



The Opportunity Space for Wireless Sensor Systems in Aircraft Platforms and Production

Robert Smith
Technical Fellow, PhD
robert.a.smith8@boeing.com
Boeing Research & Technology
256-464-7116



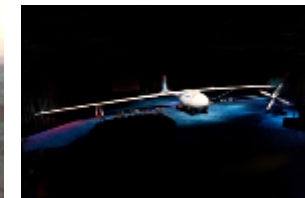
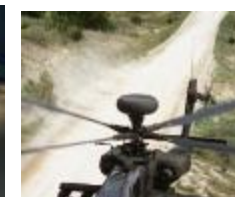
Engineering, Test & Technology
Boeing Research & Technology

What is Boeing?



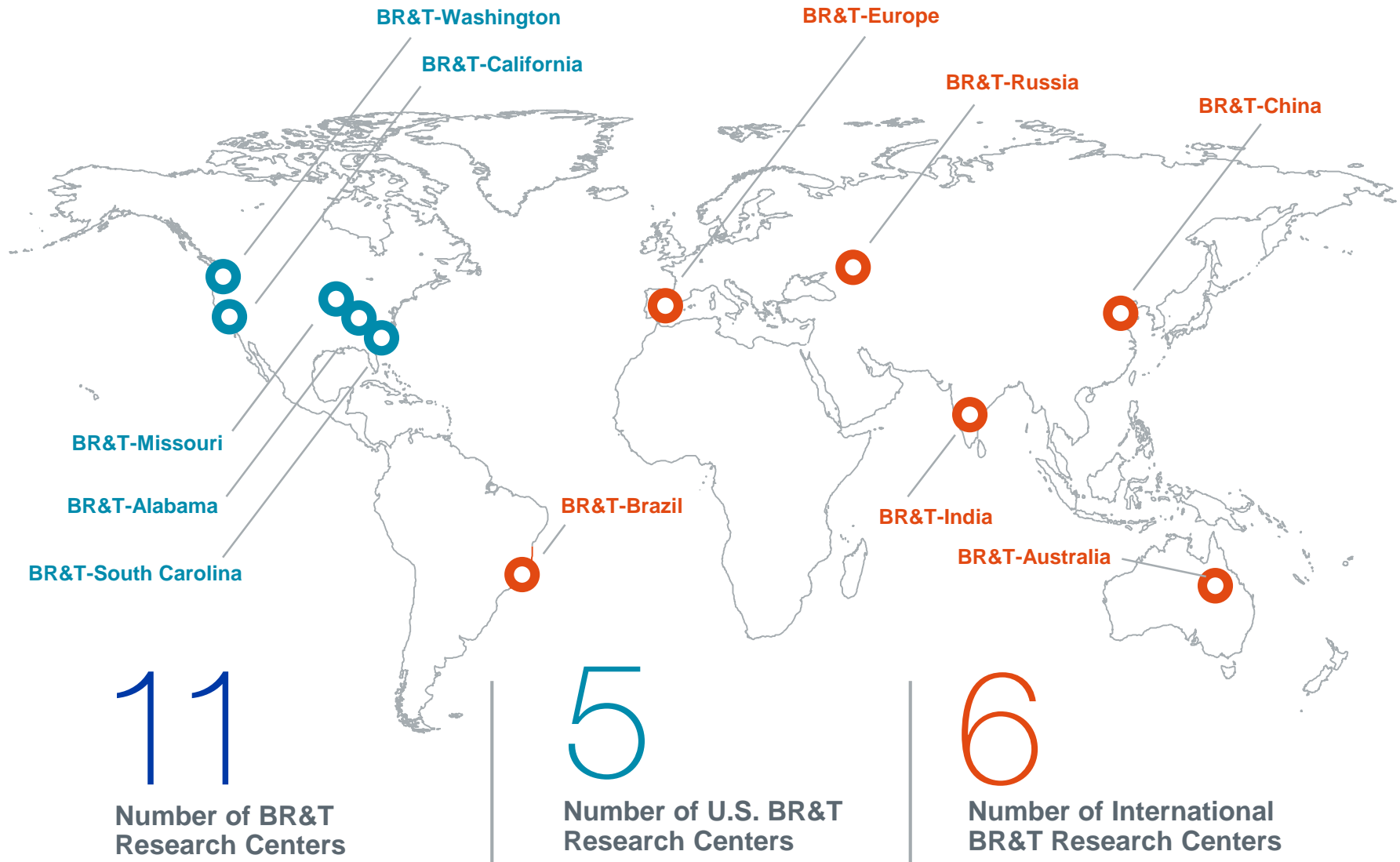
1925: Boeing Air Transport enables cargo transport in the emerging Air industry

2017: Boeing is World's Largest Aerospace Company



Research Centers

Supporting innovation around the world 24/7



Boeing's Interest in Passive Wireless Sensor Technology

Lighter Weight

- 1% weight reductions can equate to billions in operating cost savings to carriers – achievable by eliminating wires.

