severity	18%	4	Small performance reduction, NON CRITICAL
Vibration	15%	4	Moderate vibration increase, within acceptable operational limits
Temperature	15%	3	Noticeable temperature rise, still within safe operating range
Strain	15%	4	Elevated strain levels, but below critical structural threshold
Part Availability	13%	3	Available but requires ordering
Diagnosis Confidence	12%	5	Confirmed diagnosis with supporting data
Time Constraint	7%	4	Minimal delay
Cost	5%	4	Low cost

Layer 2: Intelligence Solution Matrix

- Recommends one of four solutions.
- Solutions are provided based on scores.
- The Chief Mechanic must approve of the solution before implementation.

Solution:	Range:	Primary Trigger:
Heavier Monitoring	> 4.0	Problem Severity ≥ 4 (Minimal impact) OR Diagnosis Confidence ≤ 3 (Uncertain diagnosis)
In-House Fixing	3.0 - 4.0	Problem Severity 3-4 (Minor/moderate issue) + Part Availability ≥ 4 + Diagnosis Confidence ≥ 4
3D Printing Hubs	2.5 - 3.5	Part Availability ≤ 2 (Parts unavailable/obsolete) + Problem Severity 2-4
Pre-Positioning System (Part Acquisition)	> 3.0	Problem Severity 2-3 + Diagnosis Confidence ≥ 4

Solution 1:	Explanation:	Approvale:
In-house Fixing	The problem is identified, and the repair can be safely completed. This is the best option when the issue has a moderate impact on aircraft performance or safety, the diagnosis confidence is high, and parts are easily attainable or available.	
Solution 2:	**Explanation:**	**Approvale:**
Pre-Positioning System	Failure is known, the diagnosis confidence is high, and downtime must be minimized. This decision is better for components that fail predictably.	

Situational Assessment

Situational Assessment

Retrofitting Constraint

- Legacy aircraft face challenges integrating modern CBM systems.
- Wired retrofits are heavy, complex, and expensive.
- Aging fleets fall behind predictive maintenance capabilities.

Situational Assessment

Economic Impact (AOG)

- Major operational and financial disruption.
- Lost revenue, crew rescheduling, labor, and expedited logistics.
- Lack of early detection drives urgent, high-cost maintenance cycles.

Situational Assessment

Data Fragmentation

- Maintenance data is siloed across OEMs, operators, and MRO systems.
- Incompatible formats and restricted access prevent unified analysis.
- Delayed diagnostics and inefficient troubleshooting.

