UPGRADE OF THE THERMAL VACUUM DATA SYSTEM AT NASA/GSFC

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ABSTRACT

The Goddard Space Flight Center's new thermal vacuum data acquisition system is a networked client-sever application that enables lab operations crews to monitor all tests from a central location. The GSFC thermal vacuum lab consists of eleven chambers in Building 7 and one chamber in Building 10. The new data system was implemented for several reasons. These included the need for centralized data collection, more flexible and easier to use operator interface, greater data accessibility, a reduction in testing time and cost, and increased payload and personnel safety. Additionally, a new data system was needed for year-2000 compliance.

This paper discusses the incorporation of the Thermal Vacuum Data System (TVDS) within the thermal vacuum lab at GSFC, its features and capabilities and lessons learned in its implementation. Additional topics include off-center (Internet) capability for remote monitoring and the role of TVDS in the efforts to automate thermal vacuum chamber operations.

INTRODUCTION

The Space Simulation Test Engineering Section at GSFC provides twelve test facilities that range in size from 2'x2' to 27'x40' and are spread out across two buildings. Nine thermal/vacuum chambers and two temperature/humidity chambers are located in Building 7. One vertical thermal/vacuum chamber is located in Building 10. All chambers can operate on a 24-hour per day schedule with three shifts of operations crews overseeing command and control for each chamber and its associated test. Because of the volume of testing and the large layout of the laboratory chambers and control systems, it is necessary to have a central point of data acquisition and test monitoring.

The previous data acquisition system was a proprietary network of terminals and scanning modules running HP-BASIC. The facility and payload data were scanned by separate modules. A typical chamber monitoring setup would include one monitor for tabular data displays and one monitor for graphical data display. Locally connected printers provided hard copies of data.

The goal of TVDS was to create a centralized, flexible, user-friendly and up to date system using off the shelf software. Required features included the following

1. Integrate facility and payload data into a single data source
2. Provide secure dependable data storage
3. System must communicate over a secure, private local area network (LAN)
4. Each client workstation must be fully customizable in terms of data display
5. System must be flexible enough to integrate with automation SCADA systems as well as be able to adapt to future needs of the lab
6. All data must be archived and readily available for user requests

Additional requirements included sensor alarming, networked printing, and the ability to connect to TVDS remotely.

DESCRIPTION

The new thermal vacuum data system (TVDS) was developed on an Oracle database using PowerBuilder for the graphical user interface. These two systems are bridged together with a custom C++ SCADA application, which acquires test data from an array of Hewlett-Packard 3852A and VXI data acquisition units. The TVDS application runs on an isolated TCP/IP network and utilizes a dedicated Digital Alpha server that allows for quick and efficient database transactions. Figure 1 shows the basic layout of the system. The network resides completely within buildings 7 and 10 and is isolated from the GSFC network. The advantage to this is limited traffic and superior speed and security.