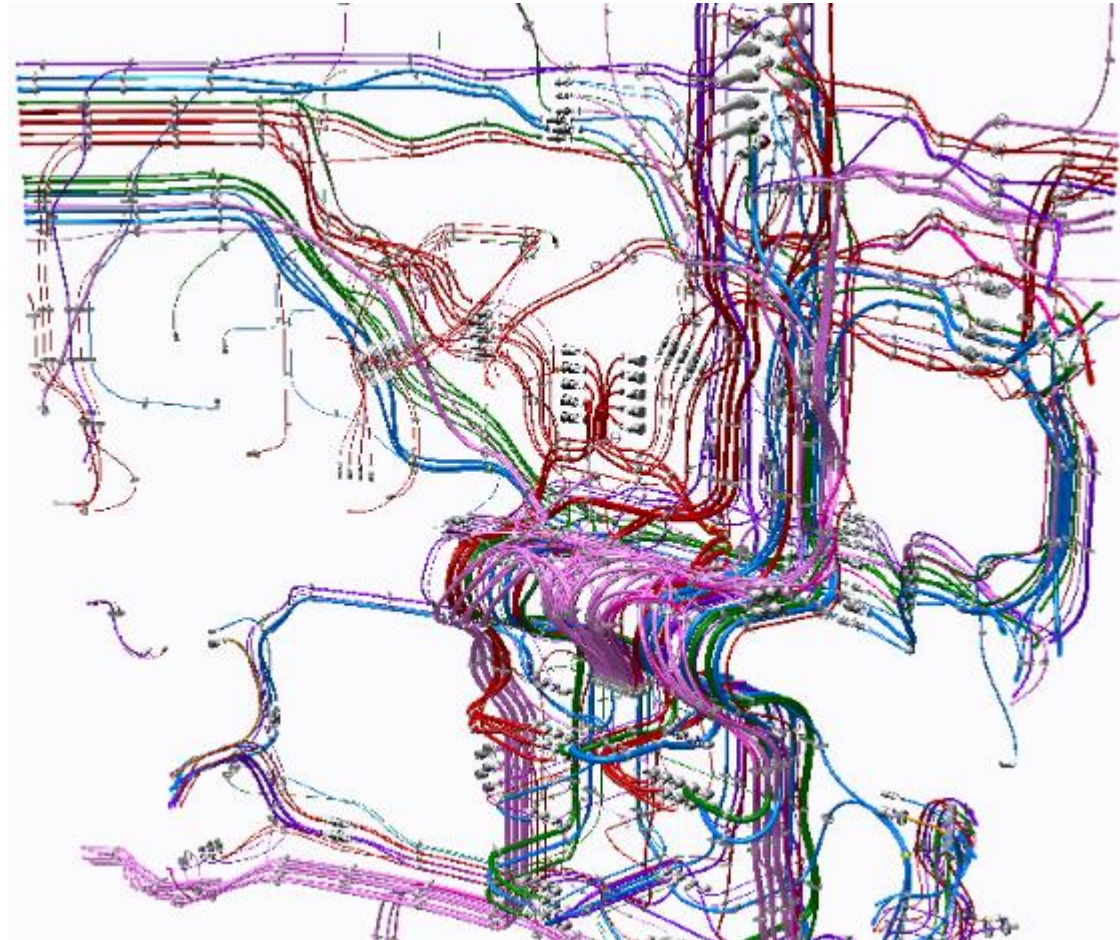
Less Complexity, Improved Maintenance, Higher Reliability



