Superior Products Through Innovation

Advanced Development Programs

Remote Embedded Micro-Systems

R. Coulter, Lockheed Martin Aeronautics Co

and

E. Berkcan & Emad Andarawis, GE Global Research

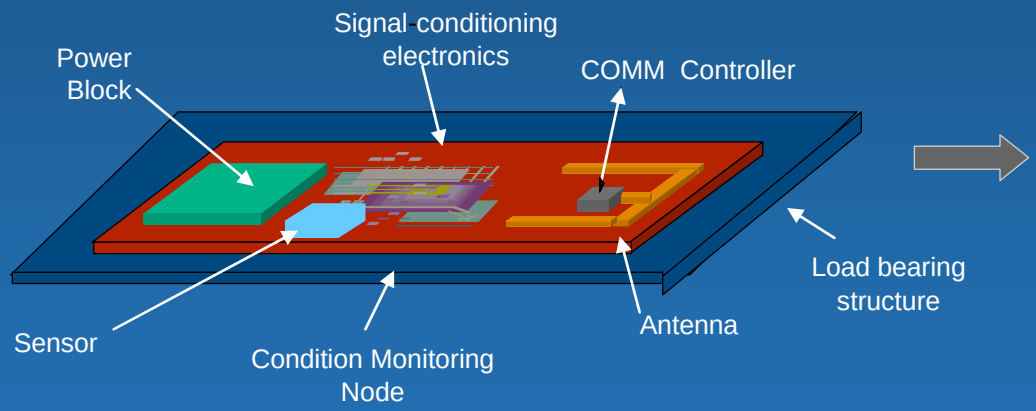
Outline

- **Introduction**
  - *Remote Embedded Microsystem (REMS) Overview*
  - *Potential Applications*
- **System Description**
  - *Current Specification*
  - *System Architecture*
  - *Sensor System*
  - *Communication and Synchronization*
  - *Power Harvesting*
- **Results - Summary**
  - *Flight Test*
- **Conclusions & Questions**

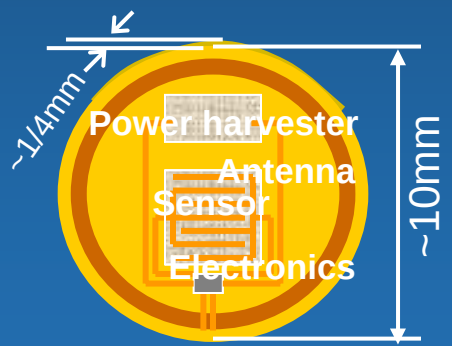
Remote Embeddable Microsystem

- Wireless, self-powered sensing technology that can be integrated into a material/structure, e.g. an airframe composite
- Demonstrated strain sensing, vibration based powering & wireless COMM
- Applicable sensors: strain, acceleration/impact, pressure, temperature, etc
- High temperature curing process tolerance

Microsystem prototype



Envisioned packaged device



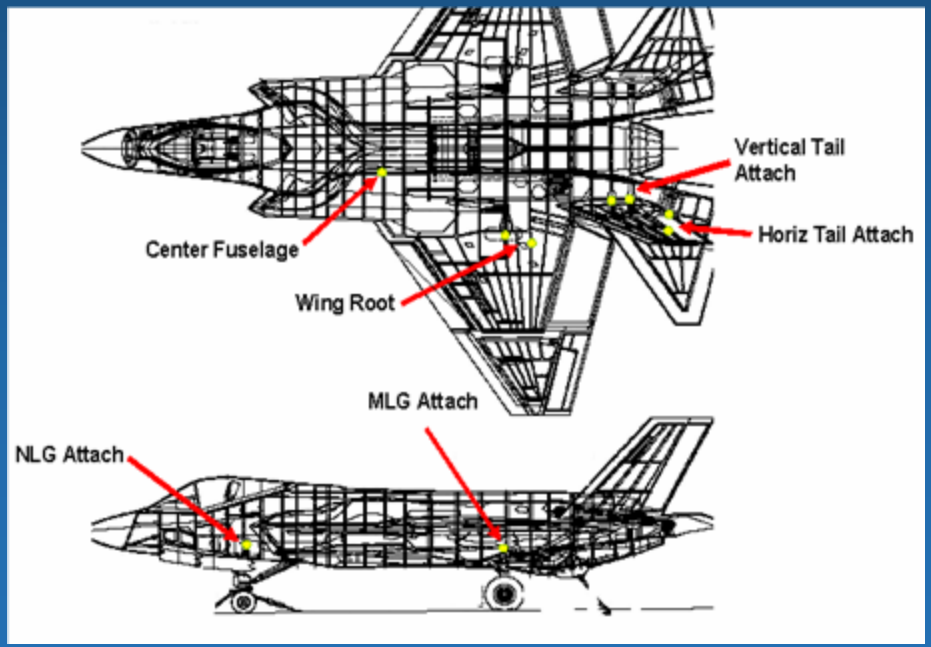
PHM sensors ⇒ Reduced maintenance costs, increased safety,

