OVERVIEW OF THE NASA WALLOPS FLIGHT FACILITY MOBILE RANGE CONTROL SYSTEM

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ABSTRACT

The NASA GSFC's Wallops Flight Facility's (WFF) Mobile Range Control System (MRCS) is based on the functionality of the WFF Range Control Center at Wallops Island, Virginia. The MRCS provides real time instantaneous impact predictions, real time flight performance data, and other critical information needed by mission and range safety personnel in support of range operations at remote launch sites.

The MRCS integrates a PC telemetry processing system (TELPro), a PC radar processing system (PCDQS), multiple Silicon Graphics display workstations (IRIS), and communication links within a mobile van for worldwide support of orbital, suborbital, and aircraft missions.

This paper describes the MRCS configuration; the TELPro's capability to provide single/dual telemetry tracking and vehicle state data processing; the PCDQS' capability to provide real time positional data and instantaneous impact prediction for up to 8 data sources; and the IRIS' user interface for setup/display options.

With portability, PC-based data processing, high resolution graphics, and flexible multiple source support, the MRCS system is proving to be responsive to the ever-changing needs of a variety of increasingly complex missions.

KEY WORDS

Mobile telemetry and radar tracking, real-time PC impact prediction, GPS and INS processing, SGI mission support graphics.

INTRODUCTION

NASA Goddard Space Flight Center's (GSFC) Wallops Flight Facility's (WFF) Range Control Center (RCC) at Wallops Island, Virginia, provides mission control, tracking, and real-time range safety support for suborbital and orbital launches, and aircraft programs. To provide similar support in remote sites throughout the world, NASA at WFF created the Mobile Range Control System (MRCS) vans, which provide a self-contained, fully mobile, range control and safety command/destruct (C/D) system with radar and telemetry data acquisition. This MRCS supported the MINISAT Pegasus from Gran Canaria, Canary Islands, Spain, in April 1997, and proved that it could provide the same excellent range capabilities and assurance for safety, reliability, and quality as the WFF RCC does. It has also been used at Coquina, North Carolina, to support Pegasus launches from WFF, and is scheduled to support the Vegetation Canopy Lidar mission from Kodiak, Alaska, in August, 2000.

MRCS CONFIGURATION

The essential components of the MRCS, as shown in Figure 1, are the C/D transmitters and antennas; timing system for input synchronization; radar and telemetry data tracking, acquisition and processing systems; communication systems; and display systems.

For fail-safe operation, the MRCS contains redundant systems for all critical functions. Twelve racks in the MRCS van contain primary and redundant systems and their consoles for C/D, data quality (DQ) control, communications, and data processing and display. Each transmitter is dependent on inputs from the C/D console and is automatically monitored and switched to a backup transmitter on fail-over. Each antenna can be slaved to either a radar or telemetry source. The vans support configurations using multiple telephones, redundant VHF radios, one HF radio, a 12-channel local intercom, and up to 25 external voice/data/video links.

The MRCS integrates a PC Telemetry Ethernet LTAS (Launch Trajectory Acquisition System) processor (TELPro) for telemetry processing, a PC Data Quality System (PCDQS) for radar processing, and multiple Integrated Range Information Systems (IRIS) for data displays, which are interfaced as shown in Figure 2.