PWST is an enabler

Highly Complex Wire Harness Environments

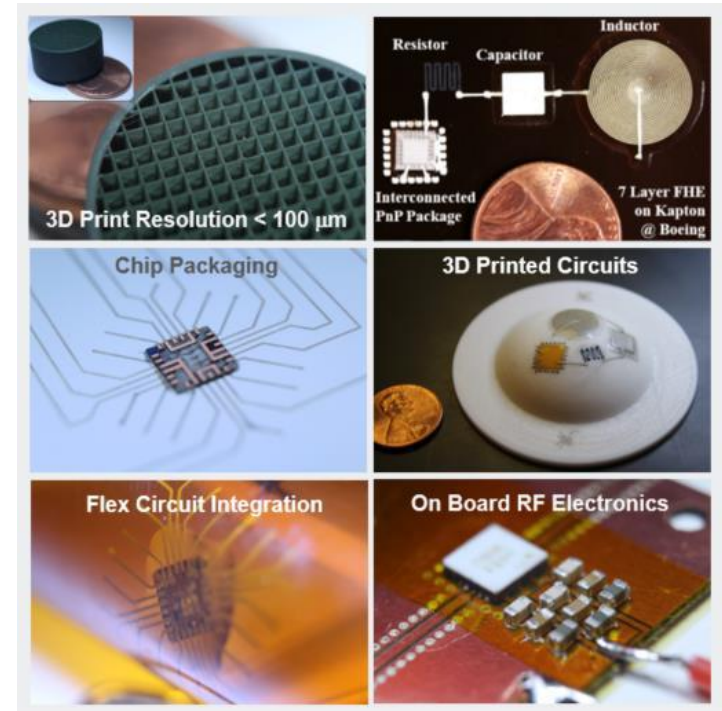
Harness Colors
Represent Different
Functional Classes
Purple = Data



Eliminate/Mitigate Wires Saves on Weight/Integration

Our Approach – Additive Manufacturing for PWST

- Printed Passives – Resistors, Capacitors, Inductors
- Printing on Non-Conformal Surfaces
- Printed Harnesses
- Integration of COTS components onto FHE
- Small, Flexible and Conformal Antennas
- Flexible & Disposable Batteries
- Energy Harvesting
 - RF
 - Vibration
 - Solar (Interior Lighting)
 - Thermal Electric
- NextFlex Access
 - Human Monitoring
 - Asset Tracking
 - Structural Health Monitoring
 - Antenna Technologies
 - 31 Funded Projects which we can leverage



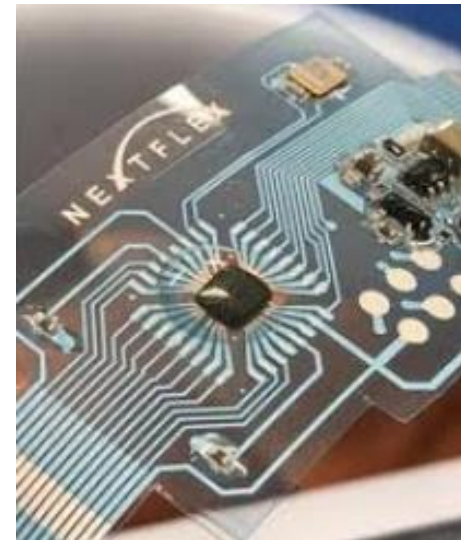
Flexible Electronics & Advanced Manufacturing



- The FHE MII is the 7th of 14 manufacturing innovation institutes
- Established as part of the National Network for Manufacturing Innovation (NNMI)
- Creating a competitive, effective, and sustainable manufacturing research-to-manufacturing infrastructure.
- The goal is to enable U.S. industry and academia to solve manufacturing challenges for advanced technologies
- Crosses the Valley of Death (MRL 4 to 7)

Benefits:

- Retain IP that is created
- Access to license and IP developed in consortium
- Access to all Project Call results
- DoD business opportunities/collaboration
- FHE supplier access



FHE printed Arduino board patterned using multilayer conductive and dielectric inks

Provides a new way to look at designing and manufacturing systems to help solve difficult problems

Current NextFlex Consortium Membership

DIVERSE AND GROWING MEMBERSHIP: 93 MEMBERS



Corporate

Academic / Non-Profit

| Tier | Corporate | Academic / Non-Profit |
|--------|---|---|
| Tier 1 | BOEING LOCKHEED MARTIN | AUBURN UNIVERSITY SAMUEL GINN COLLEGE OF ENGINEERING BINGHAMTON UNIVERSITY BROOKS UNIVERSITY OF NEW YORK Georgia Tech UMASS LOWELL |
| Tier 2 | brewer science EASTMAN United Technologies Research Center GE QUALCOMM BAE SYSTEMS DUPONT APPLIED MATERIALS SRG GLOBAL | PURDUE UNIVERSITY UConn SCHOOL OF ENGINEERING W UNIVERSITY of WASHINGTON W WESTERN MICHIGAN UNIVERSITY |
| Tier 3 | Acellent American Semiconductor JABIL Raytheon SP2 MicroConnex SRI International ON Semiconductor molex Eink ZEON EPICORE BIOSYSTEMS CARPE DIEM TECH flex Hewlett Packard Enterprise parc OPTOMECH i3 electronics esi Averatek microcross components Intrinsic materials BASF NOVACENTRIX GORE EMD PERFORMANCE MATERIALS UES ANALOG DEVICES Sony FUJIFILM Universal Instruments MEYER BURGER Lubrizol Sensor Films IMPRINT ENERGY USHIO Hitachi Chemical | THE UNIVERSITY OF ARIZONA CAL POLY IPC Sigma Team100 TEXAS INDIANA UNIVERSITY CLEMSON UNIVERSITY MIT UNIVERSITY OF MARYLAND UC San Diego BOISE STATE UNIVERSITY Berkeley fcc MITRE UCSB UMASS AMHERST R.I.T. NDSU EWI UCI UNIVERSITY OF DELAWARE |