Aircraft Test Applications

- Ground static and fatigue tests
  - 1000's of nodes
  - ~5 Hz data sampling rate
- Flight test
  - 100's of nodes
  - ~100 Hz data sampling rate

Prognosticative Health Monitoring Sensors

- REMS will enable insertion of additional sensors
- Sensors will result in decreased inspection labor hours
- REMS power harvesting has potential to power other types of sensors
  - Corrosion & acceleration

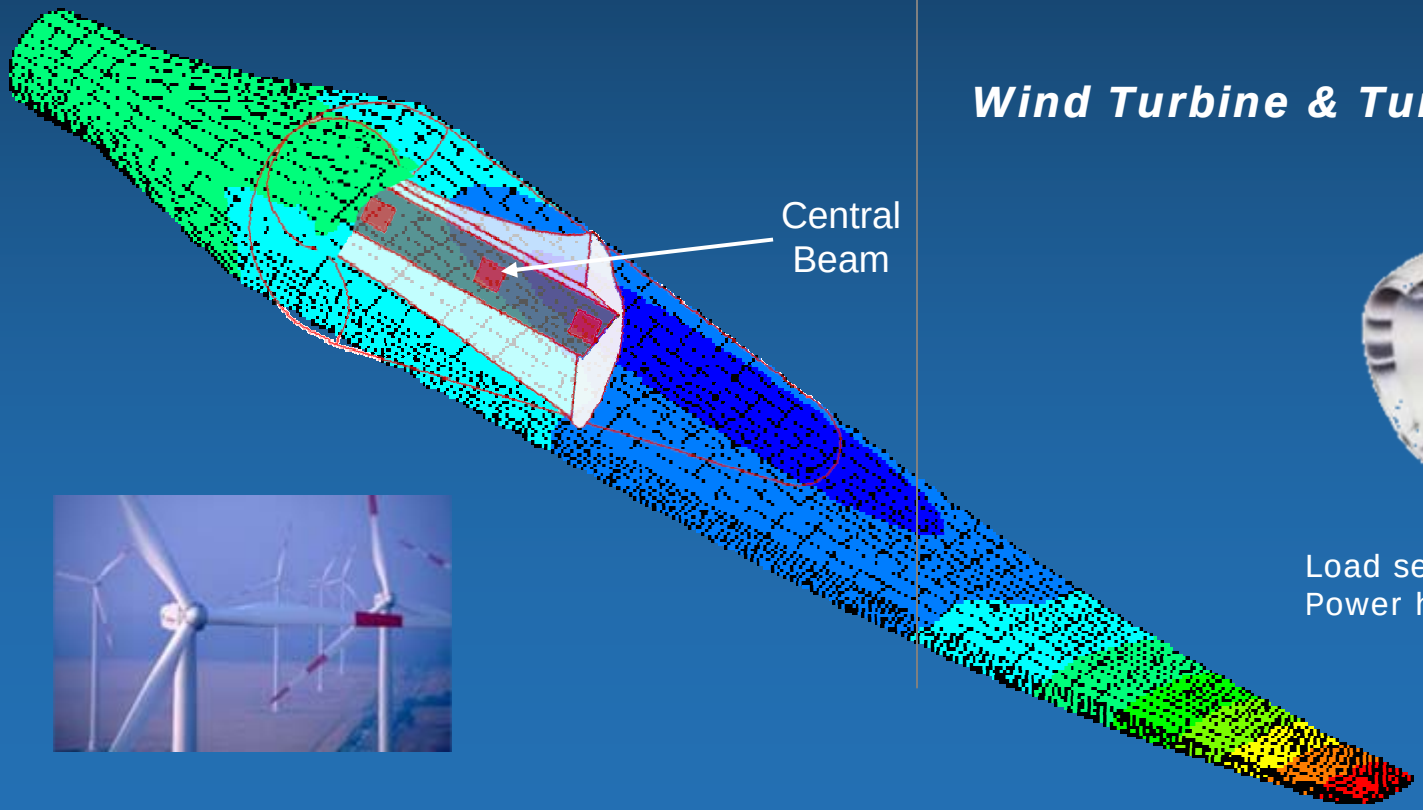


Condition Monitoring Sensors

GE Interest: Sensing & communicating from unpowered locations.

