Robust Large-Scale Distributed Wireless Communication for Aircraft IVHM

Fly-by-Wireless Workshop

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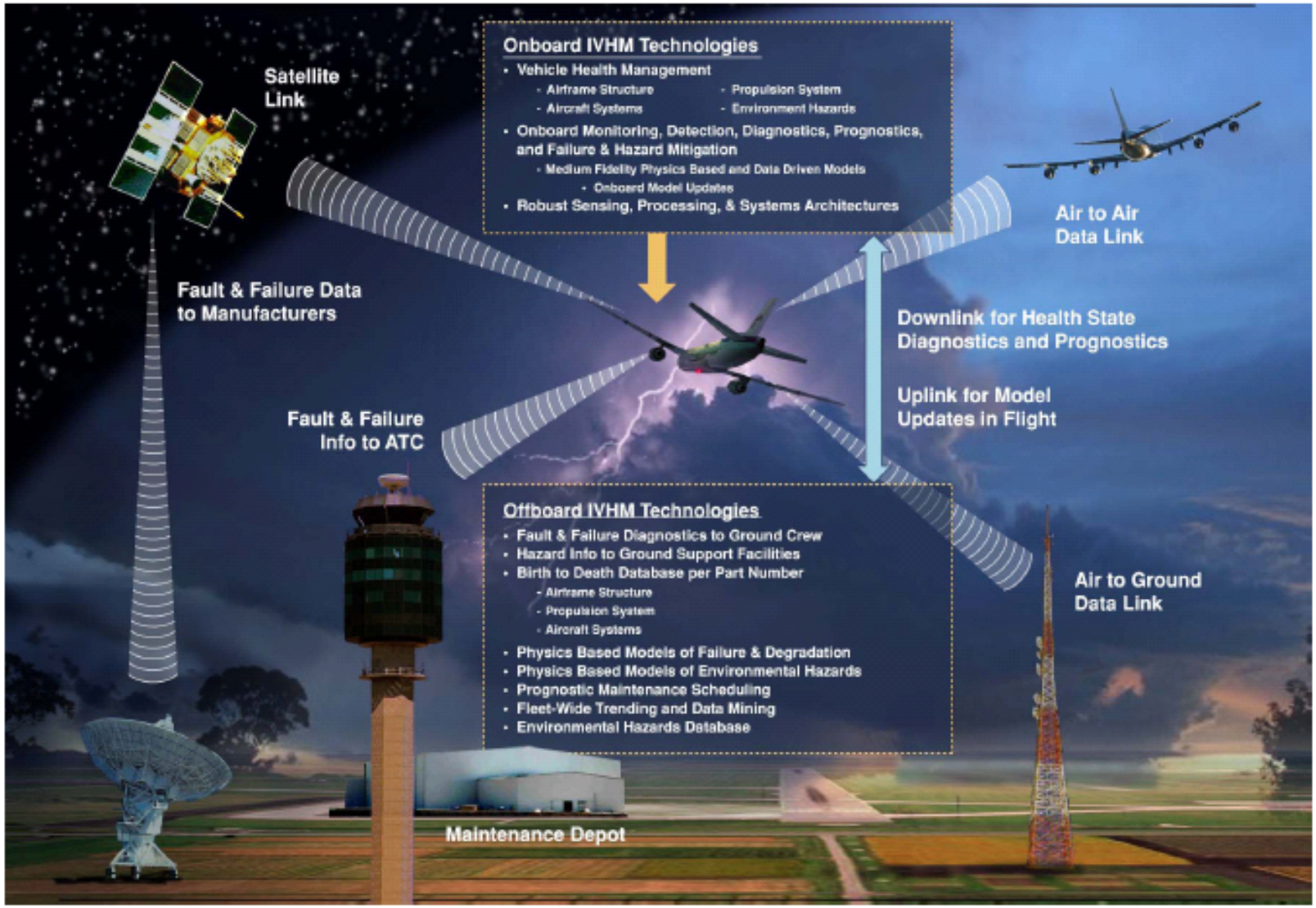
IVHM Future Concept of Operations