Equipment Affiliate



Observer

Honorary



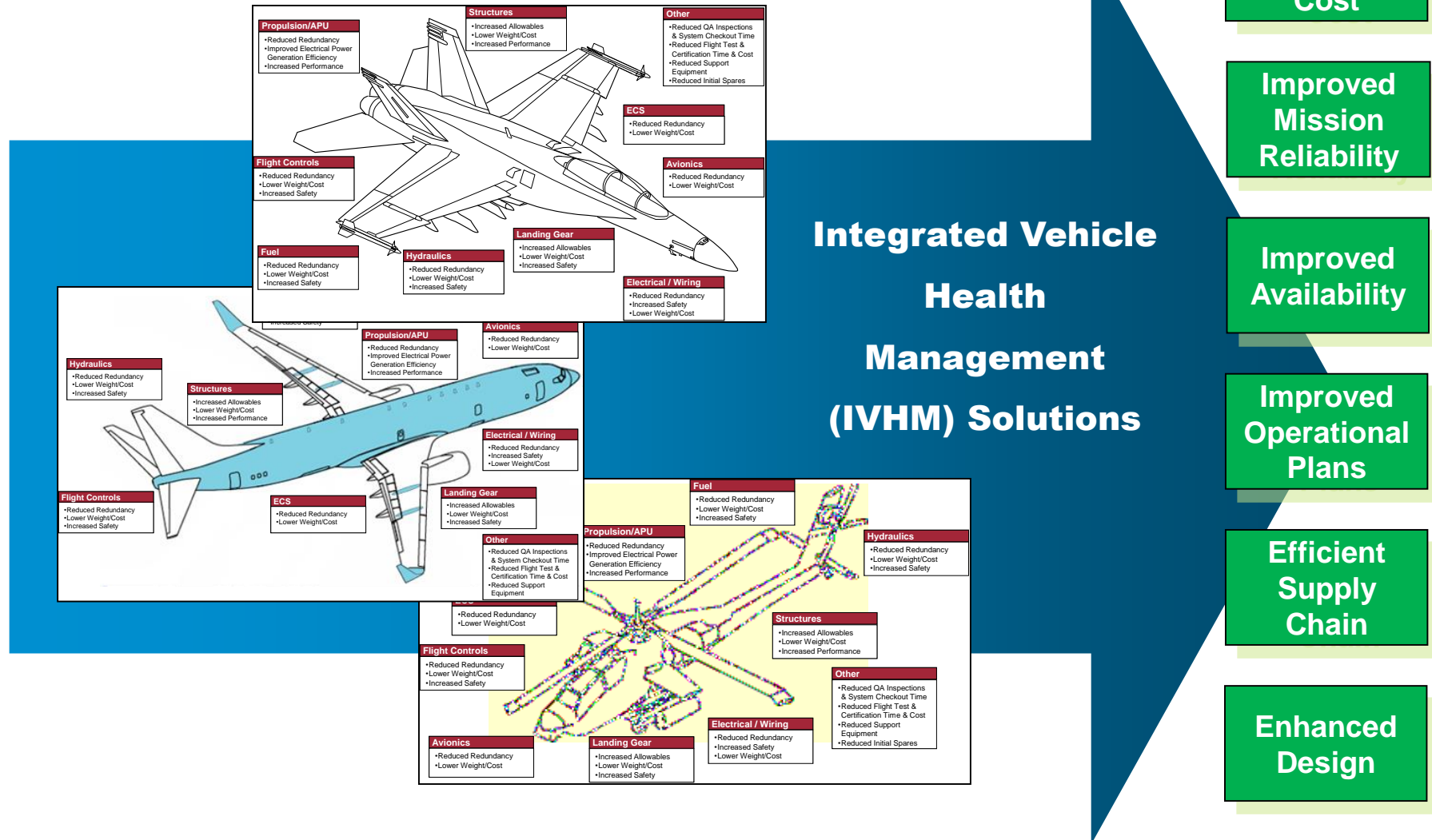
Primary Government Agencies
Interacting with Us