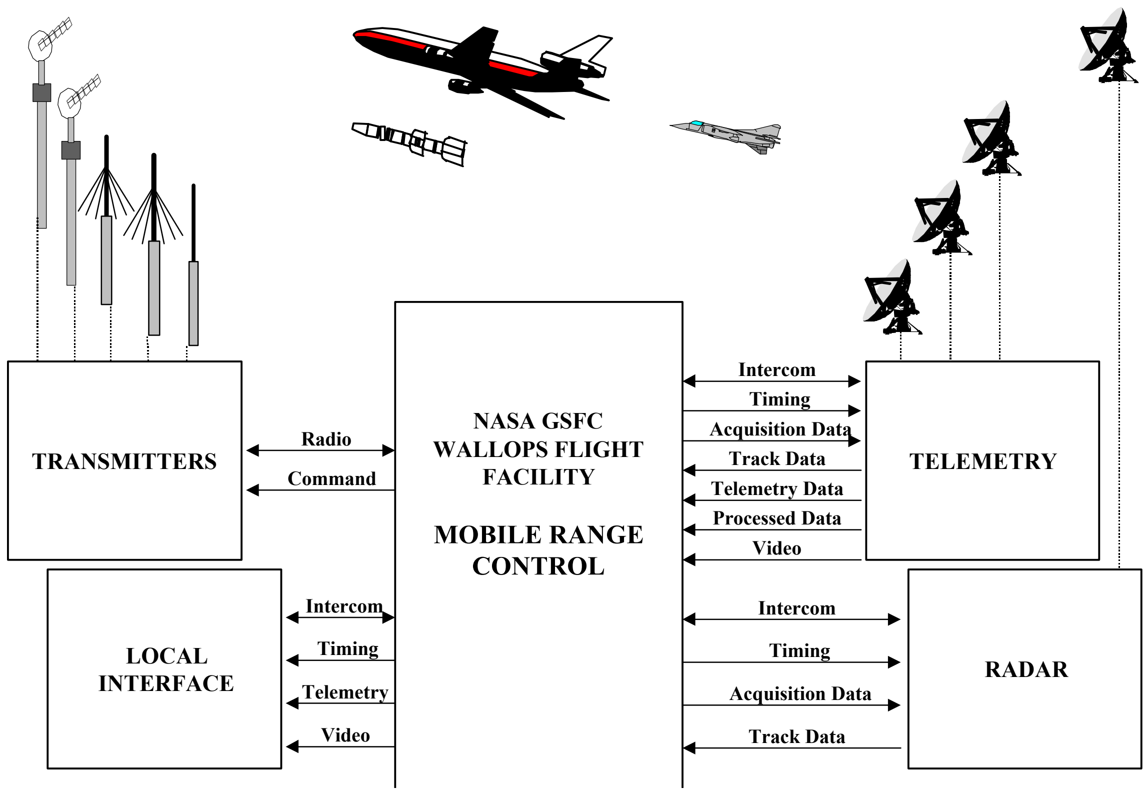

Figure 1 – Sample Pegasus

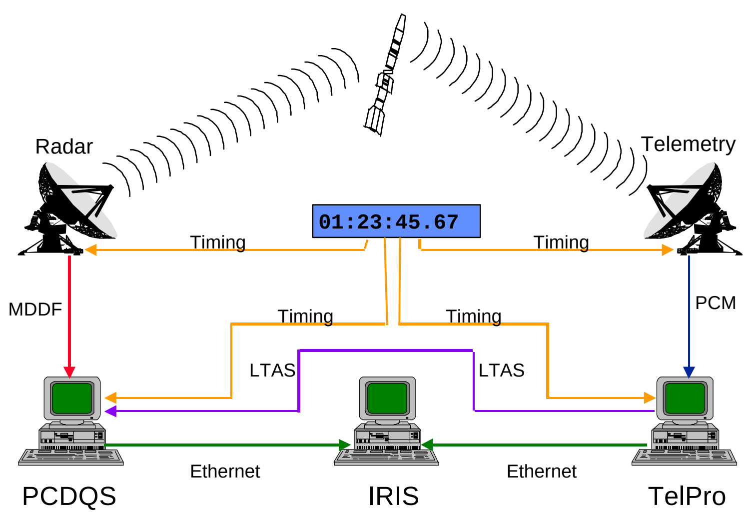

Figure 2 – Process & display system interfaces

The telemetry (TM) and radar tracking and data acquisition systems provide data to the TELPro and PCDQS processing systems, whose output is displayed on IRIS systems at the DQ console. The DQ operator selects the best tracking sources for display on IRIS systems for Range Safety (RS) personnel. Using vehicle positional and performance information, and instantaneous impact prediction (IIP) data calculations from the processing systems, the RS officer can determine when to command destruct an unsafe vehicle so that its impacting debris is within an acceptable operational area. The remainder of this paper describes the TELPro, PCDQS, and IRIS systems and their capabilities.

