Implementation of Wireless TPS Sensors

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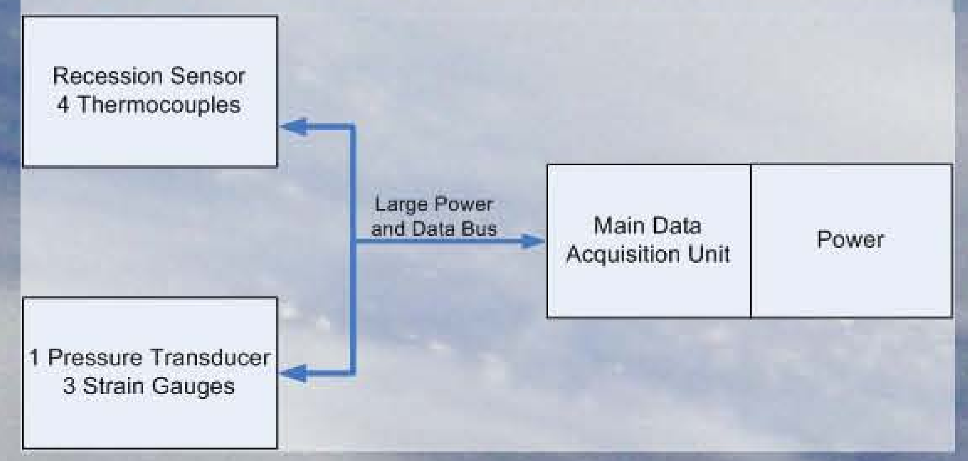
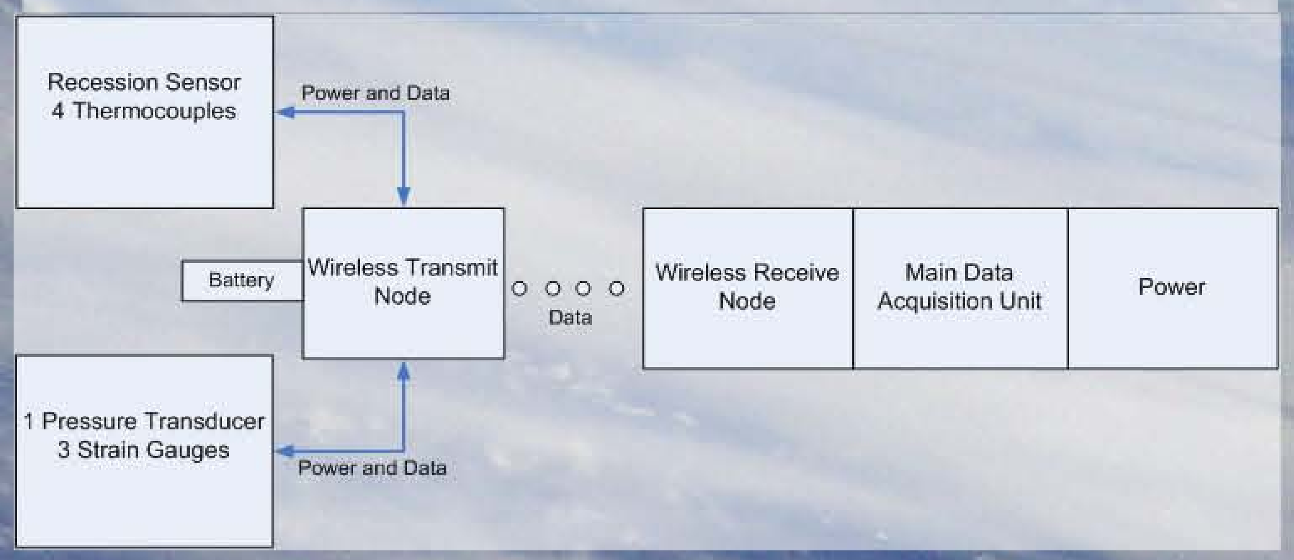
BACKGROUND

Every spacecraft entering a planetary atmosphere needs a Thermal Protection System (TPS). The TPS must endure severe heat loads, which requires an understanding of atmospheric properties, vehicle aerodynamics, TPS material properties and the physics of the entry environment. NASA and other space agencies would like to collect temperature, pressure, heat flux, radiation and recession measurements on flight tests and flight missions in order to verify TPS design and to aid in the characterization of physical and chemical phenomena in the entry environment. As of now the missions that do fly thermocouples have them wired into the TPS of the spacecraft. This architecture adds risk to the system due to the process of routing wires in the shield and the difficulty of jettisoning the system after entry. Many current and past spacecraft engineers have decided not to fly embedded sensors in an effort to mitigate the risk of spacecraft failure during entry. A wireless instrumentation system could collect the required measurements needed for scientists and engineers to improve future spacecraft design while lowering the overall risk of incrementing entry vehicles.