Railcars

Shock sensing, & vibrational power harvesting



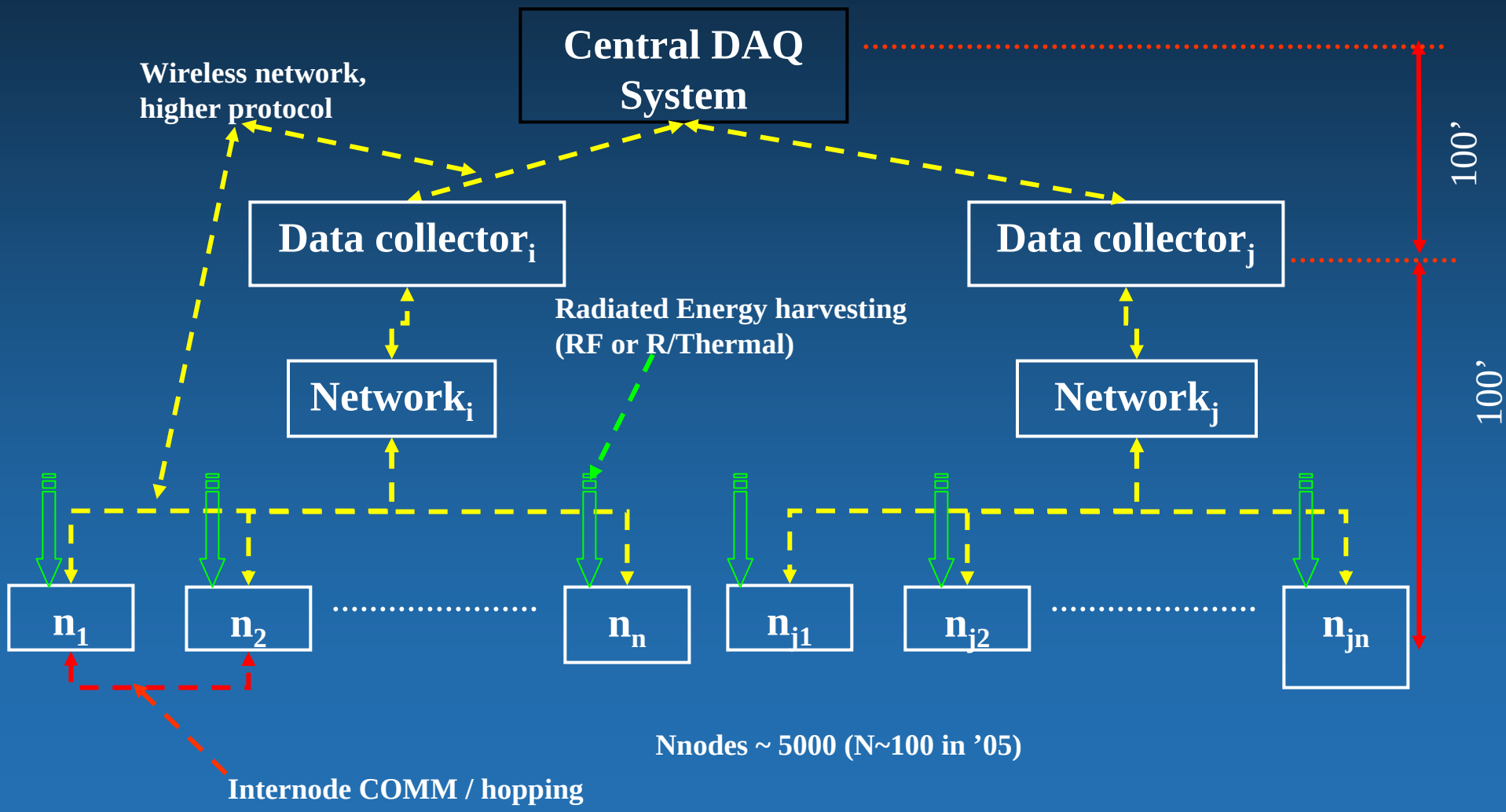
Wind Turbine & Turbine Engines

Load sensing, strain & stress sensing
Power harvesting

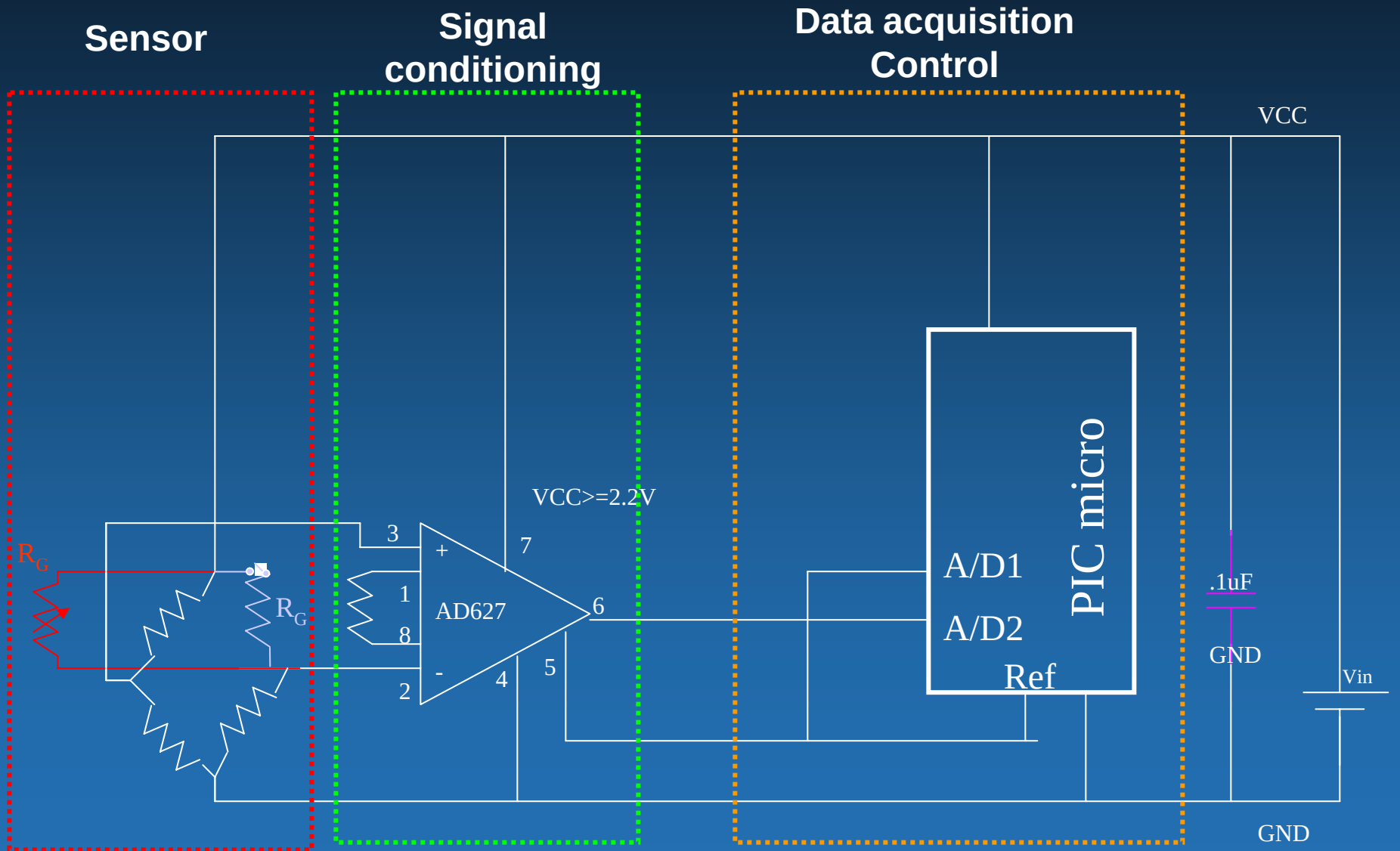
Current System Specifications

Uses of off-the-shelf strain gages with *no further wiring*	
Number of Sensor nodes	**Up to 5000**
DAQ Frequency	
Ground Test	**1-5Hz**
Flight Test	**100Hz**
Synchronized Data	**~40μs**
Wire reduction	**100%**
Density of sensors	**several per sq. ft.**
Operation time period	**4 - 7 yrs for ground test**
	Goal is 30 years for operational environments
Sensitivity/Accuracy	**1% FS over temperature range of op.**
'Smart' self calibration	**Shunt calibration**
On-chip temperature compensation	
Node Size (foot print)	
inc. electronics,	**1/2"x1/2"**
COMM, power	
Gauge incorporated in same unit	
Thickness	**Compliant with the structure**
Power harvesting	
No external devices mounted on the airfoils	
No active RF emission during flight	
Applicable for metal or carbon structures	

