Using PXI to Rapidly Develop Structural Test Systems for a Space Exploration Vehicle

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Introduction

We successfully conducted the first structural test for the Orion Ground Test Article (GTA) in August 2010. This proof pressure test at 1.05 atmospheres required the following three distributed systems working together:

- Pressurization and vent (P&V) system for automated control of the pressure within the module
- Data acquisition system (DAS) for real-time collection of structural data, real-time calculation of virtual channels, and analysis of limits and alarms
- Data distribution system (DDS) for real-time and post-test distribution of synchronized parametric, video, and audio data to test controllers and data clients

G Systems developed each system using PXI hardware and software components, which helped us shorten development cycles and maintain advanced functionality. Figure 1 shows the relationships between the various system elements.

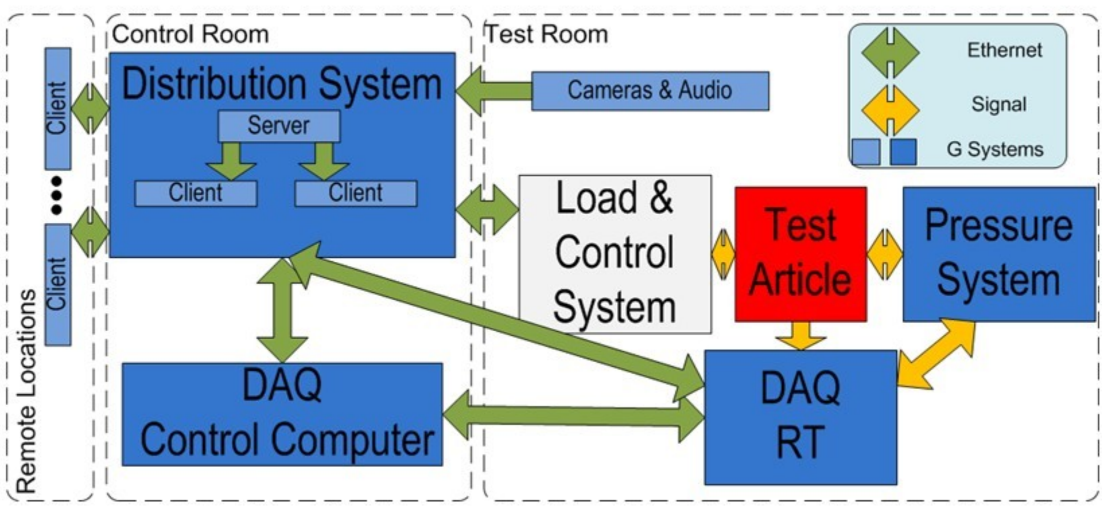

Figure 1. System Architecture Overview

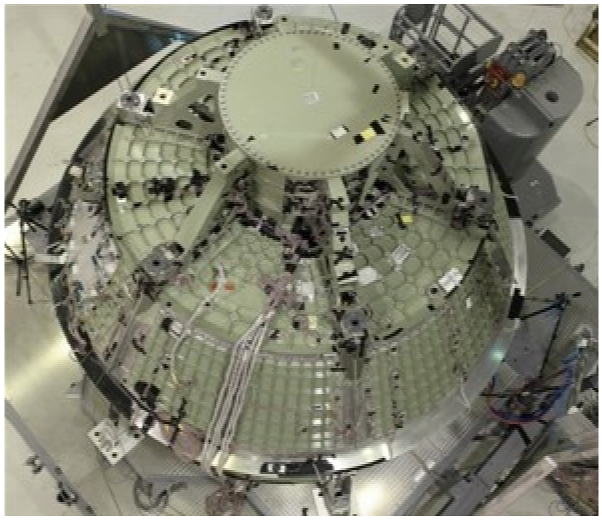

Figure 2. Orion Crew Module During Proof Pressure Test (Photo Courtesy of Lockheed Martin Space Systems)

Pressurization and Vent System

The P&V system, which precisely controls the interior pressure of the crew module during testing, is a portable cart with high-pressure gas bottles that provide the gas for the pressurization process.

Figure 3. Pressurization and Vent System

This system has a control unit built around CompactRIO. It simultaneously controls pressure and monitors for critical faults or alarms. We chose CompactRIO and the LabVIEW Real-Time Module to reliably control this critical process. A “brick PC” with a touch screen provides a LabVIEW GUI in a removable pendant form factor so that the operator can control the pressurization process from a safe location.

Data Acquisition System

The DAS collects parametric data, primarily for strain measurement. The heart of the DAS is a PXI and LabVIEW Real-Time system that collects over 1,800 channels of synchronized data. In addition, the DAS can calculate several thousand synchronized, user-defined, virtual channels and simultaneously monitor alarm and limit levels that may trigger a test shutdown. A quad-core PXI real-time controller, optimized to execute specific loops on each processor in order to maintain deterministic performance, performs all of these activities in parallel.

