

NETWORKING SATELLITE GROUND STATIONS USING LABVIEW

Kendall Mauldin
New Mexico State University

ABSTRACT

A multi-platform network design that is automated, bi-directional, capable of store and forward operations, and low-bandwidth has been developed to connect multiple satellite ground stations together in real-time. The LabVIEW programming language has been used to develop both the server and client aspects of this network. Future plans for this project include implementing a fully operational ground network using the described concepts, and using this network for real-time satellite operations. This paper describes the design requirements, RF and ground-based network configuration, software implementation, and operational testing of the ground network.

KEY WORDS

Space Telemetry, Satellite Networking, Scalable Networking, Ground Station

INTRODUCTION

Small satellites known as “Nano-sats” are more commonly being designed and built by small organizations and research institutions. There exists a need for a scalable, reconfigurable ground station network for use by these smaller organizations that may not have the time or money to design their own full-scale, multi-site satellite ground station network. For such a network to be easily useable by small research projects, the bulk of the network design should be already done. The network must also be scalable to be able to adapt to the needs of the particular Nano-sat project. To demonstrate this, a specific Nano-sat project called “3 Corner Sat” will be used as an example.

The “3 Corner Sat” (3CS) project is part of the AFOSR/DARPA University Nanosatellite program. It is a joint effort between Arizona State University, University of Colorado at Boulder, and New Mexico State University. The project is building a constellation of 3 satellites that will perform tests on new types of Nano-sat technology such as stereo imaging of cloud and land formations, formation flying, and new types of command and control scheduling. Because of the nature of the constellation and communication system configurations, a custom design for the ground station communications network is needed.

This paper will discuss a means of constructing such a ground network using the LabVIEW™ version 6 software suite developed by National Instruments™. The network is comprised of two different Multi-platform Virtual Instruments (VIs). These VIs were designed to be compatible with many computing platforms and operating systems. In this paper, we will examine the design goals for this ground network, the server/client configuration, the data interaction between the server and client, selection of a programming environment for implementation, and the virtual instruments that were created to complete the design.

GROUND NETWORK DESIGN GOALS

The ground network has several key design requirements that are defined by the nature of the satellite configuration. These requirements were not able to be met with the use of conventional, commercially available satellite networking systems. Thus, a new ground network system will be designed and tested with the following requirements in mind:

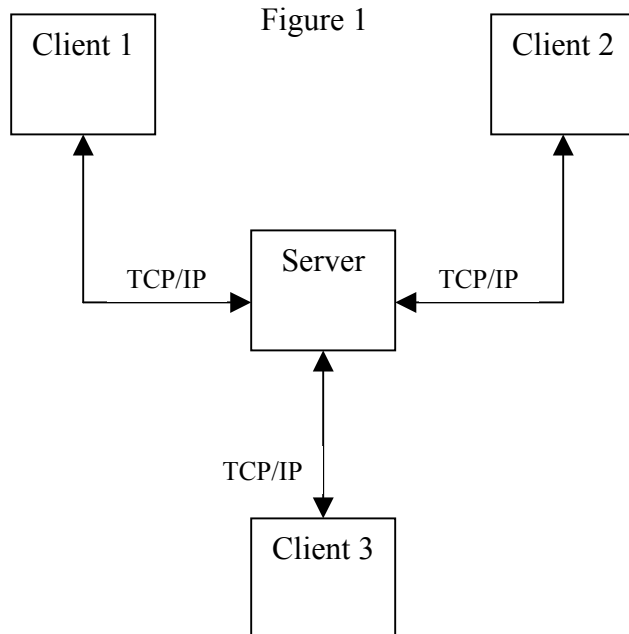
- 1) The ground communications network shall support a minimum of three remote ground stations from a control station.
- 2) The ground communications network will provide a means to remotely initialize each remote ground station.
- 3) The ground communications network will provide a means to monitor the status of the remote ground stations.
- 4) The ground communications network will provide data transfer between each remote terminal and the central control station.
- 5) The data transfer function will include the ability for store-and-forward of bi-directional data.
- 6) The store-and-forward data transmission will have the means to send data from the control station to each remote terminal for later transmission to the satellites.
- 7) The store-and-forward data transmission will have the means to record satellite data at each remote terminal for later transmission to the control station in the event that the internet link goes down.
- 8) The control station and the remote terminals shall have synchronized clocks
- 9) The ground communications network shall have security measures that protect against unauthorized use of the system
- 10) The ground communications network software will be capable of execution on current Windows (98/NT/2000/XP), Unix, Macintosh, and Linux operating systems.