General System Architecture

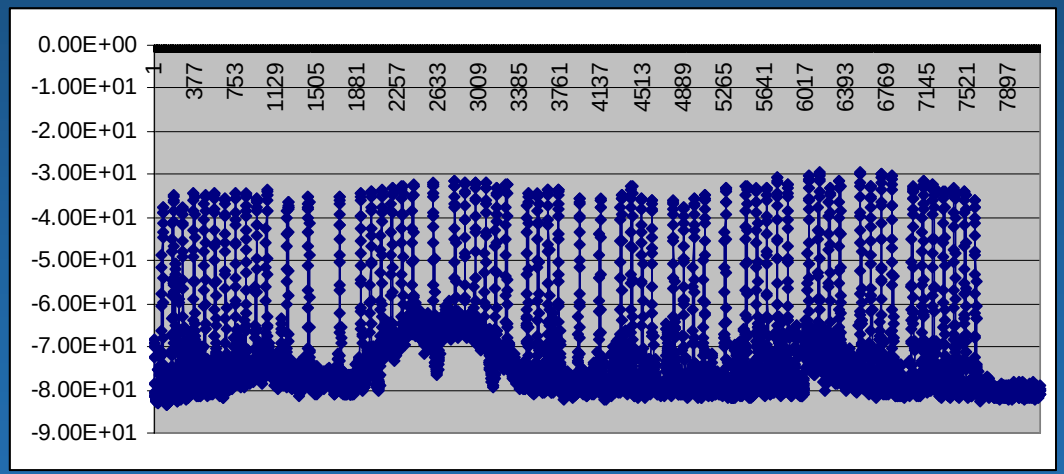


Self Compensating Sensor Electronics



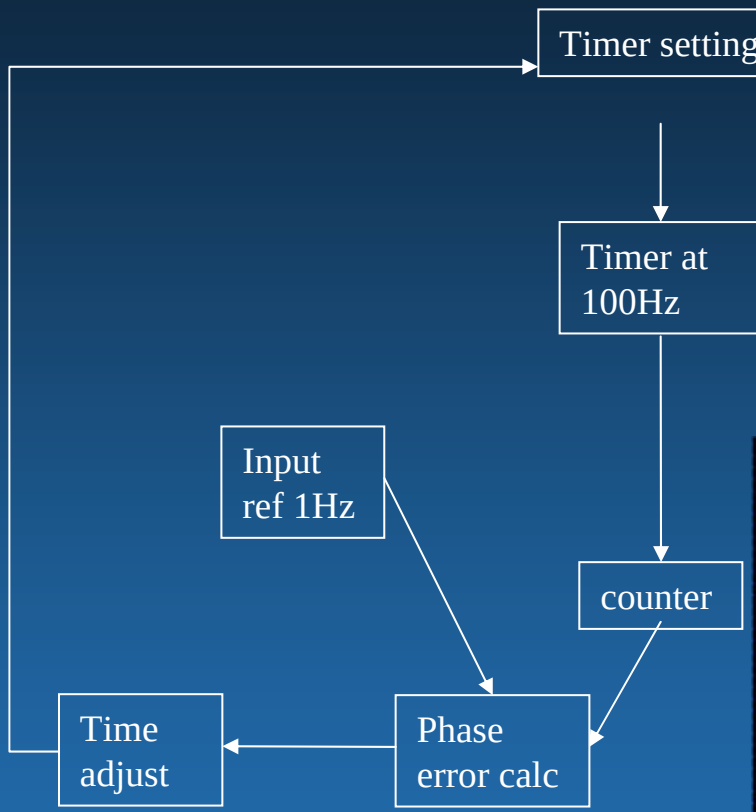
RF Communication

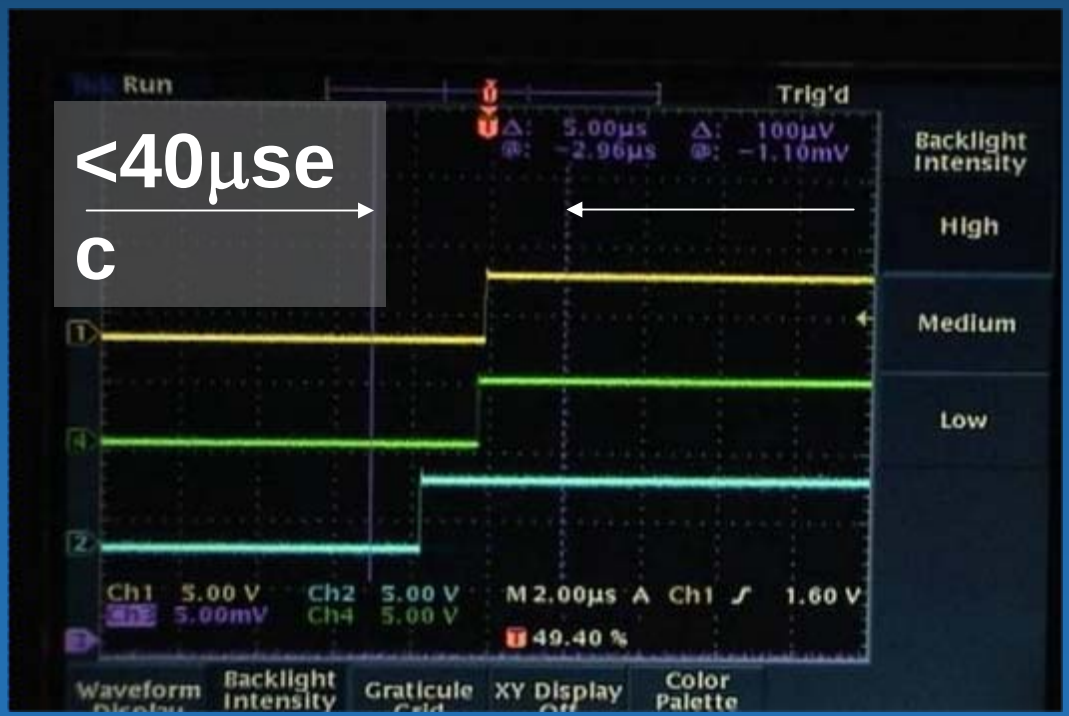
- **Wireless communication in harsh**
  RF environments
- **Communication including tight flight compartments**



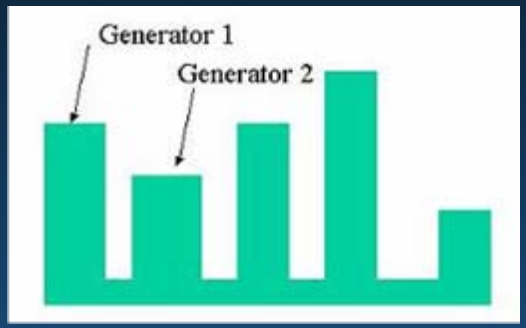
Freq. Hopping details in Rear Engine Compartment