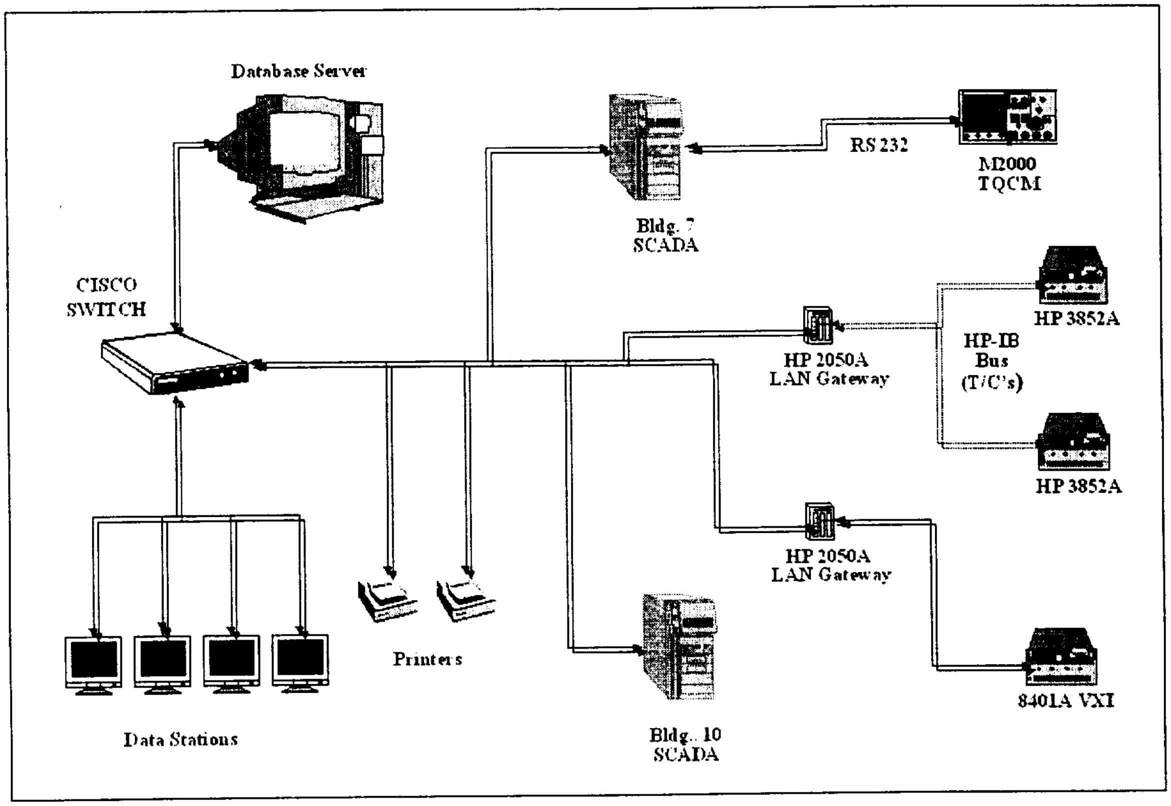

Figure 1 Overview of Thermal Vacuum Data System

Database Server

The database server is the central repository of data acquired throughout lab testing. The database engine, Oracle Server was chosen for its flexibility, robustness and multi-platform packaging. Third party software and applications can easily integrate into an Oracle database. This allows for a wide range of solutions and possibilities as the data system continues to grow. Software already integrated includes PowerBuilder, Intellution, FactoryLink and custom SCADA C++ and Visual Basic applications.

The Oracle server runs twenty-four hours a day on a UNIX platform. The computer is a Digital Alpha Server 2100 5/300 with 256 MB RAM and 18 GB hard drive space. This server uses a RAID 5 setup. All data is routed to and from the database through Cisco Fast Ethernet switch.

Database Structure

The Oracle database is structured into a series of tables based on each chamber. This was done for two reasons. By limiting tables to hold data specific to a facility, the size of the tables may be smaller and easier to maintain, and it allows for a faster retrieval of data. Because of the large volumes of data that are involved in thermal vacuum testing, the speed of data retrieval is very important.

Each chamber has a table devoted for measured test data, a directory of chamber and payload sensors, alarm limits associated with each sensor, and a list of sensors in use (active). Within each chamber's subset of tables, specific test data is referenced by a unique test number. This test number is the primary key that identifies all test parameters, recorded data, alarm limits, and user display configurations.

TVDS Network

TVDS makes use of two network systems: TCP/IP local area network (LAN) and Modbus+. Figure 2 shows how communication with the Oracle server is possible. SCADA and TVDS use TCP/IP protocol for all data transmissions, including SQL*Net transmissions from the SCADA to server and TVDS client-to-server communications. Because the LAN is only accessed by clients using TVDS, network traffic is minimal. This is important because data requests from the TVDS application can often produce large data sets. Historical data display showing data of 8 to 24 hours may take 1 to 2 seconds for retrieval. The number of connections to the system ranges from 6 to 20 connections with each instance updating every two minutes.

Using the TCP/IP protocol, it is also possible to access TVDS through and Internet browser. As shown in the bottom of Figure 2, a link from the Goddard Code 549 website gives access to an application server. This server runs multiple instances of TVDS and redirects their displays to remote connections. This will be discussed in detail in this paper.