It is the goal of the 3CS communications team to meet all design requirement expectations by using new, innovative implementation methods. These methods will allow such a ground network system to be customizable for future Nano-sat or similar projects.

GENERAL IMPLEMENTATION

The ground network will consist of one “Server” and multiple “Client” systems. The server and client labels that are given to these stations describe the nature of operation and data flow present at that location. The server will consist of one computer at the Nano-sat mission control center. This station is responsible for all data that is distributed to the constellation, and collected from the constellation. It is also responsible for the operation of the individual ground communication stations. The client will consist of a computer running at each of the ground stations. This client will act as a conduit for all information that is to pass to or from the satellite constellation. It is also responsible for control of antenna movement to be able to track satellites across the sky during a pass.

It is desirable to have all client stations collaborating to be able to schedule operations based on satellite passes. For example, one of the ground stations may have a better vantage point for communications to the satellite constellation than the other ground stations. For this reason, all satellite communications are done through that ground station for that particular pass, until another station becomes a better candidate. The station with the best accessibility to the satellite constellation is determined by the personnel at the mission control center, who will have satellite pass prediction software aiding them in their decision. The communication connection between the clients and server are made by using standard TCP/IP sockets over the internet. This allows the client stations to be anywhere in the world, theoretically.



SERVER IMPLEMENTATION

The program that runs on the server computer was developed using the LabVIEW™ version 6 software suite developed by National Instruments™. This development environment allows graphical construction and modifications of executable programs called “Virtual Instruments” (VI). See figure 2 for an example. A VI was created that performs several tasks:

- 1) Disperses data that is to be transmitted to the satellite cluster to a specific ground station or multiple ground stations.
- 2) Receives live or stored data from ground stations that has been received from the satellite constellation.
- 3) Provides a Graphical User Interface (GUI) to personnel at mission control, allowing them to control ground station network operations at each individual ground station, and the network as a whole. Figure 3 displays the front panel of this GUI.
- 4) Provides an internet-based interface to other mission control computers for real-time data acquisition and analysis.

Figure 2: An example of an actual VI's source code.