- *Provide continuous on-board situational awareness of vehicle health state for use by the flight crew, ground crew, and maintenance depot*
- *Reduce system and component failures as causal and contributing factors in aircraft accidents and incidents*

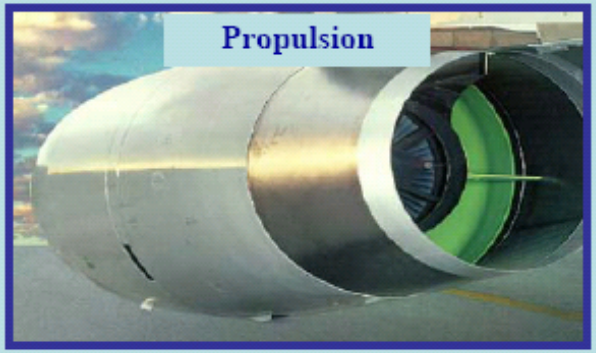
NASA's Aircraft IVHM Research Areas

Aviation Safety Program — **IVHM**

Integrated Continuous Onboard Vehicle Health State Assessment and Management

Airframe

Propulsion



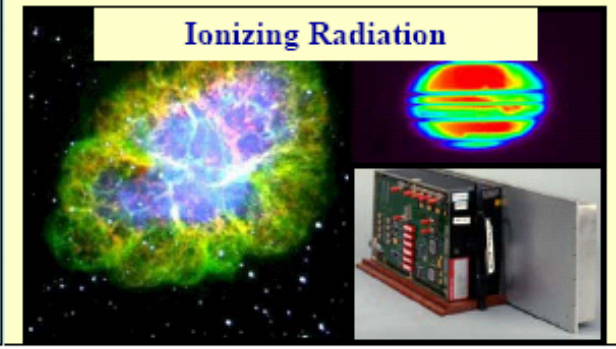
Aircraft Systems

Onboard Environmental Hazard Detection and Effects Mitigation

Icing & Fuel Tank Safety

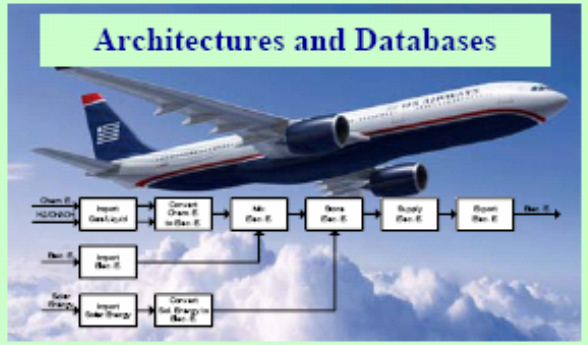
Lightning and EMI/EMC

Ionizing Radiation

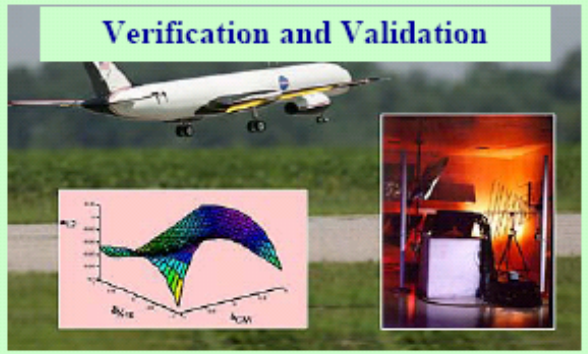


IVHM System Technologies

Architectures and Databases