The Modicon Modbus+ network is a token ring style system that is used by the programmable logic controllers (PLC) in buildings 7 and 10. PLCs that control valves, motors and pumps can also scan chamber sensors. Automated chambers use SCADA machines to monitor and control these systems. These SCADAs are setup to communicate on both the Modbus+ network using SA-85 network cards as well as the TVDS Ethernet LAN using standard 3Com 10/100Mb adapters.

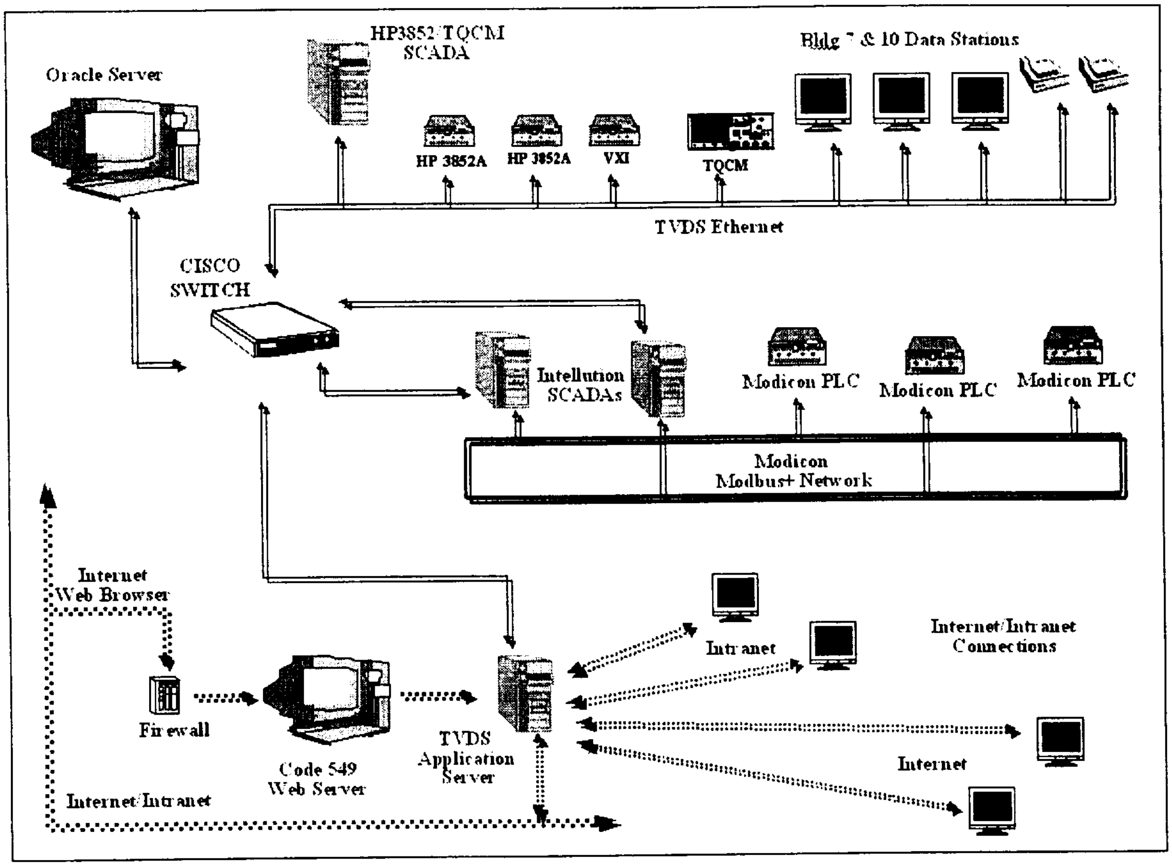

Figure 2 TVDS System Networks

Data Acquisition

Data is acquired by the Supervisory Control and Data Acquisition (SCADA) computers every two minutes and recorded in the Oracle database. Two SCADAs are utilized within the lab for facility and payload data, one for building 7 and one for building 10. Each machine is time synchronized with the database server. The SCADA applications are custom C++ or Visual Basic programs that establish and maintain communication with the acquisition hardware and Oracle database. After each data acquisition cycle, temperature averages and gradients are calculated and written to the database with other measured data. In addition, each measured sensor is compared to its sensor limits. Any sensor breeching a limit (high and low temperature, rate) is displayed in an alarm window on each client station.

