UEI App Notes:

PowerDNA Hardware Helps Tinker AFB Achieve Design Goals for New Engine Test Cell

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UEI PowerDNA I/O Hardware Helps Tinker AFB Achieve Design Goals for New Jet Engine Test Cell

The Pacer Comet 4 (PC4) jet engine test facility recently introduced at Tinker Air Force Base in Oklahoma sets a “next generation” standard for high performance testing of a wide range of gas turbine engines deployed by the Air Force. The new design supersedes the Pacer Comet 3 (PC3), which has been in use nearly 25 years, and is planned for use in multiple facilities at Tinker and other sites.

Key Design Goals

The new system was designed to achieve several key goals:

- Enable development of standardized, repeatable tests for specific engine types, independent of each other
- Mount data acquisition (DAQ) and control equipment directly on the thrust frame
- Transfer all measurement/control data via single Ethernet bus
- Use short sensor leads for minimum noise pickup and reduced wiring costs
- Make design of each test procedure independent of the test cell itself and of other tests
- Permit “out-of-cell” calibration of each thrust frame, simplifying test setup/changeover
- Achieve scan rates of 10-100 samples/sec
- Use COTS components to reduce equipment/installation cost and to increase reliability
- Improve safety, reliability, maintainability, production throughput, and facilitate expandability

By taking advantage of recent developments in DAQ hardware/software technology, communication system design, and new test cell operating concepts, the PC4 achieves an efficient, highly flexible, and easily configurable facility that can meet the testing requirements for all jet engine types currently serviced at Tinker AFB. A major feature of the PC4 design is the use of detachable “quick change” thrust frames that are readily swapped and configured for use with different engine types as testing needs change.

Since each thrust frame is separable from the cell, it can be configured and calibrated as an off-line task, independent of the cell in which it will be installed. It is then ready for quick setup in a cell whenever the specific engine type for which it is calibrated is scheduled for a test — without requiring any modifications of the test cell itself. This quick setup concept is a significant aid in achieving rapid and efficient test turnaround.

The requirement for on-frame mounting of the data acquisition and control equipment mandates the use of very compact, rugged, hardware devices with high density input/output capabilities that can operate reliably in the severe environment of an engine test cell. The on-frame design also means very short wire lengths (less than 10 feet) are needed between sensors and DAQ, resulting in much reduced signal noise or loss of signal strength.

In addition, the need for reliable, high speed communication between DAQ and host with minimal “waterfall” wiring logically leads to the use of an industry-standard Ethernet network over a single twisted-pair cable — all of which is immediately available with COTS equipment from UEI.

Major Test Cell Equipment Components

Figure 1 is a block diagram of a Pacer Comet 4 Engine Test Cell that shows how the Data Acquisition and Control System interacts with other major components of the test cell.

