Improving Efficiency of Jet Engine Testing Facilities at AEDC using IEEE's Sensor and Synchronization Standards

Oak Ridge National Laboratory (ORNL) is working with Arnold Engineering Development Center (AEDC) to drastically reduce installation time for their turbine engines by minimizing instrumentation connection and check-out tasks upon test article delivery. Such a reduction is possible by implementing a distributed and networked data acquisition system based on the IEEE 1451 Smart Transducers family of standards.

ORNL has been involved for several years in sensor networks and related standards such as SensorNet and several of the IEEE 1451 standards (1451.0, 1451.1, 1451.3, 1451.4 and 1451.5). ORNL has developed a reputation and expertise in implementing such systems. The implementation described here is based on an Ethernet network of distributed nodes collecting data from IEEE 1451.4 compatible sensors. Time correlation of data from different nodes in an Ethernet based sensor network is very important. This correlation can be achieved by synchronizing the Ethernet nodes using IEEE's 1588 (Precision Clock Synchronization Protocol for Networked Measurement and Control Systems). ORNL was also involved in the development of this standard.

AEDC is comprised of numerous aerospace ground test facilities. Among these are turbine engine test facilities, which include test cells and associated data and control systems for performing simulated altitude testing. Prior to testing a turbine engine in a test cell, facility personnel must make extensive wire connections from up to 200 stationary strain sensors mounted on the engine through various patch panels. These wires traverse significant distance carrying low-level signals across electrically noisy environments. The wires are ultimately terminated at a remotely located instrumentation rack where the signals are amplified, conditioned, digitized, and read by a data processing system.

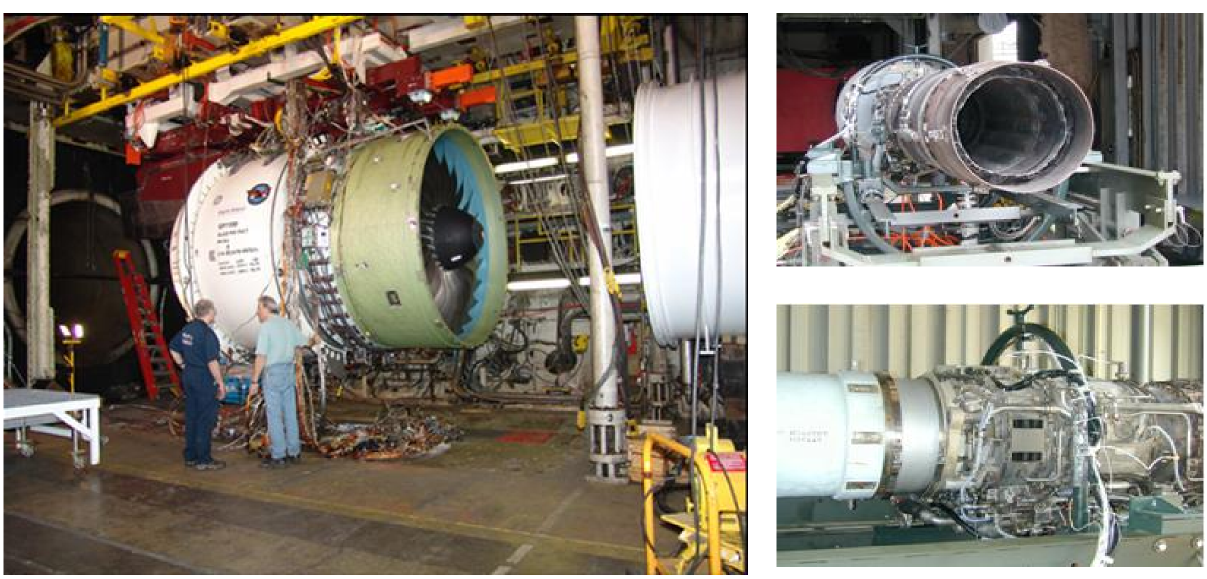

Figure 1 Preparation of different jet engines for testing at AEDC

Figure 1 shows a typical example of different engines being prepared for testing. The bundles of wires under the engine pictured at left are currently routed through the back wall to the data acquisition system. Reducing the time to connect the sensors to the instrumentation and to verify and cross-correlate the sensor positions to the data collected would allow more efficient use of the test facilities by decreasing the total test cell occupancy period without impacting actual engine operation time.