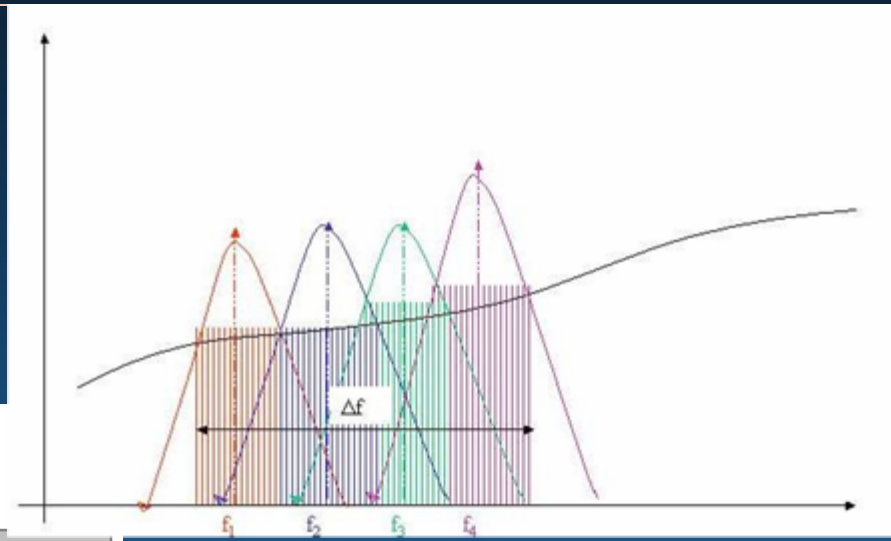
WYNCH – Wireless SYNCH



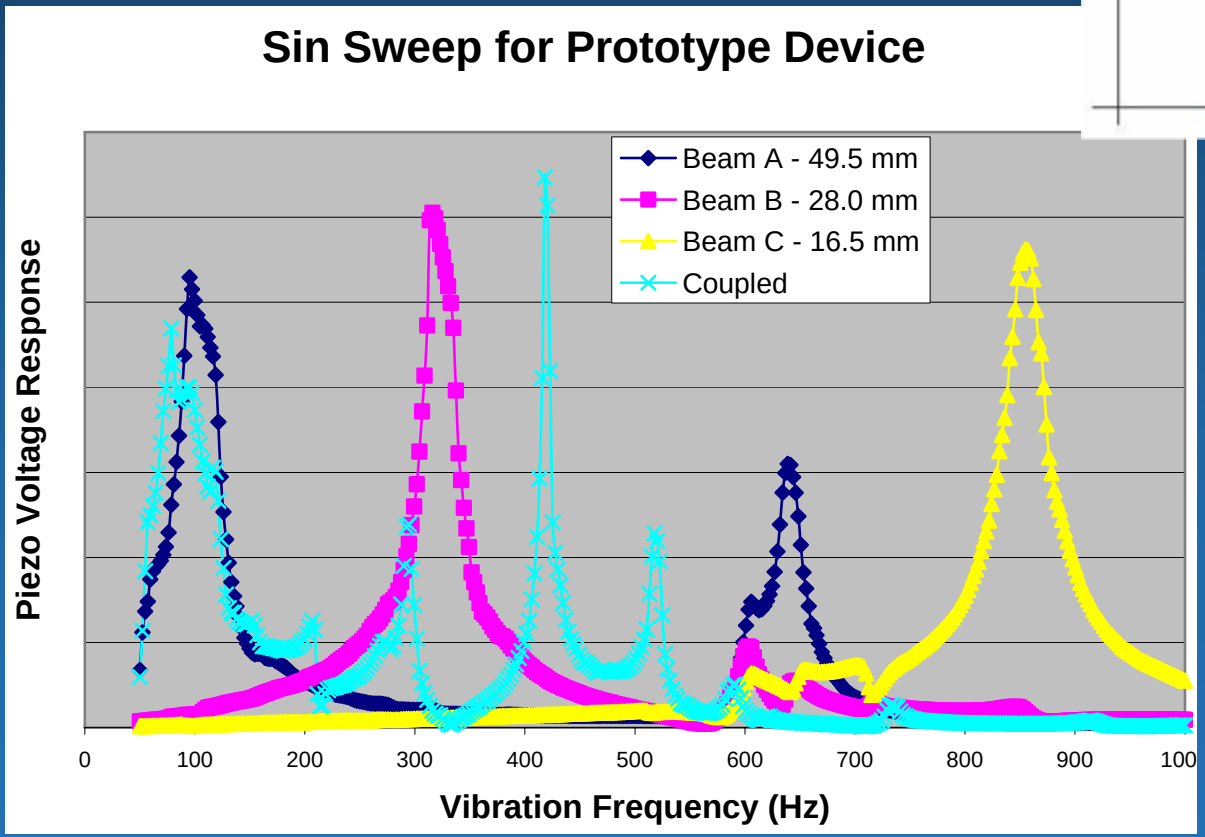


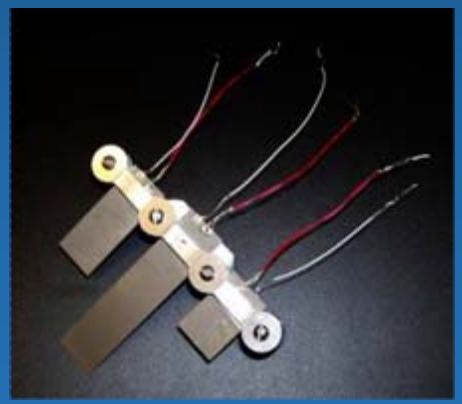
Broad-band Power Harvesting