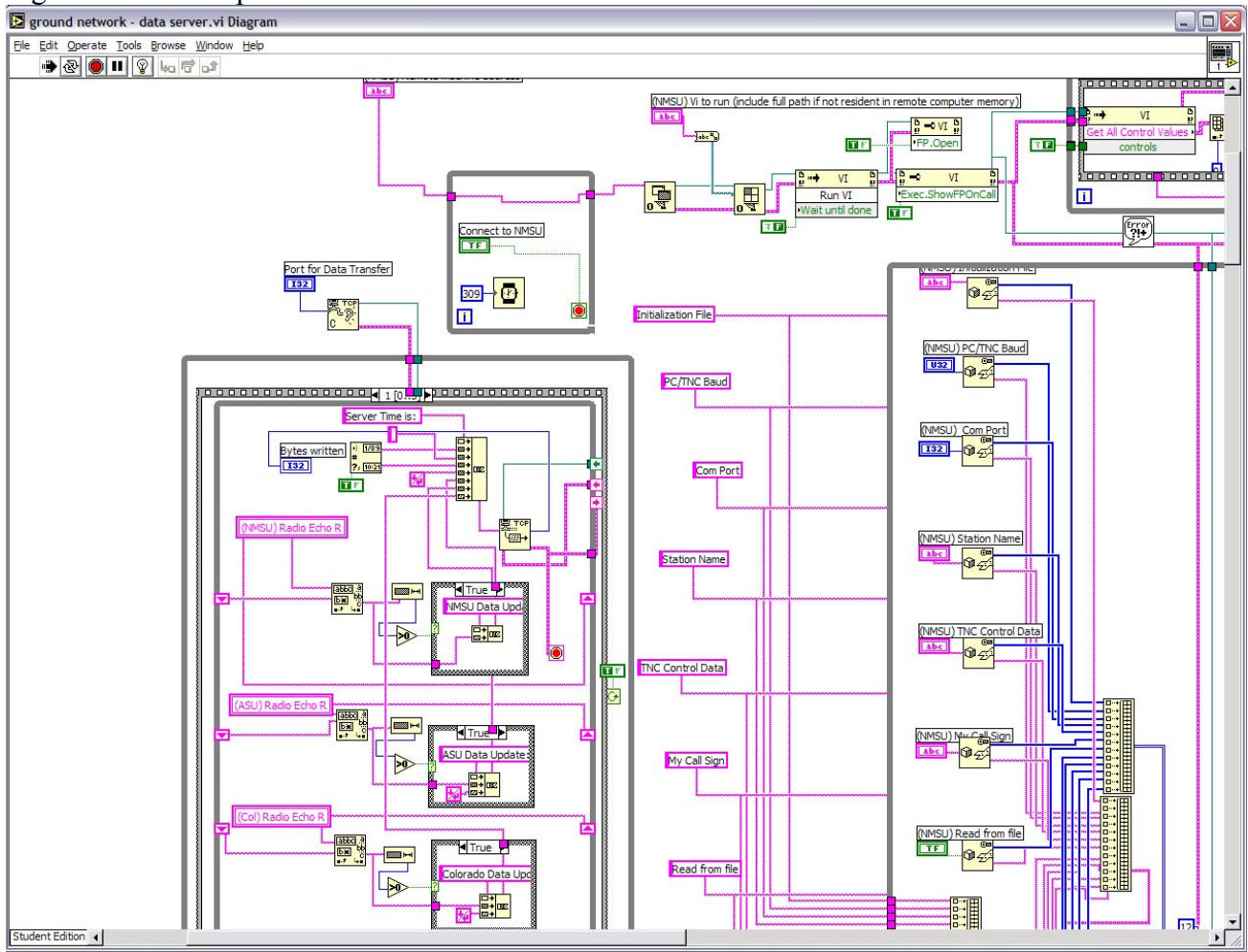
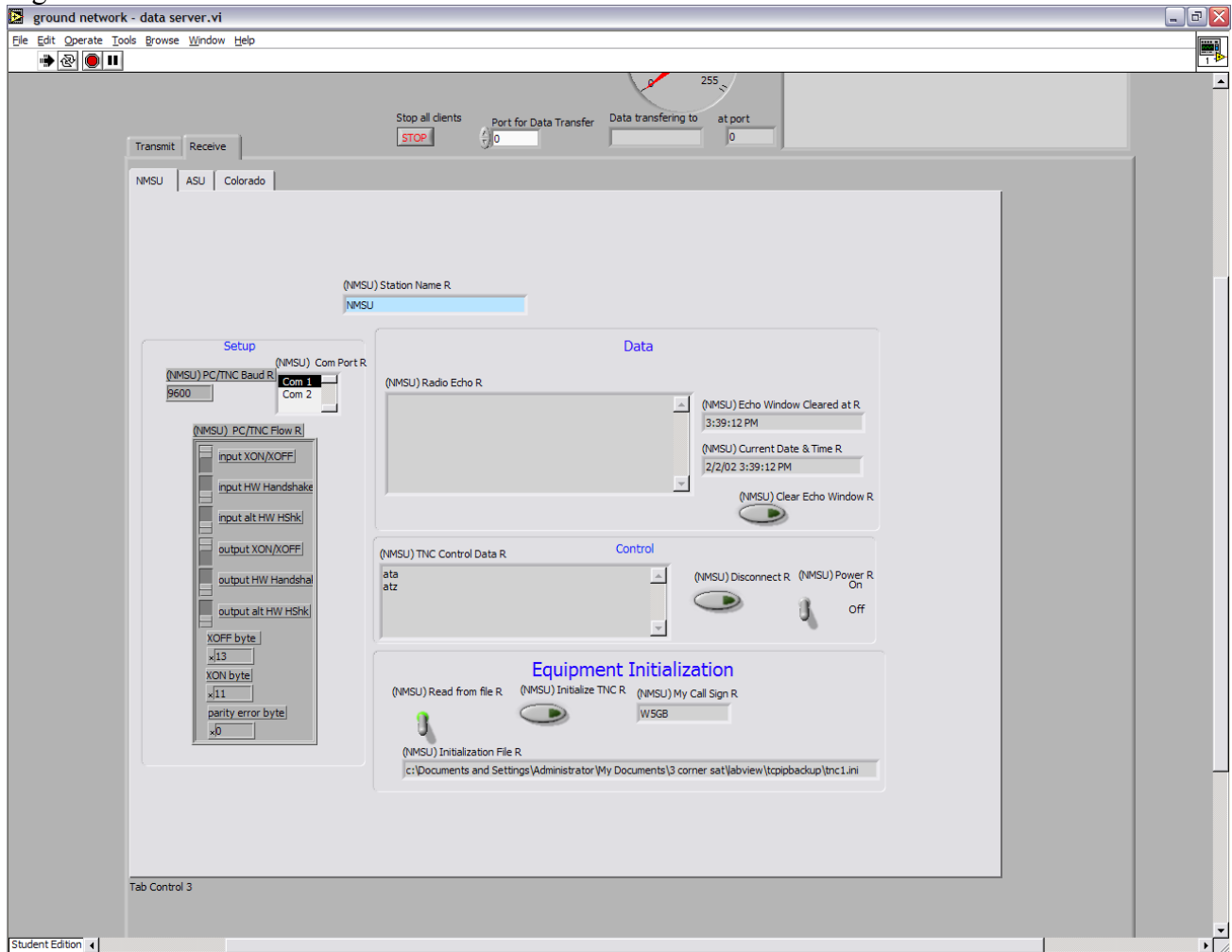