PC TELEMETRY PROCESSING SYSTEM

The TELPro was developed to provide RS officers critical flight performance in real time. This system is used at the NASA WFF RCC and the MRCS. The system is portable, reasonably inexpensive, and requires minimal operator interaction. New mission functions and TM formats can easily be added. This system's configuration is shown in Figure 3, and consists of a standard PC with the following cards:

- a TDP/GDP frame synchronizer card to collect PCM NRZ-L data and 90° clock from a bit synchronizer
- a NASA36 card to receive a 10 points per second (pps) interrupt and time of day
- a DRT card to receive program time and to transmit LTAS data
- an Ethernet card to transmit Ethernet buffers

The GDP card and the Ethernet card are commercial off the shelf (COTS) products. Commercial replacements for the NASA36 and DRT boards may soon be used.

In addition to the custom TELPro software, the system includes custom TDPlus software, which sets up the frame synchronization boards. COTS software products (DOS 6.0, Borland C++ 3.1, and PC/TCP) complete the system.

The TELPro system is a PC based tool which transmits Ethernet and LTAS buffers. The TELPro system is designed to receive TM data, a 10 pps interrupt, and timing inputs, and to output an Ethernet buffer and up to two LTAS buffers. The TM data is collected by the WFF TM mobile van, synchronized, and transmitted to the TELPro as NRZ-L TM data. The TELPro system then decommutates the TM data via a frame synch board (TDP/GDP). Once a lock is determined, data is ready to be processed as defined by the TELPro setup file. The setup file tells the TELPro system how to put the TM words together, scale them, and how to process them. The TELPro system stamps time tags, checks data quality, applies format conversions, calculates limit flags, performs coordinate transformations, combines vectors, and produces impact predictions. After the TM data is processed, it can be transmitted at a 10 pps rate as either Ethernet buffers or

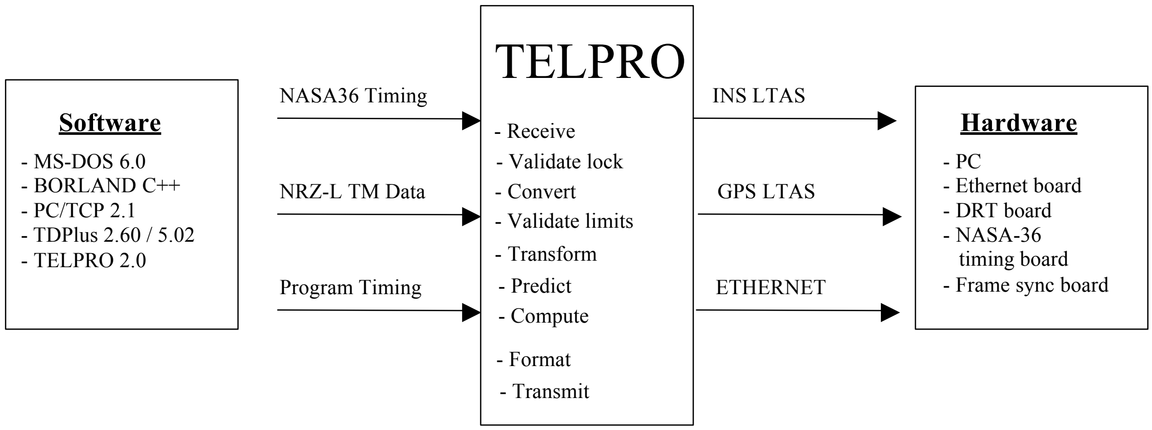

Figure 3 – TELPro Configuration

serial LTAS buffers. The Ethernet buffers are used by the IRIS graphics systems for displays. The LTAS buffers are used by the PCDQS system for processing raw TM positional data into smooth positional data. The LTAS buffers contain TM Inertial Navigation System (INS) data and TM Global Positioning System (GPS) data. These LTAS buffers were also used during the Pegasus MINISAT mission as input to a radar slaving system.