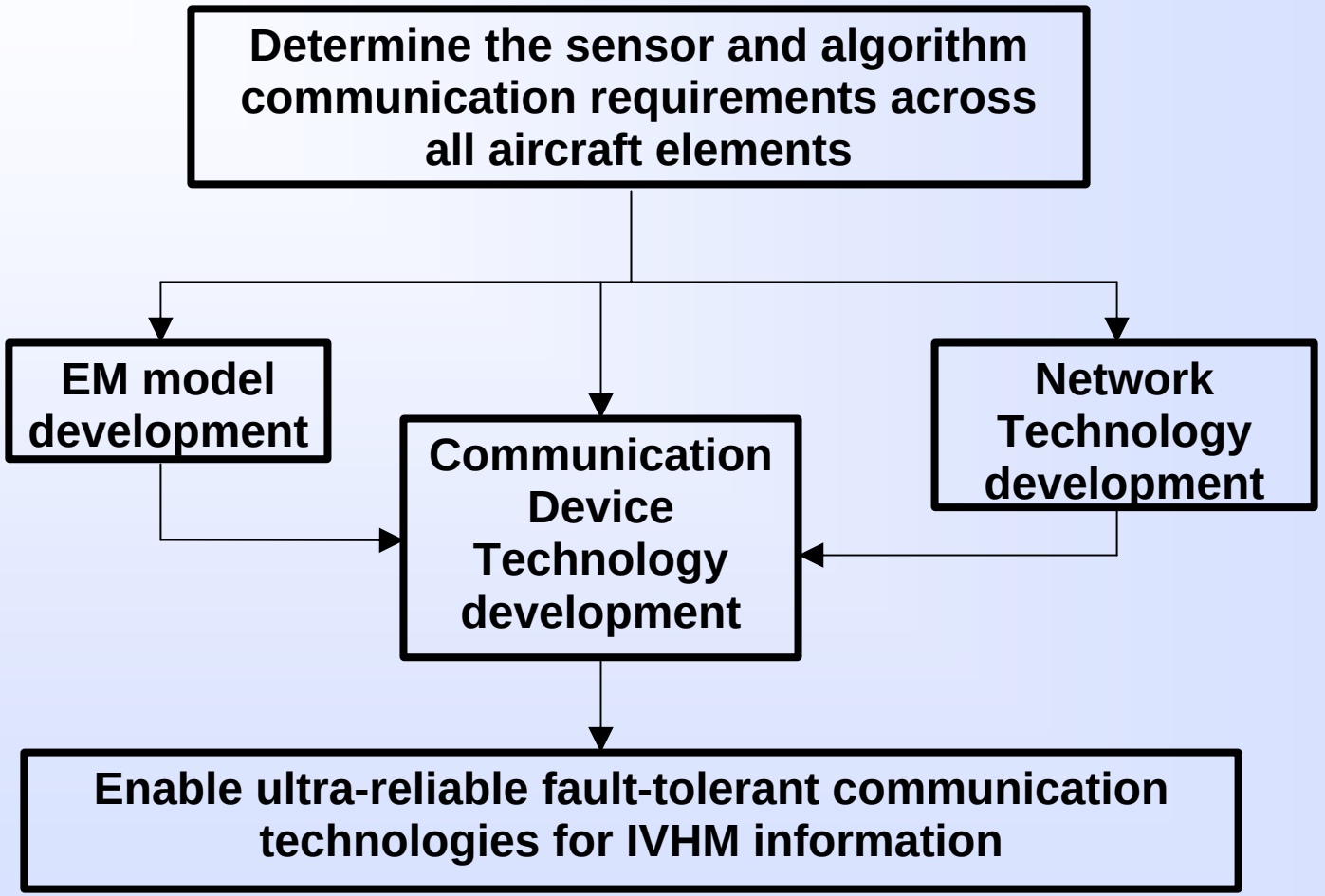


Verification and Validation



Integration & Assessment

Wireless Communication Overview



Requirements Development

Determine overall communications requirements for IVHM data and information for both onboard and offboard a commercial transport aircraft

- Determine current sensor locations, data precision, and data rates for a typical commercial transport aircraft
- Determine future sensor locations, data precision, and data rates from sensor and algorithm developers
- Determine communications necessary to sensors, for calibration, data rate “throttling,” etc.
- Make tradeoffs considering: data rates, network architectures, transmit power, and data processing within the sensor
- Determine offboard communications requirements for transmission of IVHM data both to and from an aircraft