Figure 3: A view of the Server GUI.



The server is programmed to communicate with the clients using a LabVIEW communications driver that is running on the client computers in parallel with the client VIs. This driver is called the “VI Server”. It allows other VIs that are running at another location to control the local VI, and also to receive data from the local VI. The VI Server drivers use a standard TCP/IP internet connection as the communication backbone.

The data received from the clients by the server is split into two categories: Satellite data and VI display data. The VI display data is extracted and used to generate displays on the server computer that are identical to each of the displays on the client computers. These displays are updated approx every 2-3 seconds. The satellite data then remains, and is made available for other computers in the mission control center to acquire via a standard TCP/IP telnet connection. For simplicity, the data that comes from the individual ground stations is tagged as being from a particular station, but is not recombined by the server computer. The tagged data is combined by another mission control computer based on the needs of the mission control team.

The data transferred from the server to each of the clients is categorized in a similar fashion. There again exists two types of data: Ground station control data, and satellite data (commands, etc.) to be

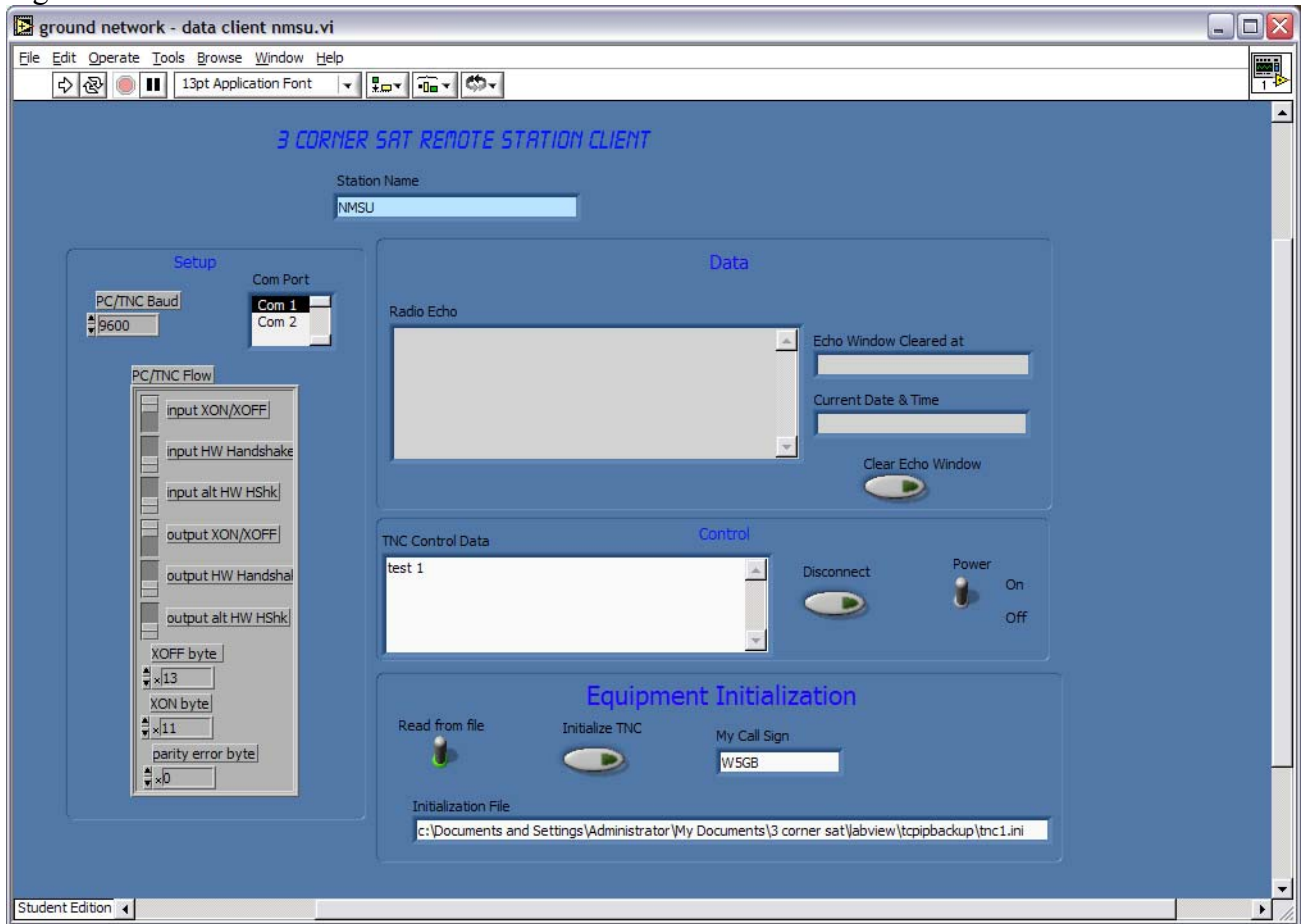
transmitted. The ground station control data is generated by the GUI on the server display. For example, if a mission control team member clicks on a graphical toggle switch on the server display that is associated with the client at NMSU, the matching button gets toggled on the client computer itself. The satellite transmit data is generated not by the server, but by other mission control computers. This data is merely relayed by the server to the appropriate client(s) as defined by mission control personnel.