NIST

Platform Application Spaces for Wireless Sensors

Health Monitoring, Wire/Cable Integrity, Damage Sensors (Structural Fatigue/Cracking/Ruptures), Icing (wings/rotor blades/etc..), Repair Integrity Monitors, Drive Train & Avionics Sensors



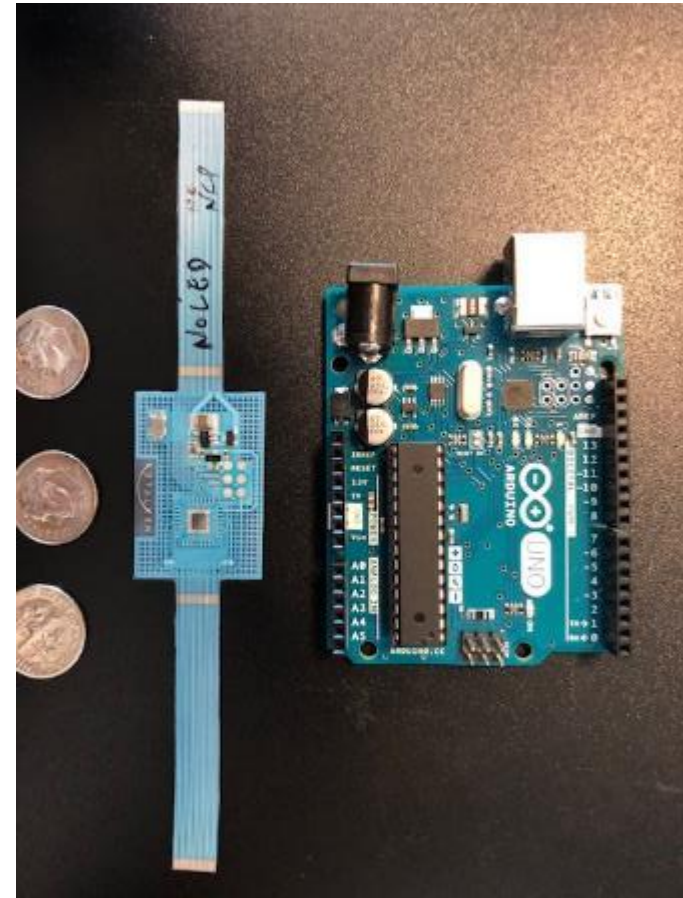
Test Application Spaces for Wireless Sensors



Eliminate the Wires...Enable Faster Setup With Flexibility

Key Sensor Attributes:

- *Flexible, Conformal or Rigid Devices*
- *In-situ Data Collection*
- *Attach to Metal, Plastic, Fabric*
- *Health Monitoring, CBM+*
- *Minimal Integration*
- *On-Board Comm Link*
- *On-Board Power, as required*
- *Some Reusability but inexpensive*



A FHE Version of a COTS Arduino circuit board. System is fraction the size, flexible and weighs 70% less

Overcome cabling, access and sensor location constraints to enable the right data and the right place with rapid setup and reconfiguration capability.

Manufacturing Applications for Wireless Sensors

Types of Sensors:

- Life History, Predict Remaining Useful Life (RUL)
- Condition Based Maintenance (CBM) (Structures Predominate)
- Coating Monitors (Delamination, Moisture Ingress, Corrosion Under Paint, etc...)
- Monitor Part Environments
- Monitor Machinery/Equipment Conditions
- Asset/Inventory Status



Track Items of Interest....

Where am I

What is my Condition

How to Make me Better



Passenger Experience Applications for Wireless Sensors

Passenger Awareness:

- Temperature & Humidity Controls
- Entertainment Controls
- Lighting
- Personal Device Charging

Crew Awareness:

- Status of Passengers in Seats
- Status of Stow Bins
- Lavatory Status
- Air Quality
- Food/Beverage Status

What Else Would You Like....



Summary - Limited Monitoring Systems Exist for Health, Environment and Location Status

Disposable: Inexpensive, right-sized capability, easy to integrate

Reusable: Long life spans (harvest energy), reliable, survive extreme environments

| Swim Lane | Need | Benefiter |
|---------------|--|---|
| Manufacturing | Tracking & Location of Assets, Environment History of Materials, Machinery Health, CBM Warnings |   |
| Platforms | Extreme Environment Sensors, Structural Health, Component Tracking & History, Accelerated Test During Development, CBM Awareness |   |
| Services | After Market Add-on Sensors for Avionics & Structural Health, Enabler for CBM Services |  |

Additional Collection Sensors (Conformal, Miniature, Smart Sensors) are required to get more data to make better decisions and be more informed.