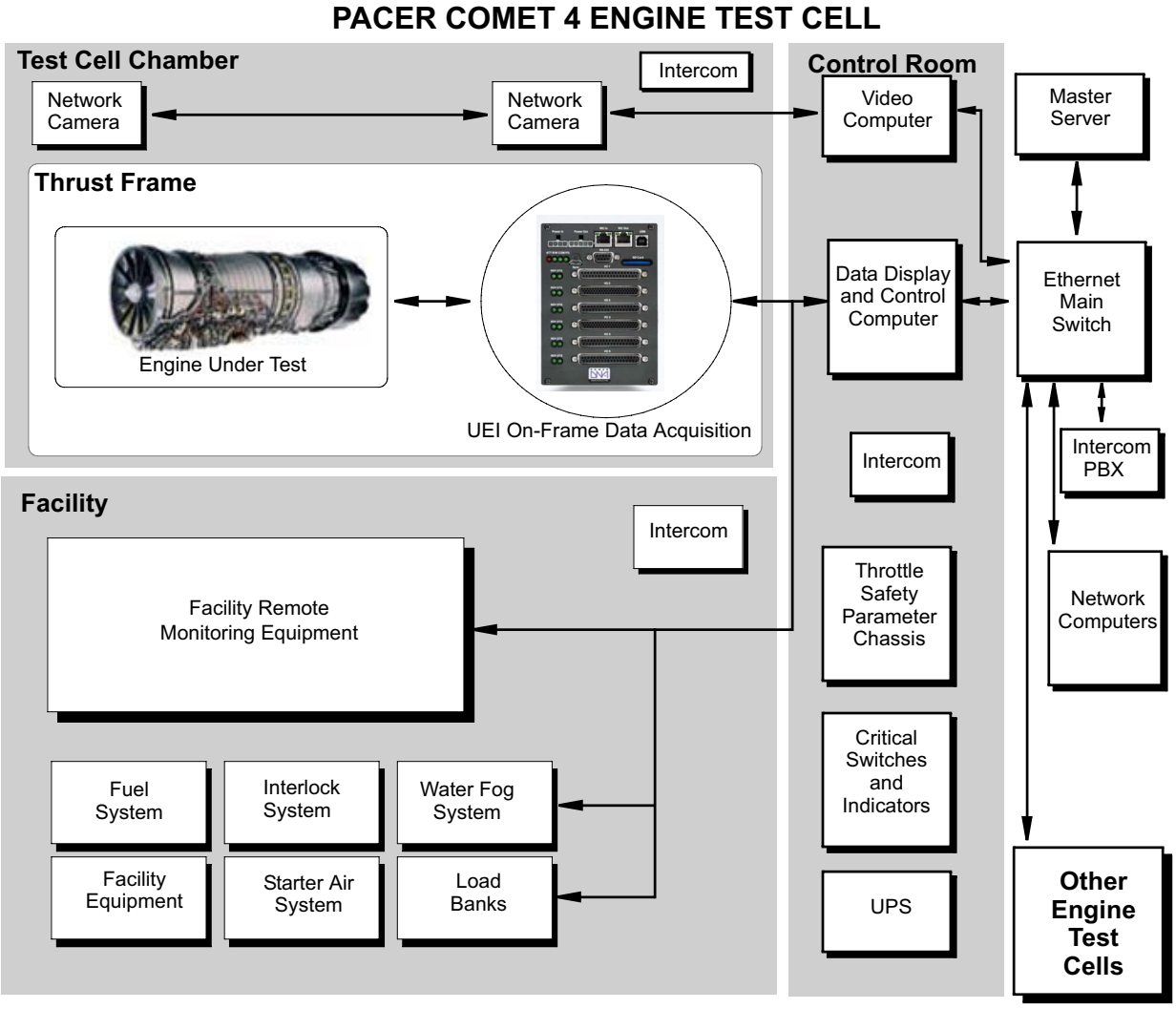

Figure 1. Block Diagram of Pacer Comet 4 (PC4) Engine Test Cell

As shown in **Figure 1**, the engine under test is suspended on a “Thrust Frame”, which in turn is suspended within the Test Cell Chamber. The thrust frame is an independent unit that can be removed from the test cell chamber with the engine. It can then be configured and calibrated off line, and set aside until needed. It can be quickly installed in any of several test cells without further modification.

The DAQ equipment is also installed directly on the Thrust Frame. Since the DAQ system moves with the Thrust Frame, it can be configured, tested, and calibrated with the engine either in or out of the test cell. It can be disconnected from the Test Cell by simply removing the single Ethernet cable and power connection.

The Test Cell Chamber is also equipped with two network video cameras and an intercom system for increased safety of personnel and immediate detection of faults or fuel leaks. The cameras are connected to a video computer in the control room via Ethernet. Video, voice, and test information are linked via Ethernet with all other test cells and facility offices for data sharing and greater efficiency.

New software developed by the Software Maintenance Group (SMXG) group at Tinker provides fully automatic closed-loop testing for all engine types and versions, plus manual control, utilities, and simulation capabilities, all managed through a Graphical User Interface. Test data for all engine types is stored in the Engine Health Management Repository Center data base, which provides baseline performance data for each engine type and also enhances security, safety, and cost effectiveness.

As shown in the block diagram, the control room of the test cell contains the video computer, the data display/control computer, intercom, critical switches/indicators for the engine under test, and an uninterruptible power supply. It also contains the Throttle Safety Parameter Chassis, which measures and controls critical parameters required for safe operation (engine core speed, engine fan speed, fuel flow, etc.). If a failure occurs in any subsystem at any time, the throttle safety parameter chassis automatically brings the engine to a safe state.

