Pratt & Whitney
A United Technologies Company

SCOPE
Senior Consulting
Program for Engineering

Modular Wireless Sensor Suite for On-Engine Testing

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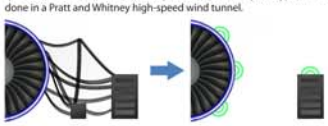
Project Description

Pratt and Whitney uses "station probes" to measure pressures and temperatures in the flow path of gas turbine engine subsystems, including the fan, low and high-pressure compressors , combustor, high-pressure turbine, and low-pressure turbine.

The principle goal for the modularized probe program is to build a working prototype of a station probe that is wirelessly connected to the data acquisition system. This requires rethinking the probe design to embed the entire signal conditioning hardware into the probe. In addition, the electronic networking and link into the data system will have to be changed.

This year's team will focus on the design of the probe-environment control systems and the integration of last year's team's work into a prototype system. The environment control system will ensure the accuracy and precision of the pressure and temperature sensors.

A wireless station probe will greatly reduce cost as less effort will be required to interface with the station probes. Tests of the prototype will be done in a Pratt and Whitney high-speed wind tunnel.



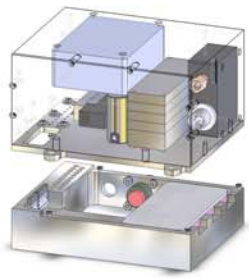
Wireless Communication

In a typical Pratt & Whitney engine test, there are thousands of sensors on the engine. This means that there can be a hundred or more wireless station probes in a test system. To accommodate the large number of nodes in the network, we chose the ZigBee mesh network protocol because of its scalability, flexibility, and low power consumption. Each station probe is equipped with a ZigBee wireless chip and will be one node in the network. The station probes transmit the data they collect to base station modules that interface with the control room computers.

The current prototype implements most of the functionality of final model at the proof-of-concept level.

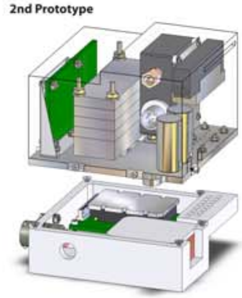
Mechanical Design

1st Prototype

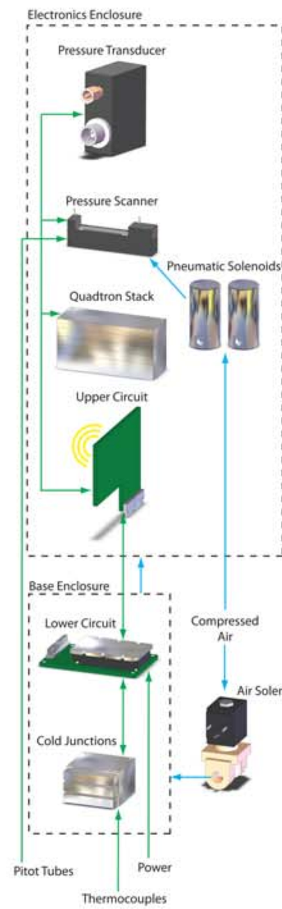


The first prototype above was constructed during the second semester to conduct thermal tests. The second prototype below was presented to Pratt & Whitney as a space saving redesign that was easier to assemble and to maintain

2nd Prototype



System Diagram



Pressure Scanner – reads pressure values from 16 air inputs as well as a calibration input and exports the data to the upper circuit board.

Pressure Transducer – measures a single pressure input pressure very precisely with very little variation due to temperature so that the pressure scanner can be calibrated

Pneumatic Solenoids – controlled to open and close a shuttle valve in the pressure scanner that allows pressure calibration

Cold Junctions – take four sets of thermocouple wire as inputs and output voltages corresponding to their temperatures

Quadtron Stack – processes all the thermocouple, pressure scanner, and pressure transducer inputs and outputs them back to the top circuit board

Internal Temperature Sensors – measure enclosure temperature in three locations for monitoring and temperature control of the entire enclosure to keep the electronics from overheating or losing accuracy

Air Solenoid – opens and closes to allow air into the enclosure for cooling

DC/DC Power Converter – steps down input voltage from 28 V to 12 V for use with all internal components. It's located on the lower circuit

Wireless Chip – processes communication through the antenna over ZigBee, reads temperature data from the internal temperature sensors, performs thermal control, and performs solenoid valve control

Upper Circuit – contains two temperature sensors and wireless chip; interfaces between the wireless chip, the Quadtron stack, and the lower-circuit; and outputs high voltages to the solenoid valves

Lower Circuit – contains a temperature sensor; external 28VDC power in and routes it up to the top board; and interfaces between the cold junctions and the top board

What's Next

Preliminary testing on the first prototype has been very promising. We are able to control internal temperatures to within half a degree and the shell gradient is minimal. The next obvious step is to get the internal system working so Pratt & Whitney can assess component accuracy in our setup. The system has basic functionality as of the end of the semester so all that is needed is someone to go back and finalize the firmware on the onboard PIC's and develop control room software to interface with our system.

Thermal Management

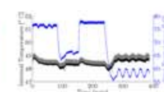
Our thermal management system needs to accomplish two goals critical to maintaining equipment functionality and accuracy

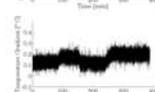
1. Keep internal components within operating temperatures

2. Minimize temperature gradient across the cold junctions.

Temperature Gradient

We chose to use a system of alternating shells to minimize the gradient across the cold junctions. We ran FEA simulations to determine feasibility and found that the cold junctions would only see a 0.1°C gradient across them given a total gradient of 200°C. We constructed the shells shown to the left in the first prototype and tested performance in an oven. The results, shown below, indicate that the actual system experiences no more than a 0.2°C gradient under normal operating conditions.





Enclosure Temperature

For controlling the temperature within the enclosure, we looked at two different methods of cooling: compressed air with a vortex tube and Peltier tiles.

We ran simulations with a crude prototype during the first semester and found that the vortex tube presented the best method of cooling. We also found it easy to control in second semester tests