Several types of sensors are used during testing including thermocouples, thermistors, silicon diodes, ionization gauges, and capacitance manometers. Four types of data acquisition units are utilized during testing: HP3852, VXI, M2000 and Modicon PLC.

HP3852

The Hewlett-Packard 3852 Data Acquisition System (DAS) is the primary acquisition unit for the lab. All facility and payload thermocouples are scanned at two-minute intervals by an array of HP3852. These units are the same as those used for the previous data system. Because some chambers have a small number of sensors (<50), their scanning is shared with other chambers on a single HP3852 unit. Larger chambers (225, 290) with large sensor libraries require dedicated units. Communication with the network is via the IEEE-488 bus and HP LAN 2050A gateway.

VXI Main Frame

Chamber 290 uses a Hewlett-Packard E8401A VXI Main Frame for acquisition of all payload sensors. Seven high-density C-size E1476A multiplexers are capable of reading up to 64 channels each which is sufficient to scan all of the chamber's payload sensors. The VXI chassis was installed as part of an effort to upgrade and standardize the data acquisition hardware. The HP3852A units, which are now obsolete, will be phased out and replaced with VXI units. VXI data acquisition offers a system-level standard design that can support a variety of hardware manufacturers, provides high transfer speeds, and plug and play flexibility.

QCM M2000

The QCM Research Model 2000 Control Data/Acquisition Unit is used for gathering all thermoelectric quartz crystal microbalance (TQCM) data. This unit is used for outgas measurement and contamination detection during testing. The M2000 communicates with the SCADA over an RS-232 link. The acquisition interface, which runs on the building 7 SCADA was developed using FactoryLink and can control up to 12 devices at once. The FactoryLink application writes all active QCM frequency, temperature and voltage measurements to the database at two-minute intervals. An example of this data is shown in Figure 3.

Modicon 984 PLC

Several of the lab chambers (225, 281, 290) make use of programmable logic controllers (PLC) for temperature and pressure measurement as well as valve, motor, and pump control. Through SCADAs, selected sensors can be written to the Oracle database. The link from Modbus+ to the TVDS LAN is established through Visual Basic scripting in the SCADA applications.

Client Stations

Client station machines are desktop computers with a CPU speed ranging from 300 to 500 MHz and RAM ranging from 64 to 128 MB. Network communication is through a 10/100MB Ethernet network adapter. The TVDS application files require approximately 2 MB of space. Additional software requirements include Oracle Client 8, any FTP utility and a time synchronization utility. The recommended monitor display setting is 1280x1024.

Each client station runs TVDS, the graphical user interface (GUI) or Human Machine Interface (HMI) that is used to display and monitor all tests within the lab. TVDS was developed using PowerBuilder from Sybase. The use of PowerBuilder for the human machine interface allows for a powerful Windows based client/server application that connects to the Oracle Database Management System (DBMS). PowerBuilder applications are developed using PowerScript, an object oriented programming language that lets the developer dynamically control objects throughout the application. Techniques such as encapsulation, polymorphism and inheritance, which object oriented programming provides, allows for efficient, powerful and reusable code. The interface is run from an executable file residing on each client computer. By running the application from each client, the server can be used exclusively for writing and retrieving data.

The interface is designed so that each chamber may be monitored from any computer at any time. Each computer independently retrieves data from the database tables. This allows for unique custom display editing of the same test for every computer

The presentation of data within the application can be customized both before and during the test without interrupting incoming data or other computer displays. Options available to the operator include activating or deactivating sensors or tags, setting alarms for any tag, configuring and monitoring multiple TQCM devices, create and edit averages and gradients dynamically, access to tag libraries and printouts of all relevant data and test information. Data can also be saved and exported to a variety of file types including text, Microsoft Excel and Data Interchange format.

Data can be presented in two formats: tabular and graphical. Both formats can present current test as well as historical data. Figure 3 shows both tabular and graphical display of TQCM data. The left side shows historical data, and calculations. The two plots on the right side show one hour of temperature and frequency data.