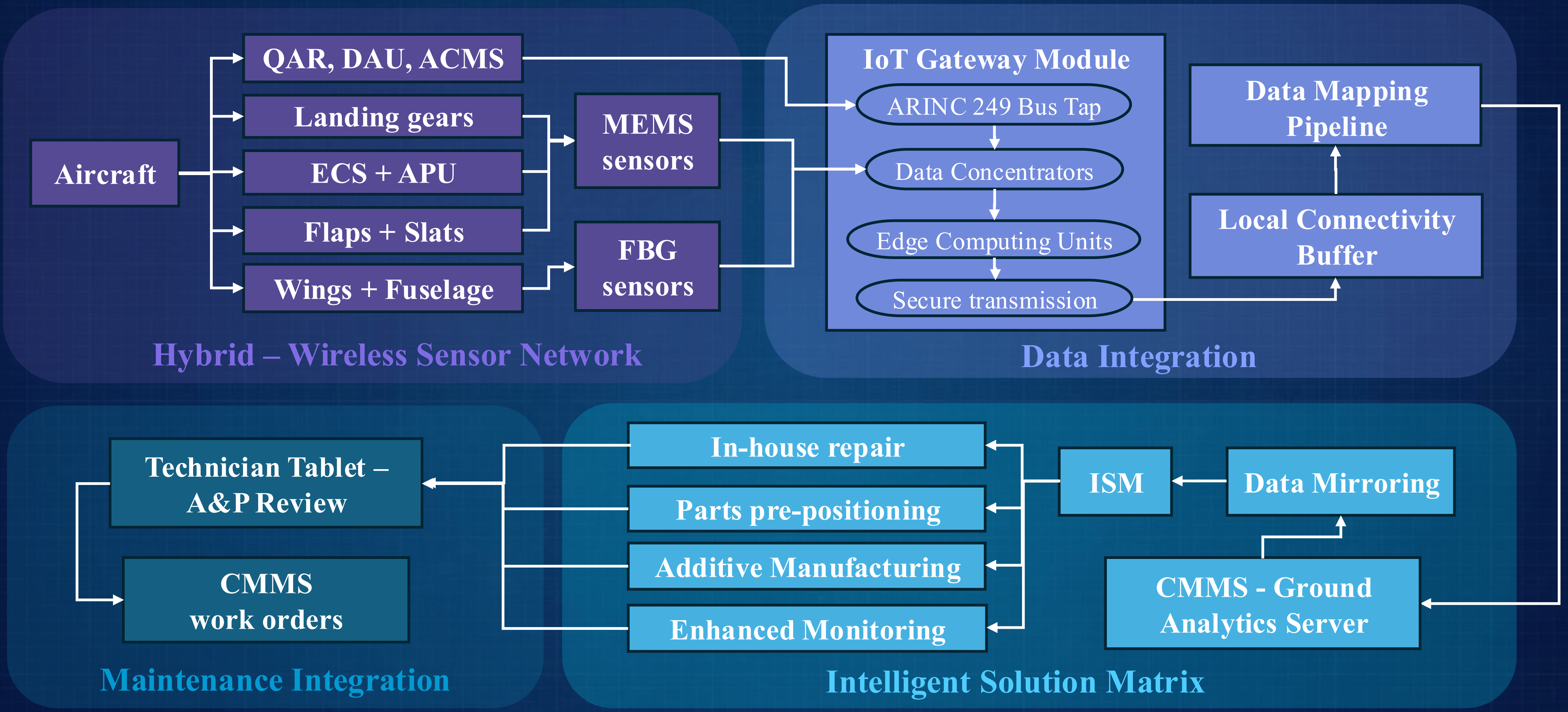
Situational Assessment

Human Consequences

- Reactive maintenance increases uncertainty for technicians.
- Intermittent faults are difficult to reproduce on the ground.
- Rushed repairs, urgent parts orders, and documentation burdens.

Concept of Operations (ConOps)

Concept of Operations



Training Plan

- **IT and cybersecurity personnel receive** training on:
  - Data mirroring
  - Cloud interface protocols
  - Intrusion detection
  - Access control policies
  - Secure data transmission
  - Gateway configuration

- **Maintenance technicians** receive training on:
  - Dashboard navigation
  - Alert interpretation
  - IoT sensor measurement understanding

- **Reliability teams** receive training on:
  - Predictive model interpretation
  - Regulatory compliance alignment
  - Data analytics literacy

Annual refreshers maintain currency across all roles.

Sensor Placements

Sensor Placements

Sensor Placements

Landing Gears

MEMS Nodes:

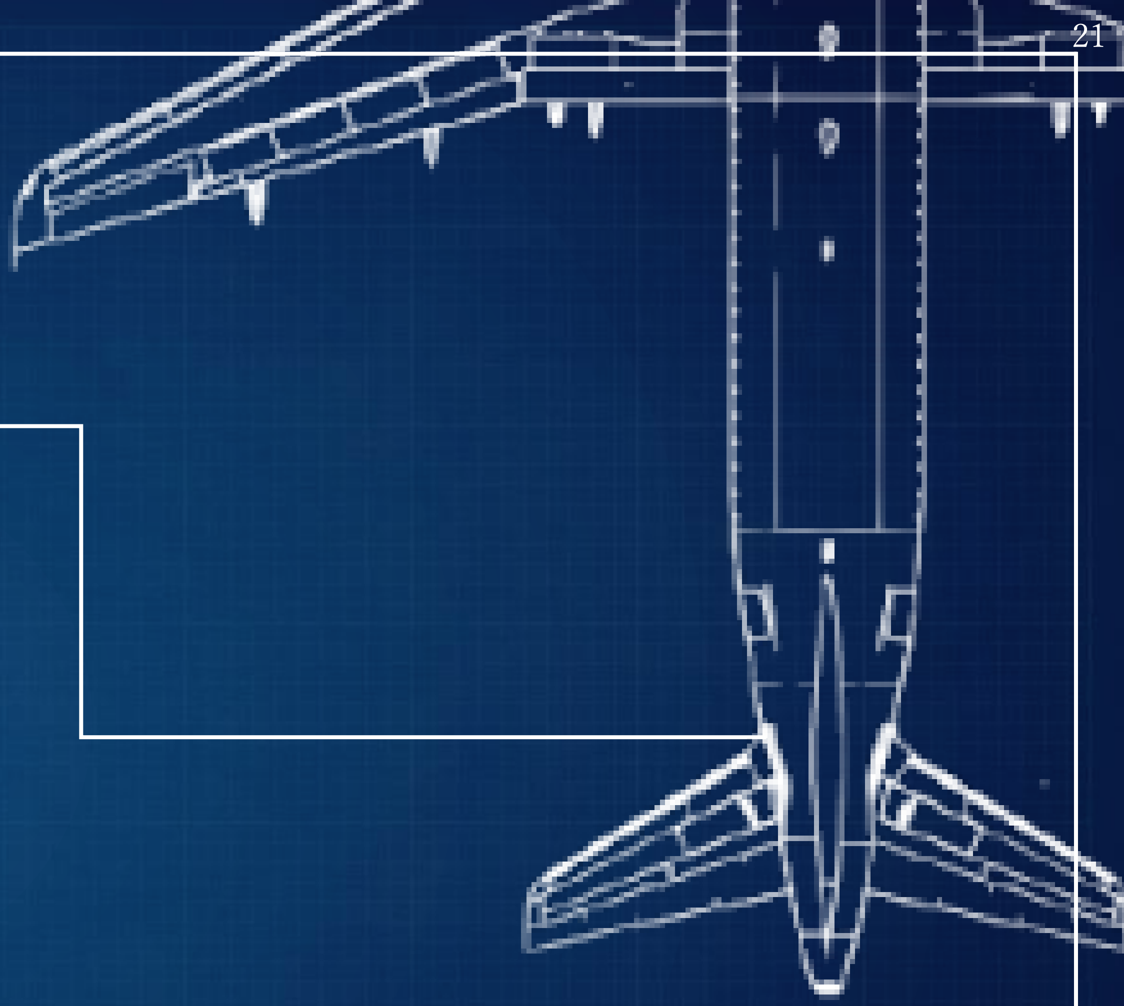
- Node LG-1: Outer barrel of each main gear oleo strut.
- Node LG-2: Brake housing on each main wheel.
- Node LG-3: Trunnion bearing housing on each main gear.
- Node LG-4: Nose gear oleo barrel.