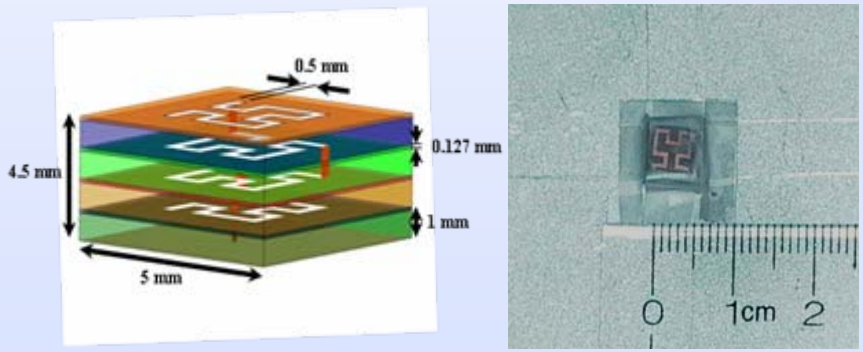
RF Modeling/Frequency Selection

- Modeling of engine environment and other confined areas (ex. airfoil sections) in order to determine a set of candidate frequency bands, considering the propagation environment and EMI encountered within the aircraft.

- These candidate frequency bands will be matched against current frequency allocations and RTCA emission limitations to narrow the candidate frequencies to a set of design frequencies.

Onboard Antenna Development

- Given the design size limitation for the embedded devices (less than 1 in^3), antenna models/designs will be developed, as necessary, considering the design frequencies.



Minaturized (λ/30) Antennas

Network Protocol Technologies

Reduce link failure detection time to less than 500ms and reduce overall network convergence time to less than 1sec.

These design metrics are at least a 10-fold decrease from current detection and convergence times, which enables continued IVHM diagnostic and prognostic sensor based calculations during off-nominal conditions.

Network Protocol Technologies

Develop network technologies/protocols to allow sensor data to be routed around wireless link problems, while maintaining data integrity.

- Determining and documenting causes of wireless link failures/disruptions
- Characterize current link failure detection protocol techniques
- Analyze selected ad-hoc network technologies in meeting design metrics.
- Develop software methods to mitigate effects of link failures/disruptions
- Develop techniques/protocols to allow faster network convergence.
- Work within standards bodies to incorporate the new protocols or protocol modifications

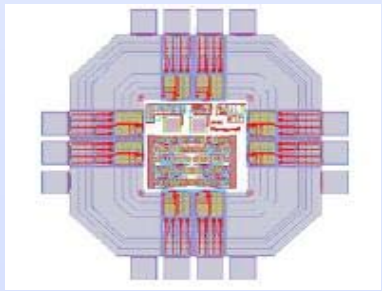
Communication Device Development

- Development of necessary communication transceiver and antenna components, in an integrated package less than $1in^3$, to operate within a constrained environment (ex. airfoil).
  - Must be compatible with sensor elements
  - Must be low-power to accommodate energy harvesting/scavenging methods
  - This work is being coordinated with a High-Temp Communication Device development activity within the IVHM Hazards Element, being conducted by Dr. George Ponchak and Dr. Gary Hunter.

Offboard Antenna Development

Develop physics based models for robust multi-beam broadband IVHM data communications, which will enable a conformal design and is able to maintain communications links during failure of 25% of the antenna elements.

This work will build upon research begun under NASA's previous Aviation Safety program, which successfully developed a novel optical interface to reconfigurable antenna elements that improved manufacturability and increased antenna gain.



Robust Reconfigurable Antenna

Summary

The NASA Aircraft IVHM Wireless Communication Element will develop communications components and systems necessary to achieve a complete IVHM system, through research and development activities in:

- Sensor System Architecture Requirements
- RF Modeling
- Miniaturized Antenna Development
- Fault-Tolerant Network Protocols
- Communication Device Development
- Robust Off-board Antenna modeling