By allowing the operator to customize each screen through simple screen editors, relevant data can be grouped together in any fashion so that tests can be monitored safely. The tabular data format displays measured test data on tab pages in columns. Each tab page can display up to 160 tags and an unlimited number of tab pages can be defined for each chamber. Data displayed in graphical or plot form is useful for monitoring trends during a test. Up to eight tags can be displayed on each plot and an unlimited number of plots can be defined for each chamber.

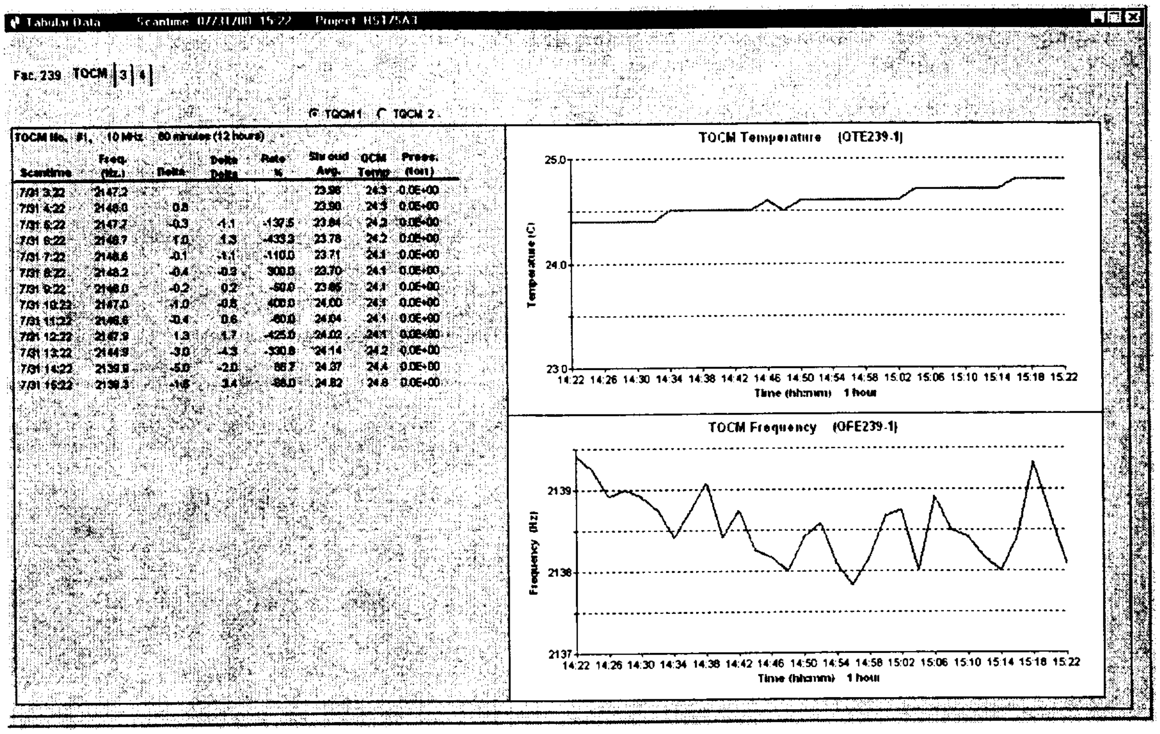

Figure 3 Tabular and Graphical display of TQCM data

TVDS FEATURES

Several features exist within TVDS that make it useful to both test operation crews as well as test projects. These features include near real-time monitoring, customized displays, shared displays, constant alarm monitoring, alarm limit editing, and remote connections.

Monitoring

Each client running TVDS automatically updates any windows showing measured data. Updates occur every two minutes on the odd minute. The SCADA machines update the database every two minutes on the even minute. Therefore, there is a one-minute lag between the data acquisition and data refresh. Because of the volume of data recorded and the necessary calculations and limit checks, it is necessary to ensure that the SCADA application has been given sufficient time to insert and update the appropriate database tables. In addition to updating data displays, any alarms associated with the monitored tests will display as well.

Alarm Limit Monitoring and Editing

As each sensor is collected by the SCADA, its value and rate of change is compared to its stored limits. Tables of limits for each chamber are configured at the beginning of a test. These limits can also be modified at any point during the test through an alarm limit editor. Font colors are used to display sensors that are under alarm. Red and yellow are used for temperature limits and blue for rate limits.