Sensor Placements

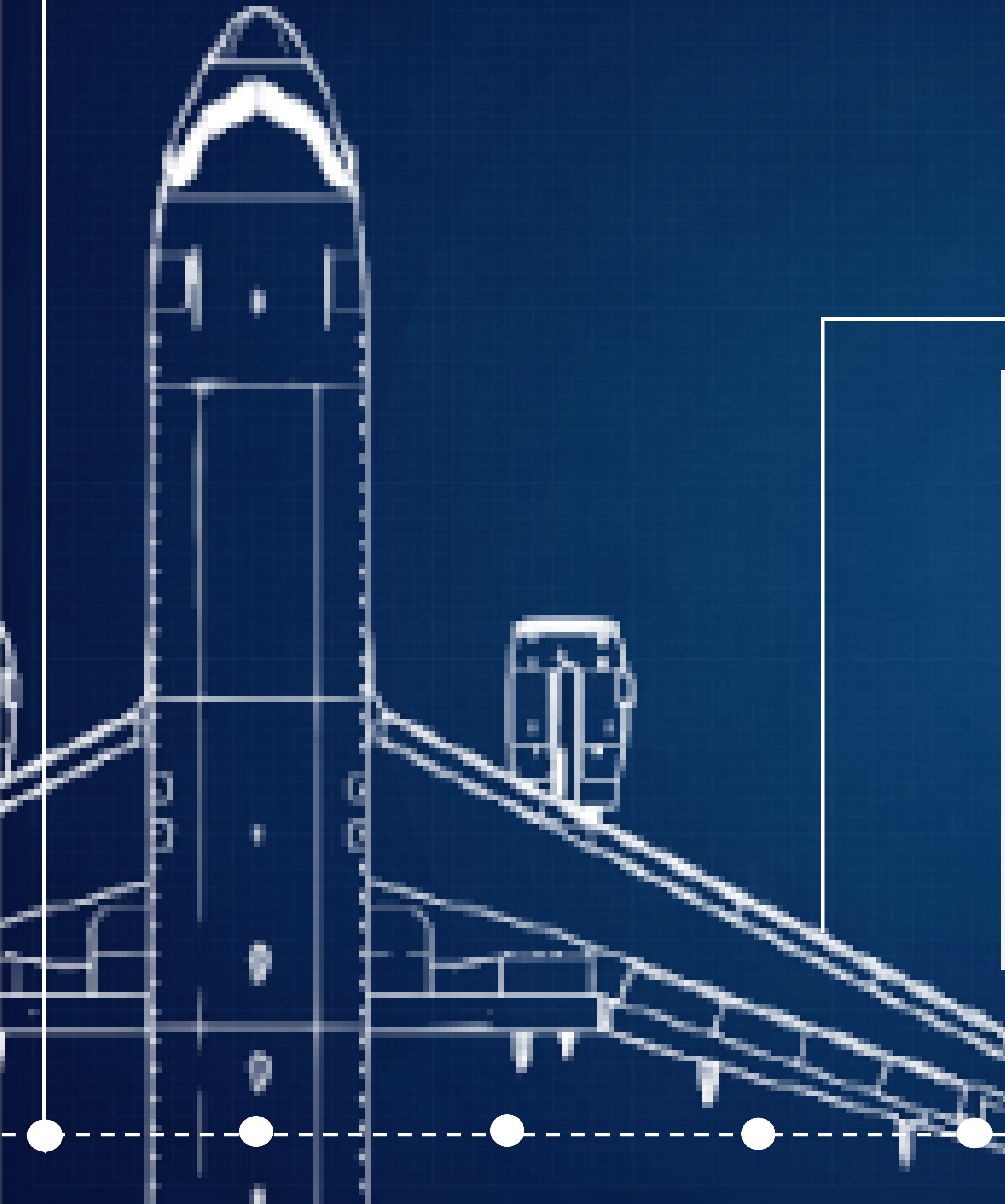
ECS & APU

MEMS Nodes:

- Node ECS-1 and ECS-2: ECS pack housing on each pack.
- Node APU-1: APU gearbox housing.
- Node APU-2: APU mount bracket.



Sensor Placements

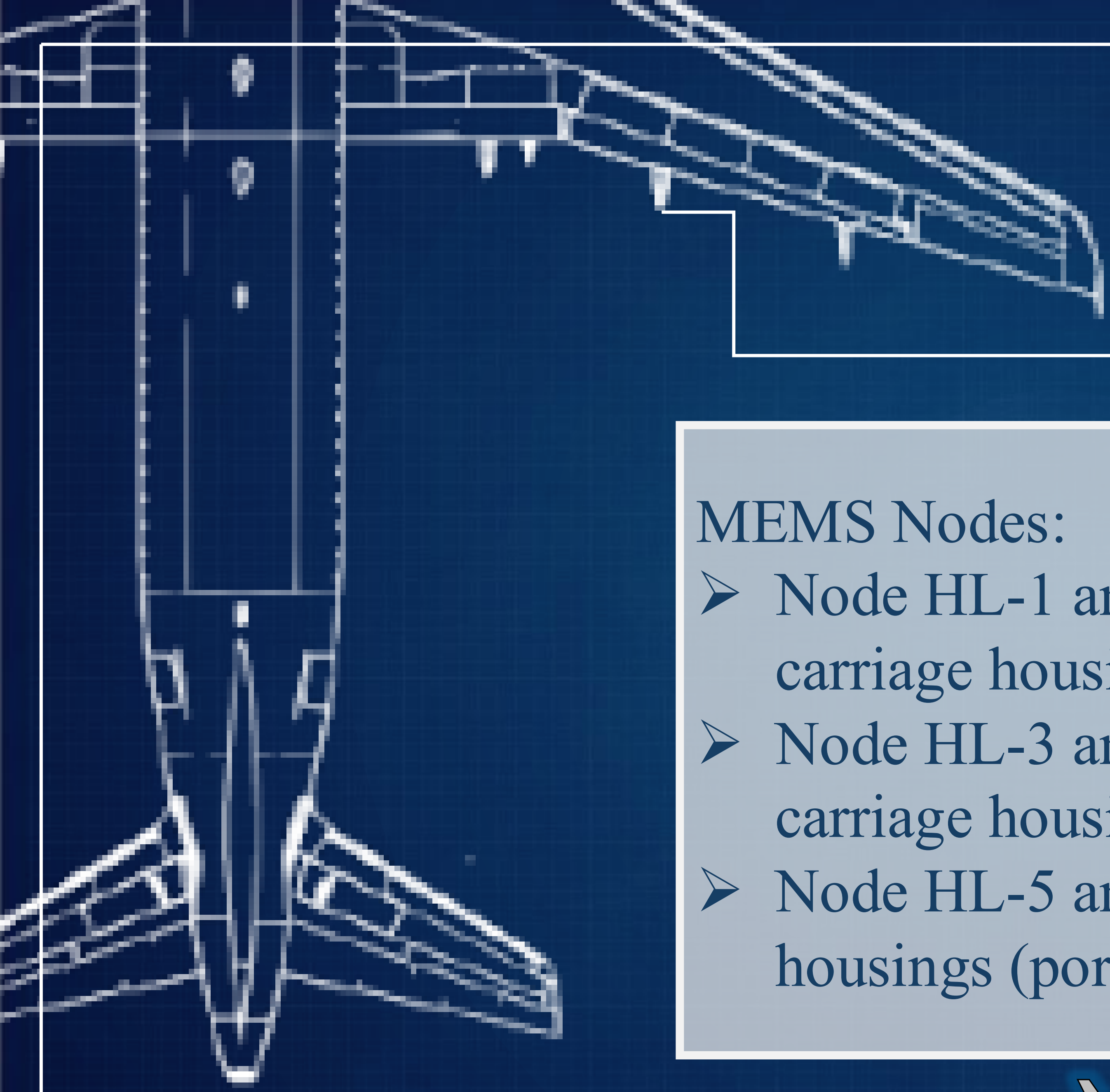


Wings & Fuselage

FBG Strain Sensors System:

- Wing front spar
- Wing rear spar
- Wing skin lap joints
- Fuselage lap joints
- Co-located Temperature compensation fibers

Sensor Placements



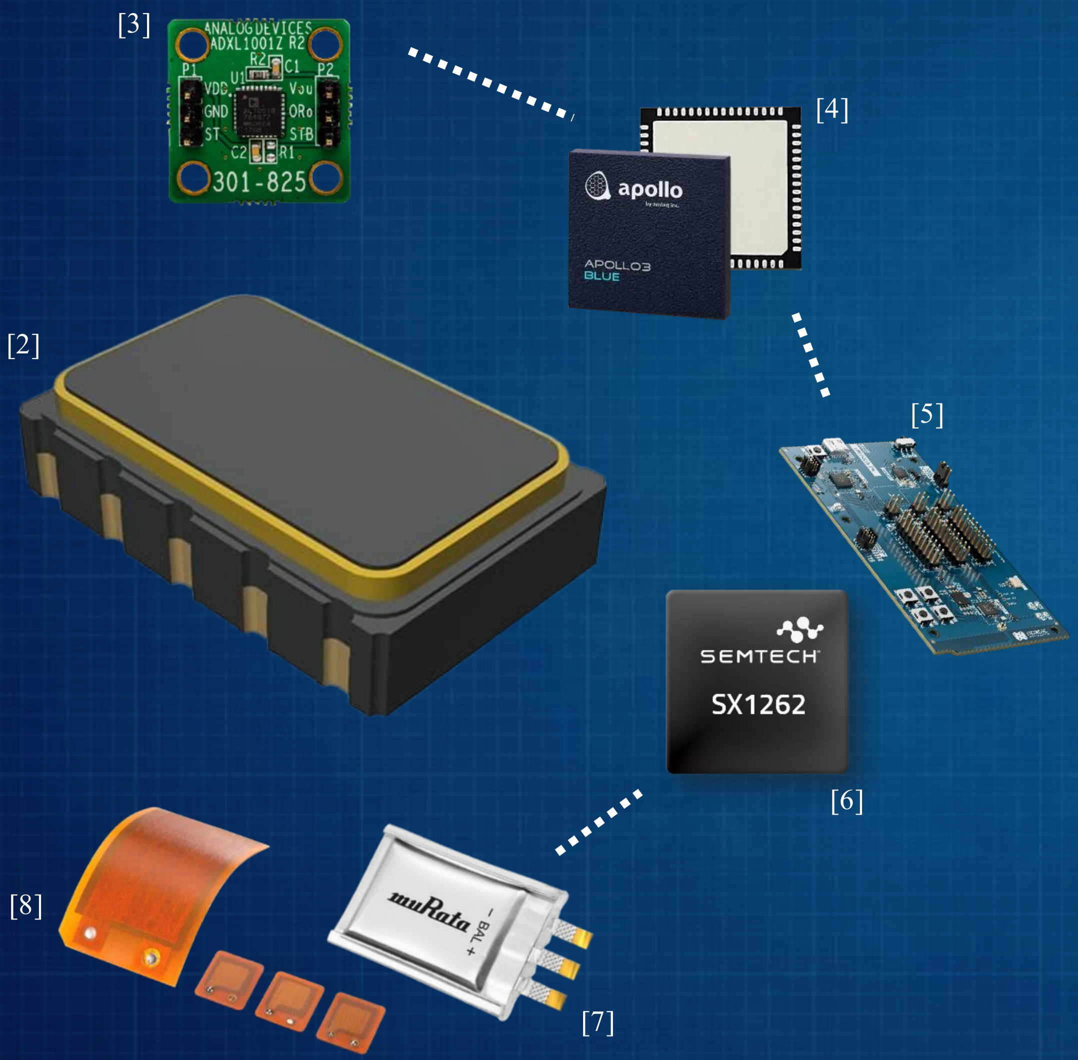
High-lift Systems: Flaps & Slats

MEMS Nodes:

- Node HL-1 and HL-2: outboard flap track carriage housings (port and starboard).
- Node HL-3 and HL-4: inboard flap track carriage housings (port and starboard).
- Node HL-5 and HL-6: slat drive unit motor housings (port and starboard leading edge).