The following are some of the functions of the TELPro system:

- perform a coordinate transformation on Inertial Measurement Unit (IMU) data to prepare data for vacuum impact predictions output
- output vacuum impact predictions for IMU and/or GPS data in the Ethernet buffer
- broadcast Ethernet data
- transform quaternion attitude information into pitch, yaw, and roll
- calculate a vector magnitude from the three components
- select a time source
- check limits for IMU and GPS position and velocity inputs
- process eight defined format types such as unsigned binary, IEEE, 2's compliment, flags, and other mission specific formats
- select MSB/LSB for each input parameter
- collect data from two telemetry links simultaneously
- read in 8, 16, 24, or 32 bits to combine into one input parameter
- convert to engineering units using up to eight polynomial coefficients for each parameter
- output IMU and or GPS in an LTAS format
- subtract a known latency from the IMU/GPS time tags
- combine parameters using addition, subtraction, division, and multiplication
- set flags when a value comparison is true after a critical time
- calculate orbital elements and transmit a two-line orbital element
- perform operator commanded system reset

The TELPro system is continuing to change to meet new mission requirements. The current system is Y2K compliant. A conversion to Windows NT and Microsoft Visual C++ is underway. Efforts continue to be made to keep TELPro portable, easy to run, and inexpensive.

PC RADAR PROCESSING SYSTEM

The PCDQS provides mission and RS support by supplying range users with positional data for one or more vehicles from multiple tracking sources. The system is used in the NASA WFF RCC and the MRCS.

The primary purpose of the PCDQS is to provide RS with present and IIP positions for the vehicle. To do this, the system processes raw positional data from tracking sources into smooth positional data. The raw data is first validated for acceptability and then edited for bad points. The data points are smoothed to remove noise through the use of a Kalman filter, and then used to calculate the IIP position. Coordinate transformations are also performed on the data. In addition, a best source selection algorithm flags the best tracking source.

The PCDQS provides much of the same functionality as the RCC's minicomputer. However it provides a number of advantages over that system including significantly reduced cost, portability, maintainability, and easy setup and use. The PCDQS was the first use of a PC based system to provide range support at WFF. It was also the first use at WFF of a real-time operating system environment on a PC platform.

The PCDQS' configuration is shown in Figure 4, and is comprised of NASA custom and COTS hardware and software. The hardware and software configurations are as follows:

Hardware

- COTS x86 based PC
- COTS Network/Ethernet card
- NASA custom NASA-36 timing card
- NASA custom synchronous data card
- COTS 2400 baud synchronous modems
- COTS Itochu LCD button panel

Software

- COTS Microsoft MS-DOS operating system
- COTS Talton Louley Engineering TL Executive real-time DOS extension
- COTS FTP Software PC/TCP network sockets software
- NASA custom PCDQS software

The system requires 3 different types of data sources in order to function. First it requires one or more tracking sources. The tracking sources are provided in either the Minimum Delay Data Format (MDDF) or the LTAS formats at a rate of 10 pps or 10 Hz at 2400 baud. The system can input any combination of MDDF or LTAS sources up to a combined total of 8 sources. Secondly the system requires time of day and program time data. This is provided by the ASCII Time source, as well as a 2400-baud, 10 pps, synchronous data source. Finally, the system requires a 10 Hz timing source in order to synchronize the system with the incoming data. This is accomplished with a NASA-36 format timing source which provides a 10 Hz interrupt to the PC system.

The system outputs data to its users in two ways. The primary means is via a buffer/packet of data broadcast on the local Ethernet at a rate of 10 per second. These buffers are used by the IRIS systems for constructing the DQ and RS displays. A secondary output is through serial transmitters. The system can package user selected sources into MDDF or LTAS formats and transmit them over 2400 baud synchronous data lines. The primary use of this type of output is to provide data to remote tracking stations or ranges. The system can support up to 4 transmitted sources.