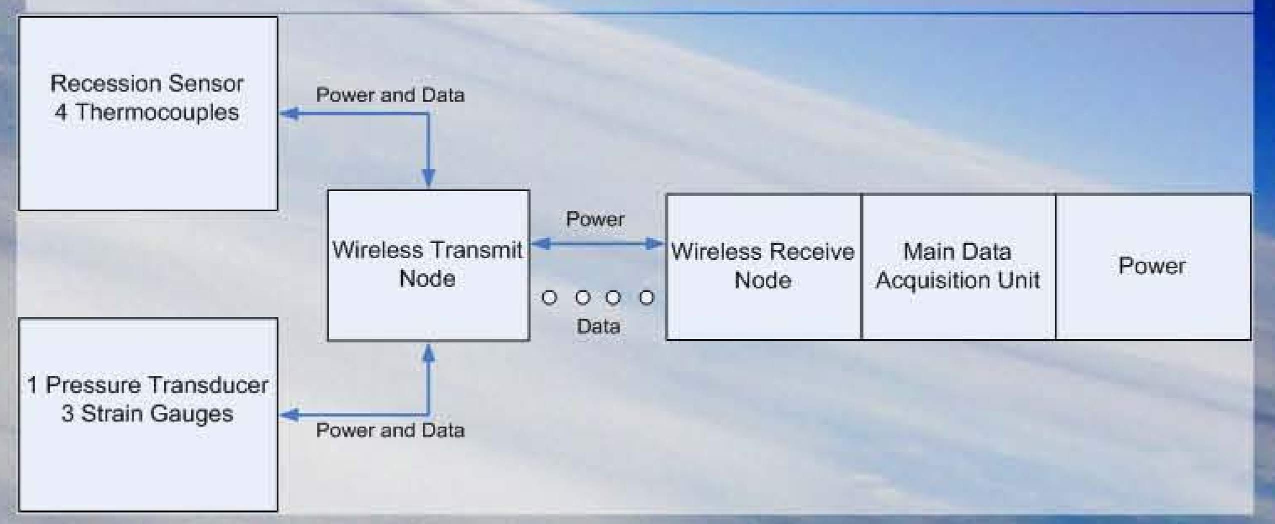
CURRENT WIRED SYSTEM



WIRELESS DATA WITH BATTERY POWER



WIRELESS DATA WITH WIRED POWER



YEAR 1 WIRELESS SENSOR PROOF OF CONCEPT

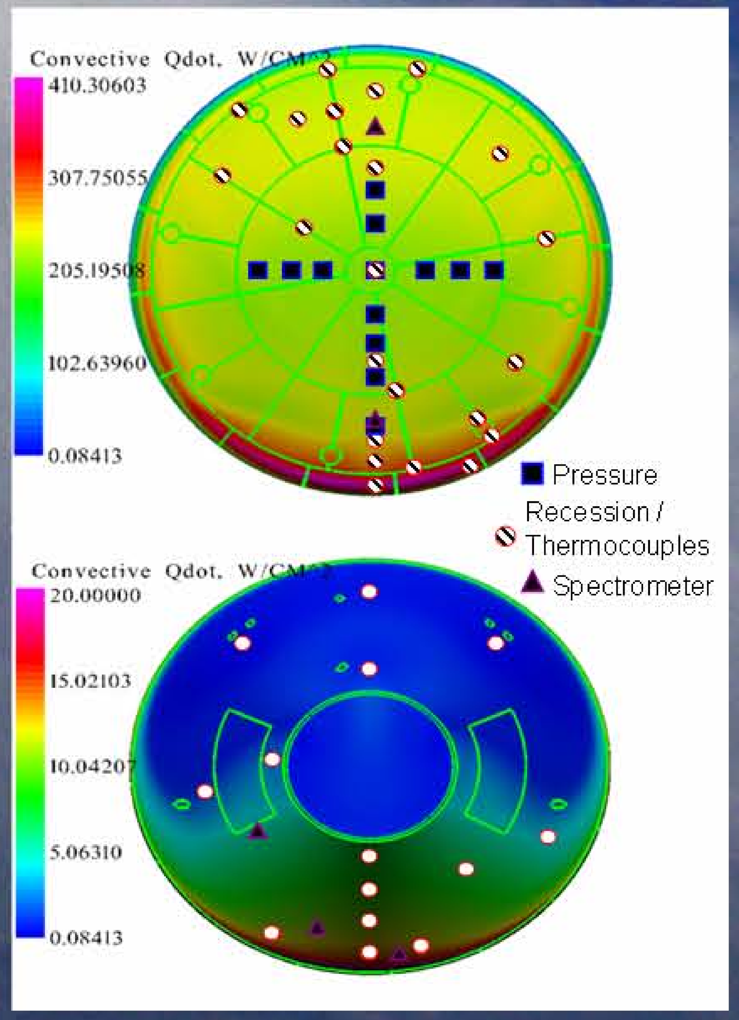
- Designed a one node wireless system
- Multiple sensors per node
- Tested system in NASA Ames X-Jet facility
- Received wireless data from TPS integrated sensors