Sensors

Sensors: MEMS



Sensing element:
- Vibration: ADXL1002 MEMS accelerometer
- Temperature: TMP117 from Texas Instruments

Microcontroller: Ambiq Micro – Apollo3

Wireless Radio:
- Semtech SX1262 LoRa transceiver
- Bluetooth Low Energy - Nordic

Power subsystem:
- Piezoelectric energy harvester – PZT patches
- Supercapacitor

Housing & Mounting:
- DO-160G qualified housing
- Clamp-and-adhesive bracket system mount

Sensors: FBG

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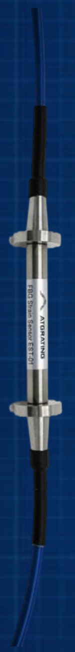

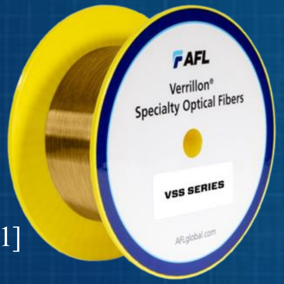

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Sensing Fiber:

- *Strain-measuring* FBG: Bonded to wing spar, fuselage lap joint
- *Temperature compensation* FBG: fitted close to the strain FBGs
- Polyimide recoat + structural epoxy adhesive

Interconnection:

- Optical path to Interrogator connection: AFL Telecommunications single-mode optical fiber
- Fiber + Interrogator connector block: Thorlabs FC/APC patch panel

Power Subsystem:

- Supplementary - PZT harvesting & supercapacitor
- Primary - Interrogator to electrical bus

FBG Interrogator Unit:

- Smart Fibers - SmartScan Aero Mini

Technology Readiness Level

Technology Readiness Level

4	MEMS Sensors
4	FBG Sensor Subsystem
4	Hybrid – Wireless Sensor Network
4	Intelligent Solution Matrix
5	Data Mapping

NASA TRL Definitions

TRL 4 - *Validation in lab.*

TRL 5 - *Validation in relevant environment.*

Deployment Timeline

2026

2028

2030

2031

Deployment Timeline

2026

Phase 1: Architecture Design + Feasibility

Goal
Develop initial concept into full system architecture and schematic design. Define installation requirements for onboard and ground-based units.

Onboard units
Initial DER compatibility review to support STC requirements.

2028

Phase 2: STC Application + Initial Testing

Goal
Validate hardware component installation and integration.

Onboard units
Refine the system iteratively based on regulatory feedback.

Grounded units
Begin implementation of ground-based systems and ISM training.

2030

Phase 3: STC Application + Flight Testing

Goal
Ensure synchronization and consistency across all connected systems.

Onboard units
Demonstrate system reliability, non-interference, and data integrity.

Grounded units
Verify integration between onboard acquisition systems and ground-based platforms.

2031

Phase 4: Fleet-wide Implementation

Goal
Fleet-wide deployment and operational integration complete.

Onboard units
Install certified H-WSN and IoT gateway during scheduled heavy C-check intervals.

Grounded units
Complete operational integration of data mapping, mirroring, and ISM functionality.

Deployment Timeline

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Policy & Regulations

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STC-driven certification strategy. Onboard systems qualified to FAA standards.

DO-160G **Hardware Environmental Qualification**

All onboard hardware qualified for temperature variation, vibration, humidity, electromagnetic interference, and altitude cycling to ensure environmental survivability.

DO-307A **Electromagnetic Compatibility**

Wireless sensor protocols and gateway modules comply with DO-307A to prevent interference with certified avionics systems.

STC **Supplemental Type Certificate Pathway**

Phased STC strategy with DER engagement in Phase 1. Gateway classified as non-flight-critical to reduce certification complexity.

Policy & Regulations

All onboard systems must pass verification and validation before STC approval.
Ground-based components developed in parallel under aviation data governance guidance.

DO-178C **Onboard Software Assurance**

Edge computing unit software developed and verified to DO-178C, with earlier DO-178B guidance applied where applicable.

FAA **Avionics Interface Compliance**

Interface adaptors developed per FAA guidance for avionics data acquisition. ARINC 429 passive bus tap causes zero impact to existing aircraft systems.

Ground **Ground-Based Data Governance**

Data mapping, mirroring, and ISM analytics systems are not STC-bound but align with aviation data governance guidance for secure, traceable data handling.

Cost, Return, & Risk Analysis

Cost Analysis

$5M – $8M
STC Development
Dominant Cost Driver

$100K–$500K
Retrofit per aircraft
(Sensors + Install)

$300K
ISM + Ground System
(One-Time, Non-Recurring)

$56.8M–$59.8M
Total Fleet Investment
(A320ceo)

Cost Analysis

STC Cost Breakdown · Total Estimate: $5M – $8M · Payback Period: 1–3 years

35% **Engineering & Compliance**
Designing the system to meet FAA safety standards.

25% **DER Approvals**
FAA-authorized engineers who review & sign off the design.

15% **Flight Testing**
Proving the system works in actual flight conditions.

13% **Conformity & FAA Management**
Inspections & ongoing back-and-forth with regulators.