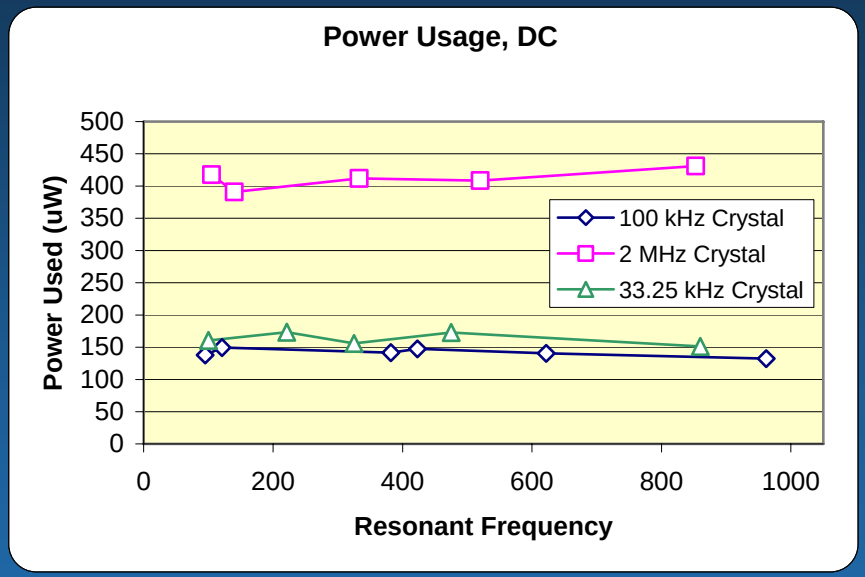


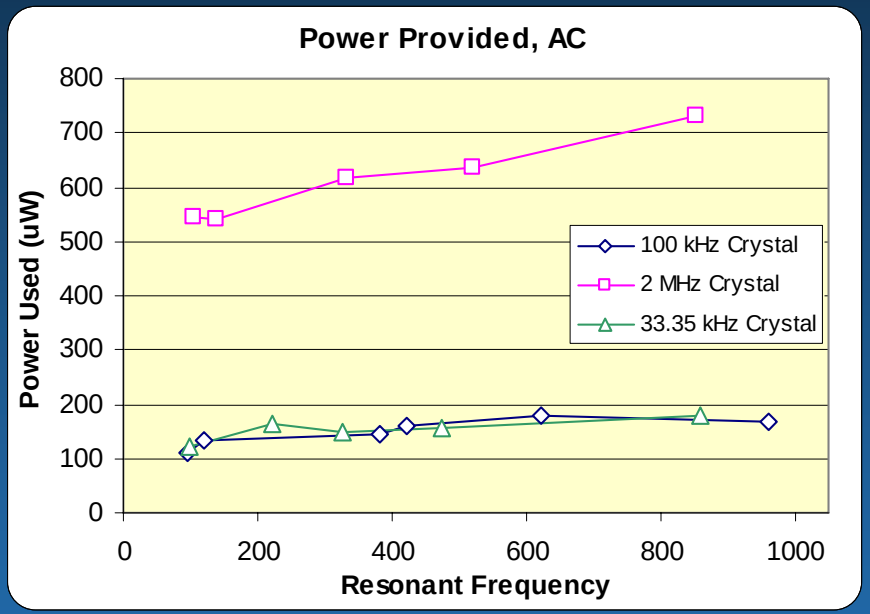
Sin Sweep for Prototype Device





Broad-band Power Harvesting (cont'd)