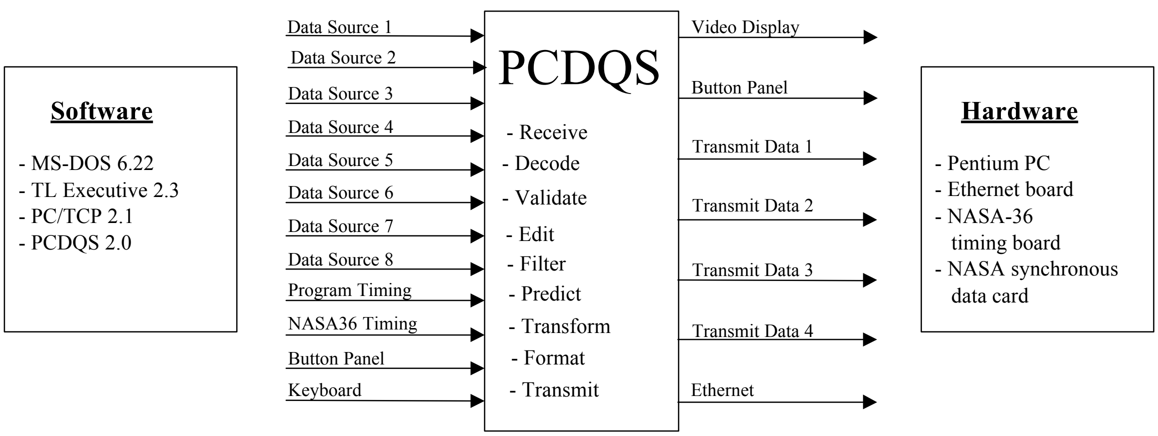

Figure 4 - PCDQS Configuration

The system was designed to require minimal setup and user interaction. The small amount of setup and interaction that is required is accomplished through a character based windowed interface, a standard keyboard, and a button panel. Through its single display the user can configure the system by specifying defining parameters for the tracking sources, the parallax/launch site, and the vehicle. The transmitters can also be configured. During a mission, the screen displays mission status and time, parameters from the tracking sources, system error messages, and processing statistics. The DQ operator interacts with the system through an LCD button panel. The buttons on the panel allow the user some control over the system and the selection of the tracking sources that are viewable by the RS officer. The buttons provide feedback by color changes and/or blinking.

The PCDQS system is currently operational in the WFF RCC and is ready for deployment around the world in the MRCS. In its present form, the system is limited in growth by constraints of the operating environment. A task is underway to port the software to Microsoft Windows NT to allow room for growth. Further, in the future the system may be replaced by a new state-of-the-art range data system.

IRIS GRAPHICS SYSTEM

The IRIS graphics system's configuration is shown in Figure 5, and is an SGI Indigo2 Extreme or Impact workstation, with at least 128MB RAM, and 1280x1024 graphics resolution with 24-bit planes and millions of available colors. In-house software development has produced formats for mission displays that give the user choices of full or split screens combining alphanumeric data; static graphics with moving sources (i.e.: vehicles moving over maps); "heads-up" aircraft displays with 1-4 centered sources, zooming, event markers, vectoring and moving maps; debris footprints plotted with BEST source; and vehicle motor displays with animation, audio cues, and timed nominals. By the TELPro and PCDQS systems broadcasting their Ethernet buffers, the same radar and/or TM data can be received simultaneously on multiple IRIS systems, which are individually configured to best display the data to support each user's mission function. Either the user at each display can actively control the selection of sources for the display, or the DQ operator can control the selection remotely for all passive displays.