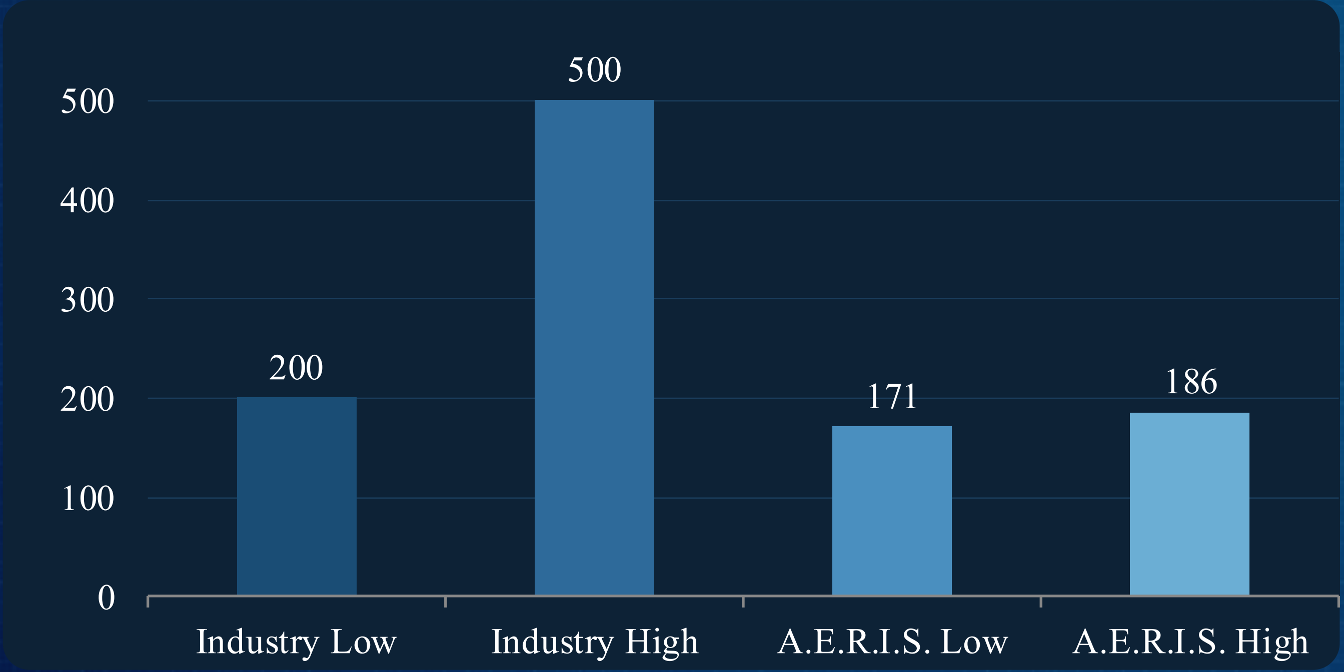
12% **Program Management & Documentation**
Project coordination, paperwork, and record-keeping.

Return on Investment

A.E.R.I.S. Low-End ROI
171%
High-End Total Cost
($59.8M)

A.E.R.I.S. High-End ROI
186%
Low-End Total Cost
($56.8M)

Industry Benchmark ROI
200–500%
Well-Implemented Predictive Maintenance



INDUSTRY EVIDENCE

- Delta & Lufthansa: 15–25% maintenance cost reduction.
- Industry-wide: $2–5B annual savings from PdM adoption.
- Aging aircraft payback period: Typically 1-3 years.
- Higher legacy failure rates → Larger incremental gains.

⚑ Our ROI excludes labor savings, fuel efficiency, and extended component life. Likely underestimated

Risk Analysis

TECHNICAL RISKS

Avionics Interference — HIGH
Potential electromagnetic interference between wireless sensor networks and certified avionics systems.

Sensor Degradation — MED
Harsh operating environments (vibration, heat, humidity) may cause sensor drift or failure over time.

False Positives — MED
Turbulence or transient loads may trigger anomaly readings that mimic bearing wear signatures.

CYBERSECURITY RISKS

Unauthorized Data Access — HIGH
Gateway modules and cloud-facing systems present potential attack surfaces for unauthorized entry.

Gateway Breach — HIGH
Compromise of the IoT gateway module could allow input of false sensor data into the ISM pipeline.

Data Loss & Breach Liability — MED
Loss or exposure of operational aircraft data could trigger regulatory and liability consequences.

Risk Mitigation & Solution

TECHNICAL

DO-307A EMC Compliance

- ➢ Gateway classified as non-flight-critical under STC pathway.
- ➢ Early FAA and DER coordination in Phase 1.
- ➢ Wireless protocols qualified to DO-160G.

DO-160G Qualification & Maintenance

- ➢ All sensors qualified for temperature, vibration, humidity, EMI, and altitude.
- ➢ Dedicated sensor maintenance schedule separate from aircraft C-checks.
- ➢ Redundant PZT + supercapacitor power system for continuity.