When the SCADA determines that a sensor has passed a limit, its value, limit and scantime are entered into an alarm table. For each test enabled on a client machine, TVDS checks the alarm table for each chamber. Any entries for that scantime are immediately posted in a small window, as shown in Figure 4. An audible alarm is also available and sounds for each update that has an alarm. The alarm window will remain on top of all other open windows and displays each entry in a color specific to its type of alarm: yellow or red for If the tabular display or summary page is displaying the sensor(s) under alarm, they will be shown in the alarm color as well. Note that in Figure 4 there are two sensors in blue in the first column as well as one sensor in the second column.

Customized and Shared Displays

An important requirement of TVDS was to allow each client to create and modify all tabular and graphical screens as needed. This is accomplished through a series of screen editors that can be used at any time during a test. For any chamber that is under test, a client can create two types of displays: tabular or graphical. As shown in Figure 4 tabular displays show data in four columns per tab. Within each column, the sensor or tagname is given along with its current value and location in the chamber. The user has full control over the layout of tags on each tab and may add or delete tabs as needed.

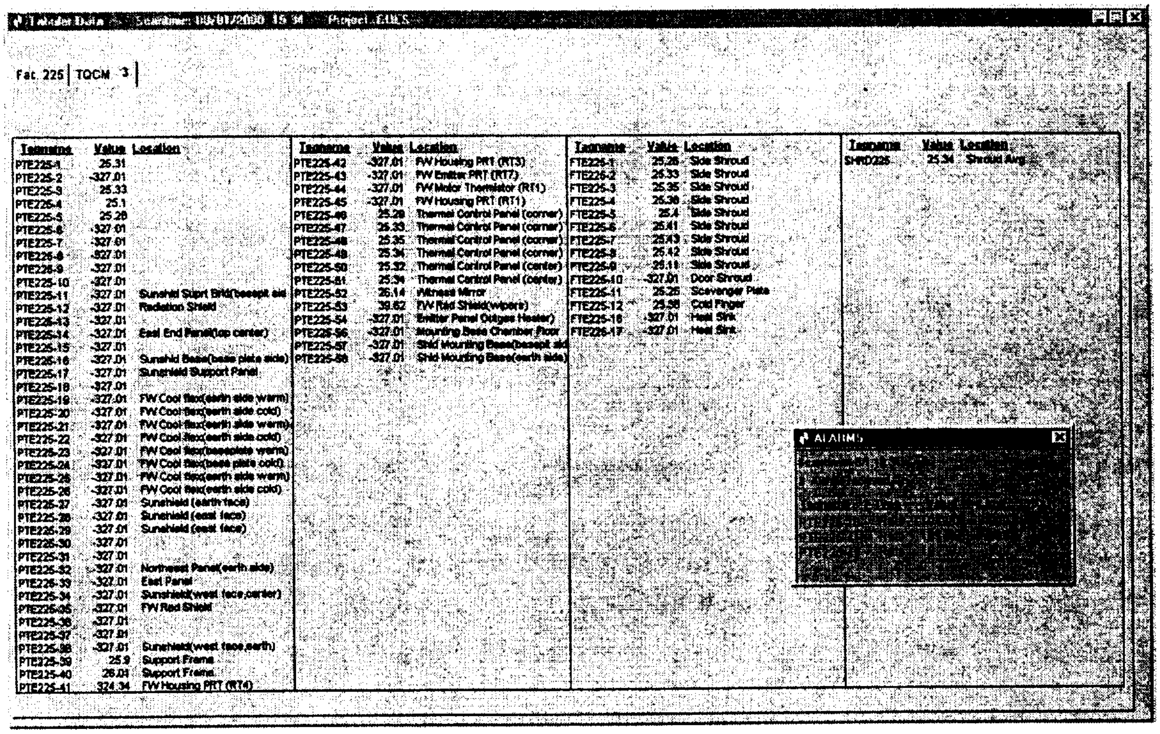

Figure 4 TVDS Tabular Display

The second method of displaying data in TVDS is graphical. Each plot can display up to twenty-four hours for eight sensors. In Figure 5, fours hours of data is shown for three payload sensors in Chamber 239. At the bottom of each plot, the legend displays the sensor name and its location within the chamber. Properties on this plot that are configurable by the user include the scale of the time and value axis, the amount of data retrieved, autoscale, auto scroll, plot title, background color, tab title and plot resize. Plots can also automatically adjust line types for black and white printing. As with the tabular displays, there is no limit to the number of plots the user can create.