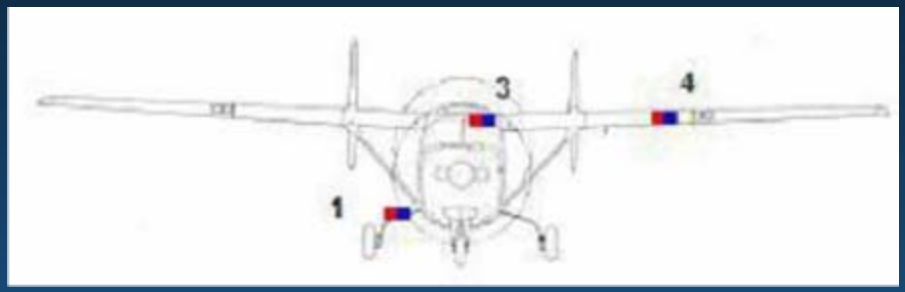


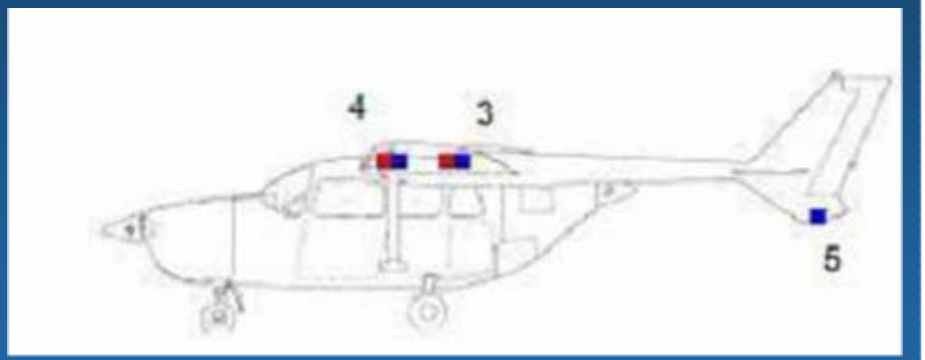
Power Harvesting/ Synchronization Demonstration

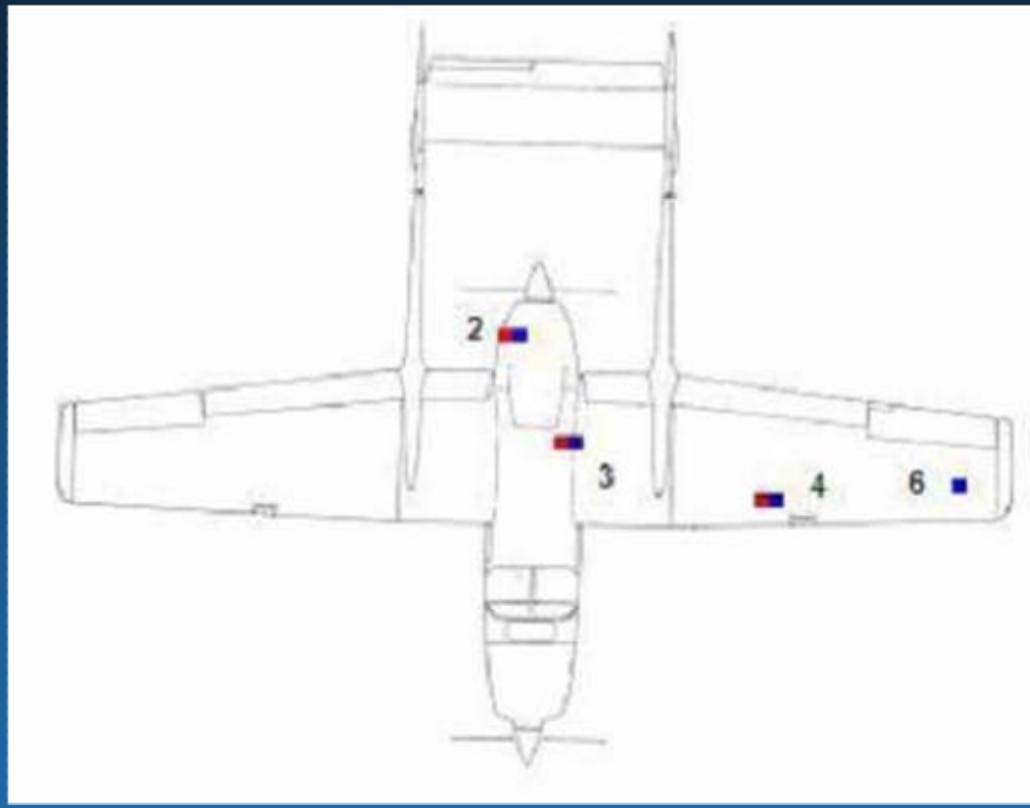
Power Harvesting Movie

Synchronization Movie

REMS Node & Reference Sensor Locations







Legend:

1. *Starboard landing gear strut*
2. *Starboard rear engine cowl flap*
3. *Bottom spar cap of trailing edge spar*
4. *Port leading edge shear web placed at 45° angle*
5. *Port vertical tail endcap*
6. *Port wiring access panel*

Wireless REMS node

Wired reference Sensor

TEES FLIGHT RESEARCH LABORATORY Texas A&M University

REMS Node Locations (Cntd)

Landing Gear Strain Data

Conclusions & Questions

Conclusion

- GEGR and LMA Have Demonstrated Basic REMS Functionality
- Prototype System Was Flight Demonstrated at the End of 2005

Questions?