Baseline Discrimination System

- ➢ Cross-references FMS turbulence log in real time.
- ➢ Anomaly thresholds auto-adjust during flagged turbulence windows.
- ➢ Advanced baseline calibration per subsystem and flight phase.

Risk Mitigation & Solution

CYBERSECURITY RISKS

Zero-Trust Architecture

- Role-based access control across all systems.
- Zero-trust principles with no implicit trust at the network boundary.
- Network segmentation: avionics isolated from IT systems.

Software Checks & Penetration Testing

- Software checks and locks. Mechanisms for safe concurrent access.
- Regular third-party penetration testing schedule.
- End-to-end encrypted transmissions from gateway to ground.

Data Mirroring & Incident Response

- Real-time data mirroring across redundant servers.
- Cloud compliance framework (FIPS, SOC 2) for data governance.
- Documented incident response and recovery procedures.

All mitigations are active from Phase 1. Safety override logic and mandatory A&P sign-off provide a final human check. A.E.R.I.S. never acts autonomously on critical systems.

Environmental Analysis

Environmental Benefits

Extended Aircraft Lifespan

- Detecting fatigue and wear earlier allows aircraft to fly closer to their maximum operational life, delaying costly and resource-intensive replacements.

Fewer Unscheduled Ground Events

- AOG events often require expedited logistics. Charter flights for parts, additional crew travel, and unplanned ground operations. Predictive maintenance reduces all of these.

Minimal Added Weight Penalty

- Wireless, self-powered sensors reduce the need for additional wiring harnesses. Minimal added weight means minimal increase in fuel burn per flight cycle over the aircraft's remaining life.

Reduced Manufacturing Demand

- Every legacy aircraft kept flying longer is one fewer new aircraft that needs to be manufactured, reducing the raw material extraction, energy use, and emissions of production.

Built-In Sustainability

Self-Harvesting Power — **PZT + Supercapacitor**

No disposable batteries. Zero battery waste over the system's operational life.

Wireless Architecture — **Minimal Wiring**

Minimal added cable weight means less fuel efficiency penalty per flight

Reduced AOG Duration — **Predictive → Proactive**

Fewer emergency logistics operations. Parts are staged before failure occurs.

Fleet Life Extension — **Toward Max Potential**

Target: Aircraft operate to their maximum potential life, not replaced early.

No New Ground Systems — **Existing CMMS**

System integrates with existing platforms. No new hardware manufacturing required.

Conclusion, References, Acknowledgments

Conclusion

A.E.R.I.S. empowers aging aircraft with the predictive awareness of modern fleets, without critical restructuring of existing layouts and workflows as soon as 2035.

Filling The Gap In Data

Legacy aircraft already generate the data. A.E.R.I.S. connects it. TSN adapters and unified data mapping turn siloed records into one actionable view.

Retrofittable By Design

Wireless, self-powered MEMS and FBG sensors add condition monitoring with no structural wiring, no added weight, and no interference with certified avionics.

Human Oversight Is Built In

The ISM only recommends, it never decides. Every action requires A&P sign-off. Safety override logic blocks low-confidence calls on critical systems.

171–186% ROI, 1–3 Year Payback

Conservative estimates based on AOG savings alone. Labor, fuel efficiency, and extended component life are excluded, meaning returns are likely higher.

References

[1] A320 - Airbus
[2] MEMS sensor - Defense Advancement
[3] ADXL1002 – Analog Devices
[4] Apollo3 Microcontroller – Ambiq
[5] BLE - Nordic
[6] SX1262 LoRa transceiver – Semtech
[7] Supercapacitor - Murata
[8] PZT Patches - Physik Instrumente
[9] FBG Strain Sensor model – AtGrating Technologies
[10] Fiber Optic Strain Sensor – Luna
[11] Optical Fiber – AFL Telecommunications
[12] FC/APC patch panel – Thorlabs
[13] SmartScan Aero Mini - Smart Fibers

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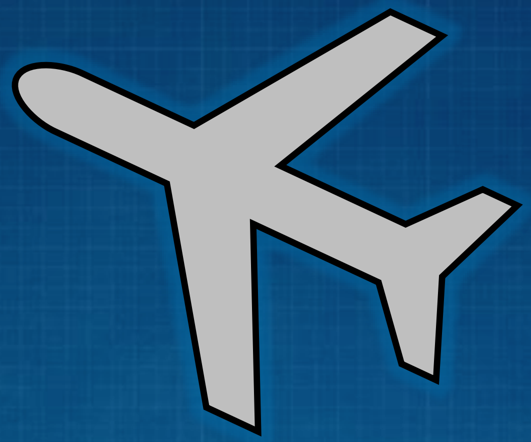

Thank you!