CLIENT IMPLEMENTATION

The client computer is running at the site where the actual ground satellite communications hardware is located. The computer is connected to ground station hardware that transmits and receives data to/from the satellite constellation. The computer is also connected to a standard full-time internet access point. The program that runs on the client computers is also a VI. This VI performs the following tasks:

- 1) Relays data from the server at mission control to the satellite ground communications radio hardware.
- 2) Relays data from the satellite ground communications radio hardware to the server computer at mission control.
- 3) Transmits health and status of client VI and ground station equipment to mission control.
- 4) Receives commands from mission control to change client VI or ground station equipment operation.
- 5) Stores data in the case that a portion of communications is cut off between client and satellites or client and mission control server computer. The data is forwarded when communications are re-established.
- 6) Provides a graphical user interface (GUI) at the ground station location for on-site control of the client VI in case of emergency operation. See Figure 4 for a view of this GUI.

Figure 4. A view of the client VI GUI.



The “VI Server” driver that was mentioned above, is running in parallel with the client VI. The driver is managing communications with the server VI via standard TCP/IP methods. The driver then separates the two types of data that is coming from the server computer. The ground station control command data is extracted and used to modify client VI operational settings. The data that is intended for the satellite cluster is passed along to the client VI as raw data. This raw data is then relayed to the ground station communications hardware.

In a sense, the same TCP/IP socket connection is being used for both raw satellite data, and ground station command and control data. This reduces the complexity of the connection that is required between the ground stations and mission control. Any reduction in complexity from the mission control standpoint will allow mission control personnel to focus on flight operations instead of how the data will be transferred to/from the satellite constellation.

CONCLUSION

A scalable, reconfigurable, and automated ground network system is a desirable feature of many satellite projects. In the case of university-based Nano-sat programs, a fairly limited budget and limited amount of manpower puts a great importance on efficiency and simplicity of the systems that are used. In the case of the 3 Corner Sat program, the capabilities that this ground network system will give the project will help insure the success of the mission. In this example, we are using an off-the-shelf product to create an acceptable solution to the logistical problems that accompany a satellite project that uses multiple ground communication stations. The 3CS communications team hopes that this ground network design might be helpful to other Nano-sat or similar programs that are in need of such system.