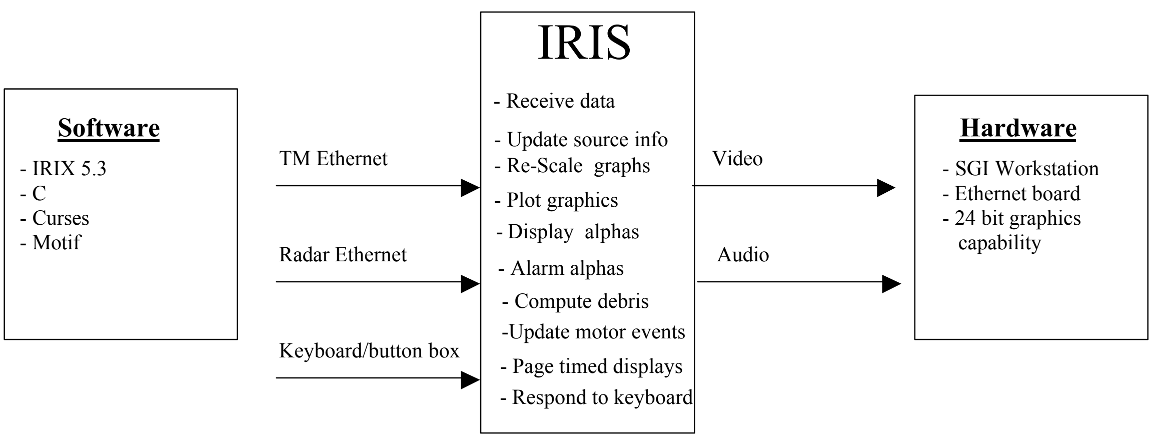

Figure 5 - IRIS

Up to 12 alphanumerics updated every second can be shown on the same display with plots or on a separate screen. The alphanumerics have been enhanced to allow the user to select alarmable and freezable data formats. The alarmables will change the corresponding parameter's box color whenever the data meets the selected alarmable state, either greater than, less than, equal to, or not equal to a value; or outside or within a range of values. Freezable alphas will show either the maximum or minimum value attained by that parameter during the mission, whichever state the user selects.

Figure 6 shows a split screen with multiple graphics plots and an alphanumeric area with multiple source values for each parameter. The plot symbols and alphanumeric values are color coded to each source for quicker user identification. In this example, the top plot is dedicated to a TM source, and the bottom plot overlays coordinate systems for IIP and present position data from both radar and TM sources.

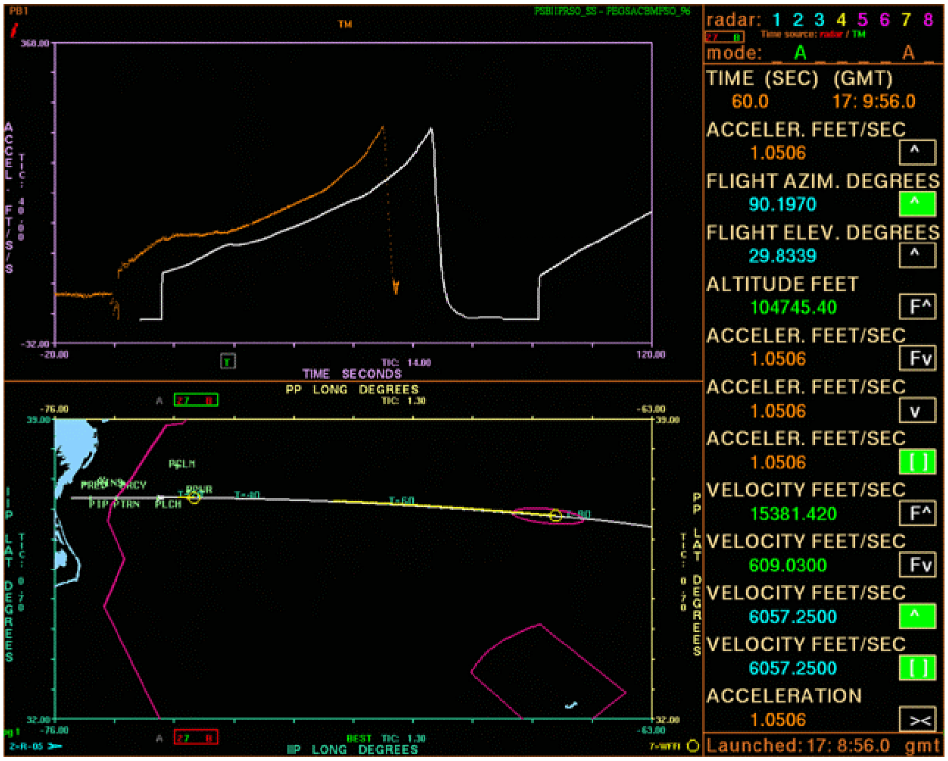

Figure 6 – IRIS motor display with multiple source alphanumerics.

Each plot can contain up to 4 radar sources, including a BEST radar, and one TM source from Ethernet data updated every 1/10th of a second. On multiple source plots, automatic scaling to user-defined scales is based on a majority of the sources on the plot needing to rescale. User-selectable underlay options in plots include maps, lines, ellipses, annotations, and boundary patterns. Paging allows up to 4 screens of graphics and/or alphanumerics to be switched during a mission on each display, either automatically by selectable mission times or manually by the user.