Displays can also be shared or copied from other client stations. This allows projects to set up one station and quickly copy the displays over to other machines. This can be done when a display is first created or at any point during the test.

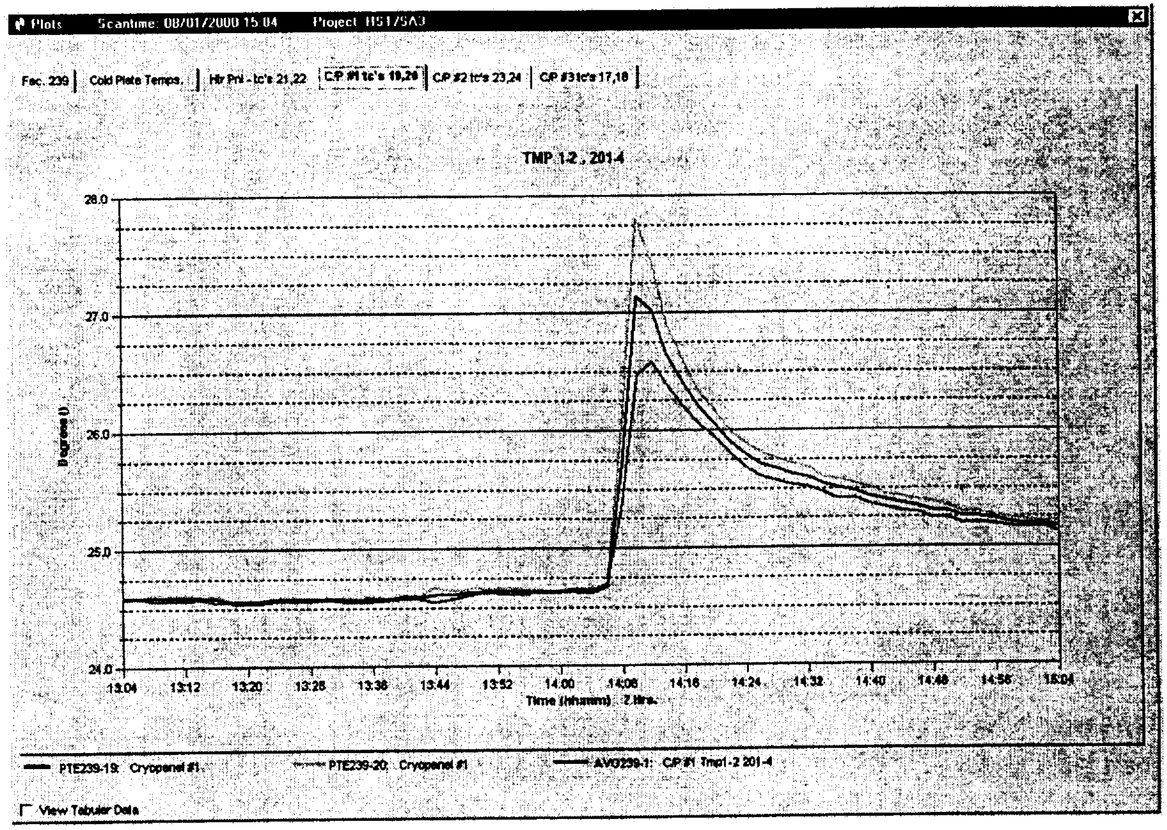

Figure 5 TVDS Graphical Display

Remote Connections

During a test, projects often require the use of several data stations. Projects members and engineers often request to have access to TVDS from their own computers. The data system operates on a private network in building 7 and 10. The obvious limitation to this is that computers on other networks cannot access test data. An additional limitation to this client-server network is that each client must have Oracle Client installed. Therefore, each client outside of the TVDS network must have access to the software as well as a license run it.