In addition to the UEI on-frame Data Acquisition/Control System, the Test Facility also contains sensors and related equipment to measure vibration, thrust, load, fuel flow, air flow, rotary and linear position, noise, and other variables. All data collected from remote monitoring equipment is transmitted to the Data Display/ Control Computer via Ethernet.

On-Frame Data Acquisition/Control System Equipment

Figure 2 illustrates the equipment items used in the Data Acquisition System supplied by UEI. As shown in the diagram, the engine of the DAQ system is a PPC8 PowerDNA Cube. This unit has a PowerPC CPU, SD card slot, DB-9 Serial Port, SD Card slot, several indicating LEDs, and an Ethernet interface plus 6 slots for any of over 30 different types of UEI PowerDNA I/O boards that interface with various types of sensors.

The Cube used in the on-frame DAQ system contains the following UEI I/O boards:

- **1 - DNA-AI-225 Analog Input Board.**

  This unit accepts up to 25 differential ±1.25 VDC analog inputs. It offers simultaneous sampling of all inputs, one 24-bit A/D for each channel, and a maximum scan rate of 1000 samples/sec per channel. In this specific application, sensor inputs for this board are routed through a universal DNA-STP-AI-U accessory board for signal conditioning and cold junction compensation, as described later in this section.

  In the PC4 Test Cell Application, this I/O board acquires data from multiple thermocouples on the engine under test and an RTD that measures engine oil temperature.

- **1 DNA-AI-207 Analog Input Board**

  This unit accepts up to 16 differential input analog voltage inputs. It has an input range of ±10 VDC, programmable gain selection, one 18-bit A/D per board, and a sampling rate of up to 1000 samples/ sec per channel (aggregate maximum of 16 kS/s per board). It also has a dedicated CJC channel for use with thermocouple inputs and automatic offset autozero.

  In the PC4 Test Cell Application, the AI-207 board accepts voltage inputs from multiple pressure transducers and also from a synchro-to-voltage converter unit measuring engine oil pressure.

- **1 - DNA-DIO-401 Digital Input Board**

  This unit has 24 digital input channels with user programmable hysteresis and an I/O throughput rate of 1000 samples/sec maximum. It has an input FIFO of 1024 samples and requires an external 24 VDC power supply unless a DNA-PC-902 Power Conversion board is supplied with the board.

  In the PC4 Test Cell application, this board is used to detect discrete open/closed inputs from relays and some critical jet engine switches such as Fire Warning, Low Oil, etc.

- **1 - DNA-DIO-402 Digital Output Board**

  This unit is a 24-channel digital output board that uses low impedance FETs to drive relays that apply/remove power to/from devices on the engine under test. Power to the outputs from this board is supplied by the DNA-PC-902 Power Conversion Board described below. Using the PC-902, the digital outputs can drive 350mA/channel (max peak of 500mA). The board also provides a 512 sample FIFO and offers user-programmable hysteresis on each of the outputs, which significantly improves noise immunity. An update rate of up to 100kS/s can be readily achieved.

- **1-DNA-PC-902 Power Conversion Board**

  This unit supplies 24 VDC power to drive the on/off outputs of the DNA-DIO-404 board. Interconnections between the 902 and the 404 boards are made through an internal inter-layer bus connector and associated jumpers.

The following items are accessory devices connected to the input terminals of the I/O boards described above.

- **1- DNA-STP-AI-U Screw Terminal Panel**

  This universal accessory unit has jumper-selectable, built-in Cold Junction Compensation, and open thermocouple detection for multiple thermocouple inputs. It also provides selectable pull down resistors, excitation voltage, and bridge completion resistors for multiple resistance temperature detectors. In addition, it also offers jumper selectable input signal filters.

- **2 - DNA-STP-37 Screw Terminal Panels**

  These accessory units, which are mounted on standard DIN rails and connected to the I/O boards by standard multi-conductor cables, provide convenient screw terminals for connecting wires from the relays and switches used for the digital inputs and outputs.