The IEEE 1451 family of standards was conceived with this purpose in mind: i.e. to allow interoperability of transducer from different manufacturers by using a standardized definition of the sensor in what is called the Transducer Electronic Data Sheet (TEDS). TEDS contains information about each sensor (manufacturer, model number, temperature range, calibration values, etc.) as well as user defined information (sensor location, calibration parameters, and additional sensor information). The standards also define a methodology to electronically access the TEDS information. The IEEE 1451.4 standard eases the adoptability of this methodology by allowing legacy transducers to become 1451.4 compatible by adding an EEPROM to define its parameters.

Figure 2 A set of IEEE 1451.4 compatible sensors developed at ORNL. The set includes a temperature and a humidity sensors and a switch closure monitor.

The strain sensors used in the prototype for this project can be true 1451.4 compatible sensors, legacy sensors adapted with an EEPROM, or a mixture of both. During sensor installation, the technician adds to the original TEDS information related to the position of the sensor on the test article using a Sensor Installation Tool (PDA like) which has a list of predefined locations. The host application, in configuration mode, polls all the nodes to identify and configure the sensors

Due to the variety of strain sensors used by AEDC (full bridge, ¼ bridge, and different sensor resistances), ORNL also developed a 1451.4 compatible bridge completion module to provide flexibility in the sensor connections as well as making sure the bridge completion module matches with the sensor.

The other improvement on the current system is the topology of the data acquisition system. Currently all the cables from all the sensors are routed through a wall to the data acquisition system. The cables are long with a greater possibility of signal degradation due to the noisy environment. The ORNL design includes a number of nodes networked together via Ethernet. Distributing the data acquisition in such a fashion allows nodes to be located in the test cell close to the sensor and requires

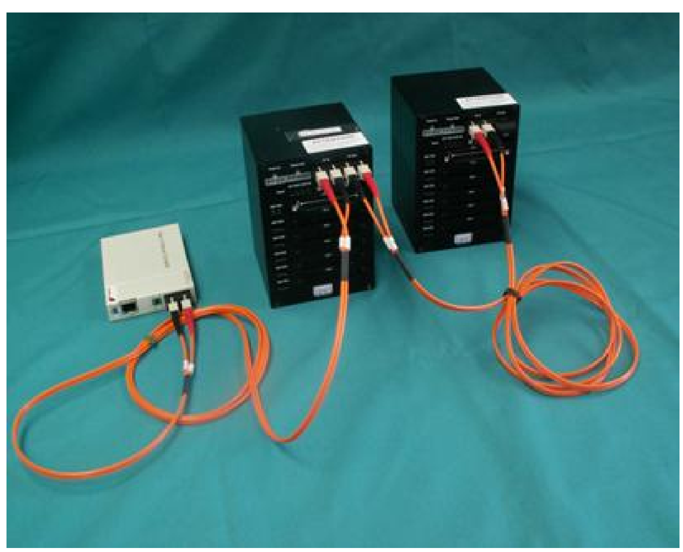

Figure 3 PowerDNA networked data acquisition nodes

shorter cables minimizing noise interference. Figure 3 shows two PowerDNA nodes from United Electronic Industries (UEI) with a daisy chain Ethernet fiber optic link. Depending on the data sampling rate required, each node services from 12 to 72 sensors.

The initial prototype, to be tested in Spring 2006, will support up to 24 sensors at 100 Ksamples/sec each. A complete system can have up to 200 of these high speed sensors and another 600-800 lower rate sensors spread over 30 to 40 nodes. With this many nodes, time correlation of the data from the different nodes becomes an issue. ORNL is working closely with UEI to implement the IEEE 1588 in the next generation hardware/firmware of the PowerDNA cubes.

This effort has been facilitated by the Tri-Lateral Alliance (TLA) agreement whose purpose is to enhance the working relationship among three major Federal research facilities in the Tennessee Valley: the Department of Energy’s ORNL, NASA’s Marshall Space Flight Center, and the Department of Defense’s AEDC.