The DAS logs data to Technical Data Management Streaming (TDMS) files, which later transfer to the DDS file server. While a test is in progress, all data streams across a network to clients for real-time viewing. Figure 4 shows the DAS equipment rack, an interior view of one of seven SCXI chassis, and the configuration GUI provided for system setup and control.

Figure 4. Data Acquisition System

We used a DAS control computer to programmatically change system configuration via network connection and to define calculated channels, alarms, and limits. The DAS also includes rugged cabling and patch panels using military standard circular connectors to ensure reliable signal connections.

We have had difficulty maintaining calibration on high-channel-count systems in the past, so we developed a verification system that an operator can use to connect a cable to each of the 42 front panel connectors and automatically run a calibration verification routine on each channel on that connector. The calibration system uses a source measurement unit and a switching DMM to check the strain module excitation source, sense lines, and verify that the lines fall within acceptable levels before each test.

Data Distribution System

The DDS collects, synchronizes, and presents several thousand channels of data in real time and post playback. Not only does the DDS present data from the P&V and DAS, but also from 32 IP cameras and eight microphones that observe the test in progress. Figure 5 shows the distributed nature of the entire system and the data sources that the DDS aggregates.

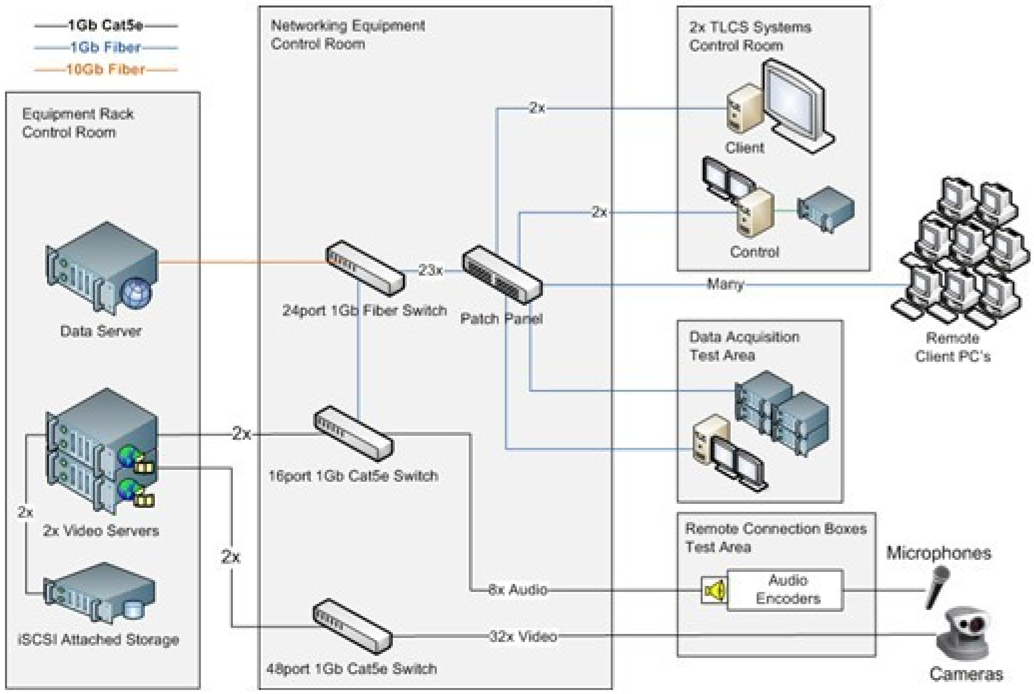

Figure 5. Network Infrastructure

Six or more test observers can use LabVIEW GUIs to view tests in progress or retrieve past test data. At any time, we can view real-time data for a test in progress, buffered real-time data, or logged data from previous tests. The DDS includes two dedicated video servers for logging and streaming video channels, as well as encoders to convert analog audio to IP-based streams that can be used in real time or streamed back in MP3 format. A dedicated server, which also serves as the test network domain controller, stores the test configuration and parametric data in TDMS files.

Test observers can use the system to define their own multiscreen GUIs with selectable size and position of tables, graphs, and video windows. They can save these configurations and recall them later to recreate the same data channel collections and views. The LabVIEW GUI operates on any Windows laptop, as well as dedicated client machines that display the GUI on large, wall-mounted, multimedia displays for group observation or demonstration. Figure 6 shows the DDS server rack and configurable GUI.

Figure 6. Data Distribution System

Benefits of Using the Graphical System Design Approach

These three systems illustrate the power of NI hardware and software in a rapid development timeframe. These systems illustrate the benefits of NI products in the following ways:

- The P&V system requires the reliability and dependability of CompactRIO and LabVIEW Real-Time.
- The DAS depends on a high-performance, multicore, real-time controller connected to proven SCXI and PXI data acquisition equipment.
- The DDS provides a rich user experience with configurable GUIs developed in LabVIEW while interfacing to multiple networked resources.

Conclusion

Each of these three systems presented its own engineering challenge – mechanical, electrical, and software. Using NI PXI products, G Systems delivered these integrated systems within the six-month timeframe, and with the capability and reliability needed to perform the first successful Orion crew module structural test.

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