In order to provide computers outside of the TVDS network with access to the TVDS application, an application server was implemented using Sybase's Web Development Kit. As shown in the bottom of Figure 2, remote clients connect to the application server through an Internet browser. For the initial run, the client downloads a small executable that allows it to communicate with the application server. The application server then establishes a secure communication path, starts an instance of TVDS and redirects the graphics to the client. By running each instance of TVDS on the application server, data transmission remains within the TVDS network and only graphical images are transmitted to the user. In this way, the remote client can run the application without any loss in program functionality and without any TVDS application files or Oracle software or licensing.

TVDS AND AUTOMATION

The automation of test chambers within the lab requires the design and implementation of computer interfaces that permit monitoring and command control. TVDS is designed to easily work with automation interfaces. The primary role of the data system in chamber automation is saving important data scanned by automated processes. This task is performed on a chamber's SCADA machine and runs as a background process. Integrating the data system into automation projects provides seamless transmission of data. TVDS is able to utilize this and display any data that a SCADA system can record.

ACHIEVEMENTS, PROGESS AND ISSUES

The new data system was brought online in November 1998, and by January 1999, the new system was recording data for all the lab chambers. By the summer of 1999, TVDS was integrated into the Chamber 290 automation project. This SCADA is responsible for acquiring all of the chamber thermocouple data. Additional projects that required the use of TVDS include a new remotely operated heater rack system that was brought online in March 2000, and a simulation/prediction model used for projecting thermocouple temperatures during a test. The new data system has recorded over 500 tests and over 67,000 hours of test data through July 2000.

The TVDS application has undergone several minor modifications since it was brought online. While some of these modifications involved code debugging or database table changes, the system has had no significant down time or failures. Feedback from the project members and operations crews has provided useful information regarding changes or improvements and future releases.

The thermal vacuum lab is a 24-hour, 365 days a year facility, therefore, the data system must run continuously. Because of this constant influx of data, large amounts physical storage space is needed. As in any networked database system, every effort must be made to maintain reasonable table space. Storage space is the primary issue for the new data system. Some tests may use several hundred sensors in a chamber that may run for several weeks. The measured data, along with any recorded alarms may require several hundred megabytes of space. To maintain safe levels of free disk space, the data of completed tests are backed up to tape and CD-ROM and removed from the server. The completed test data is available for requests in ASCII format. The complete test and all database tables are also backed up in a compressed Oracle export file.

FUTURE GOALS

TVDS will continue to grow and change as lab needs dictate. As part of the original design, TVDS is flexible enough to integrate with other applications and communicate with other systems and networks. The automation project of chamber 238 began in March 2000 and will require data logging with the new data system. This will require an Intellution based SCADA system similar to that of chamber 290 mentioned above that scans and writes facility data to the database.

Another goal of the data system involves the standardization of data acquisition hardware. With the rise of VXI as an industry standard and a variety of manufacturers that support VXI data acquisition, it is a logical choice for replacing the HP3852 units used throughout the lab. This step towards standardization within the lab has started with chamber 290 as mentioned earlier.

A third goal of the new data system will be to investigate and possibly incorporate fiber optic networking into the lab. While sections of the Modbus+ network already uses fiber optic, the standard twisted-pair Ethernet LAN cabling is vulnerable to electrical interference, which can often present cable routing challenges within the lab. Fiber optic cable would eliminate the issue of networking in an electrically hostile environment. In addition, because fiber optic is capable of carrying large volumes of several types of data, it may be possible to combine the data transmissions of Modbus+ and TVDS into one fiber optic system.

Additional goals of the thermal vacuum data system include modifications to TVDS that allow for quick setup of tests. This would include an automated process of updating database tables relating to sensor descriptions and alarm limit configurations. The post-test distribution of data based on user request is another feature that will be automated.

CONCLUSIONS

The upgrade of the thermal vacuum data system for Space Simulation Test engineering lab at GSFC has produced a flexible, robust and dependable system that can provide and array of test monitoring and support capabilities. By establishing a centralized acquisition system, projects and operation crews can realize an increase in data accessibility, as well as an overall reduction in testing costs and payload and personnel safety. With over 67,000 hours of test monitoring completed in less than two years, the data system has established itself as a reliable tool of GSFC's thermal vacuum testing process.