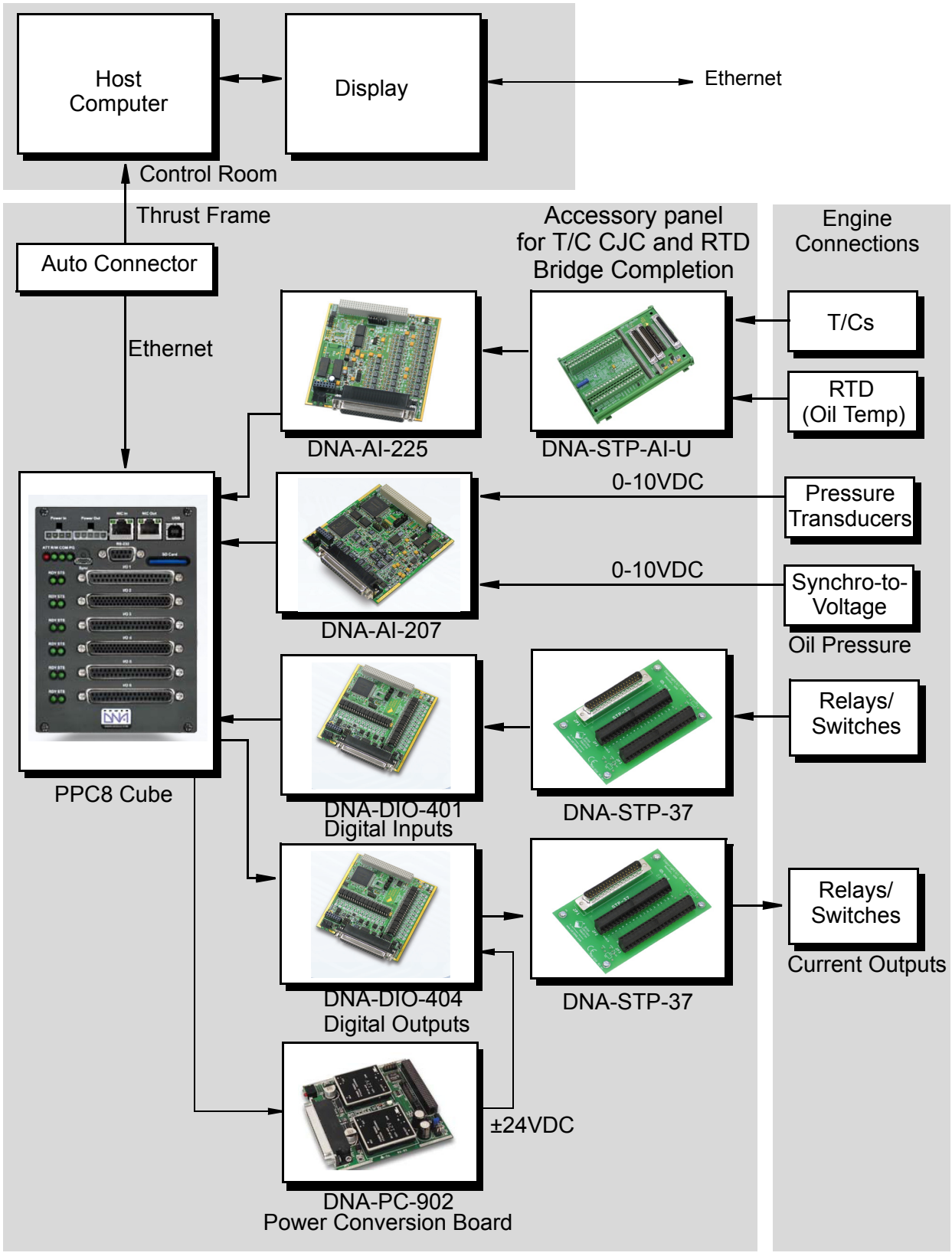

Figure 2. UEI DAQ System Equipment (All Mounted Directly on Thrust Frame)

Summary

Just as with the Pacer Comet 3 during the last 25 years, the Pacer Comet 4 represents a major step forward in Test Cell Design and is expected to set the standard for efficient, high performance jet engine testing for many years to come. UEI is proud to play a role in its success.