YEAR 2 WIRELESS SENSOR DEVELOPMENT

- Designed a multi-nodal wireless system
- Multiple sensors per node
- Multiple sensor types per node
- Testing in NASA Ames X-Jet facility
- Received accurate wireless data from TPS sensors
- Integration into high altitude balloon launch

CASE STUDY

LE-X SENSOR CONFIGURATION

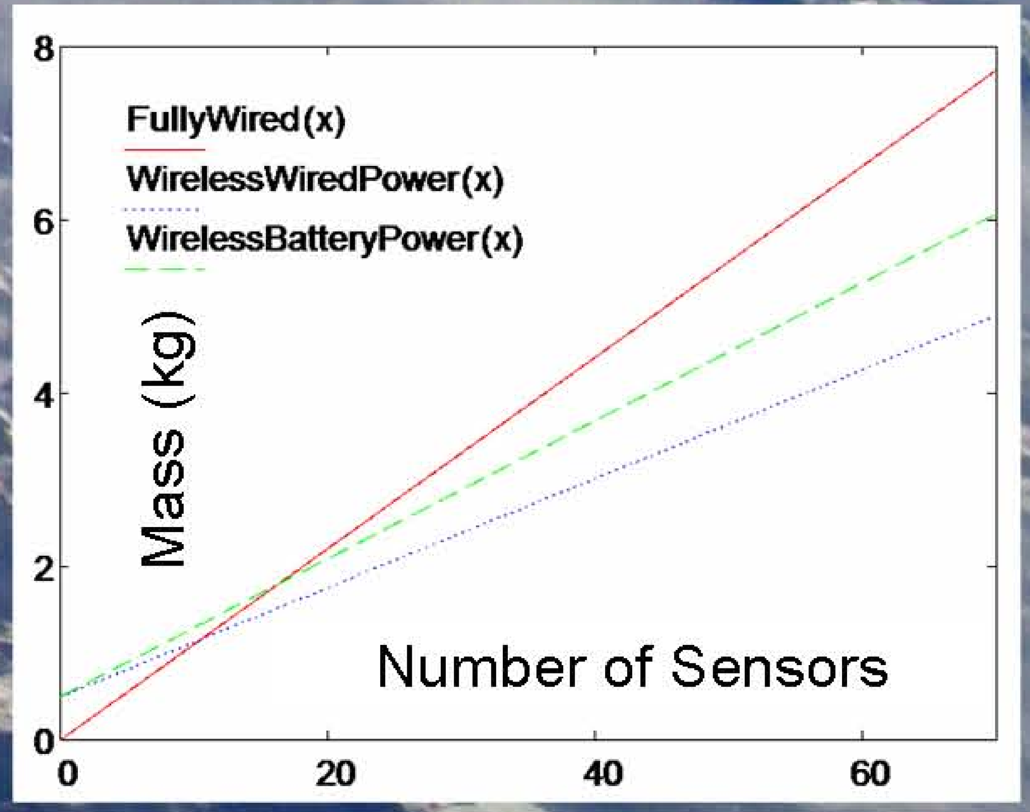


PARAMETERS USED

Average Wire Length	10	m	Pressure Data Wires	4
Wire Mass	0.0015	kg/m	Thermocouple Plug Wires	8
Node Mass	0.055	kg	Node Power Wires	2
Battery Mass	0.07	kg	Receiving Node Mass	0.5 kg
Pressure Power Wires	2		Strain Gauge Wires	8

SYSTEMS MASS COMPARISON

	Fore Shield [Kg]	Aft Shield [Kg]	Total [Kg]	Reduction %
Wired	7.511	2.436	9.947	0.00%
Wireless w/ Wired Power	4.669	1.602	6.272	36.95%
Wireless w/ Battery	5.806	1.729	7.535	24.25%



BENEFITS

- Reduced mass
  - As much as 30% reduction in mass
- Reduced System Complexity
  - Significantly less wire runs
  - Heatshield Jettison Risk Reduced
  - Manufacturing
- Double Data Redundancy
  - Each node has two transmitters / receivers to increase robustness

DISADVANTAGES

- Only at a TRL 4
  - Needs More Flight Testing
  - NASA Standards Integration
- Greater Power Consumption
  - Adding receiving nodes require more electronics requiring more power
- High Sampling Rates
  - Greater than 10Hz sampling rate would require more sending nodes

CONCLUSION

The wireless data transmission of sensor data on future missions will reduce the mass and the complexity associated with the instrumentation of the TPS. The wireless system reduces the number of wires and helps in the integration of the sensor network by allowing sensors to be placed in a myriad of topologies without significant changes.

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LE-X Instrumentation Vehicle Description Document