To support orbital launches, motor displays, as shown in Figure 7, have been developed to provide roll, pitch and yaw indicators as well as simulations of separations and burns as indicated by on-board vehicle sensors. Audible clues allow a user to be aware of these events even while viewing other screens during paging. A moving indicator on the circumference of the pitch display shows the nominal pitch value during the mission, giving the user a quick reference for vehicle performance.

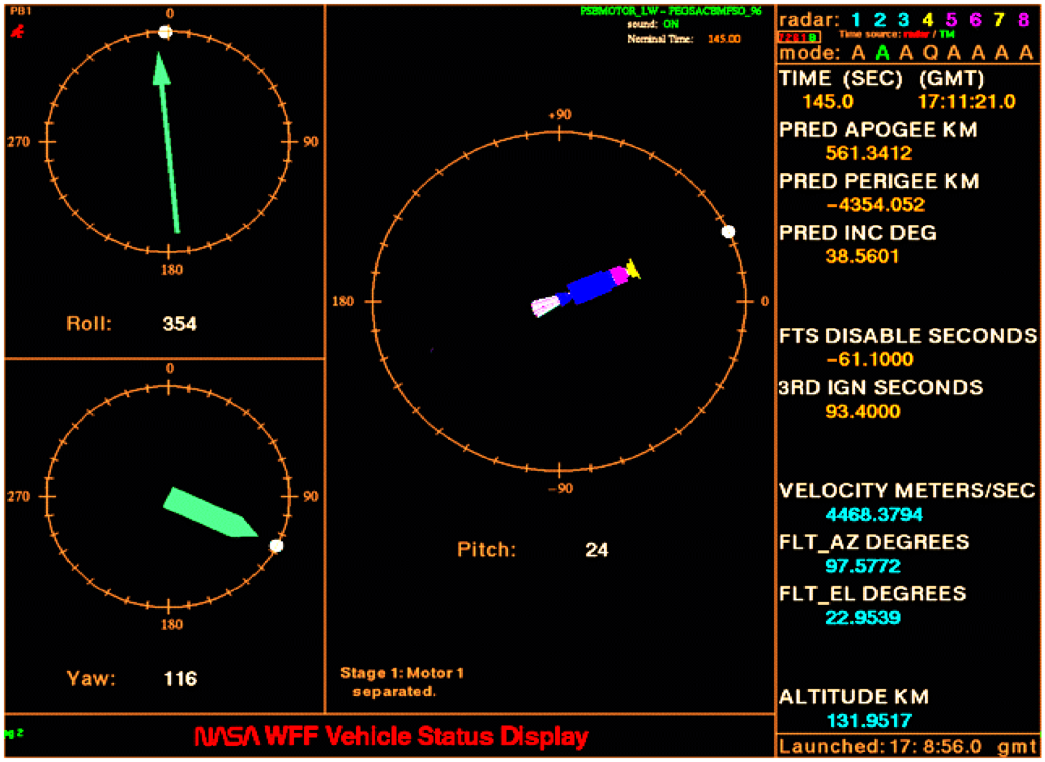

Figure 7 - IRIS motor display with multiple source alphanumerics

The use of alphanumeric and graphical representations of real-time data combined with nominal expectations can greatly enhance the user's ability to interpret the rapidly changing mission events. The graphic simulations help mission personnel to determine mission performance faster than trying to interpret alphanumerics alone. Having multiple sources of data on the same plot has reduced the number of displays needed to provide mission personnel with the information they need to evaluate the relative quality and reliability of each source to ensure the safety of the mission.

The software and/or hardware of the IRIS graphics system can and will change to meet or exceed the requirements of the ever changing missions NASA supports, and also to be more responsive to the users in assisting them to perform their range support functions.

CONCLUSION

The concept of the Mobile van has proven itself in the field, and with its ability to be deployed virtually anywhere in the world, it will continue to be a great asset for range support. With the availability of new technology, both the WFF RCC and its mobile counterpart, the MRCS, will continue to evolve to meet the needs of a variety of increasingly complex missions.

RELEVANT CONTACTS

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3. TM van development and design: Robert Wessells (Robert.L.Wessells.1@gsfc.nasa.gov/(757)824-1297).

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ACRONYMS

C/D	Command/Destruct		MRCS	Mobile Range Control System
COTS	Commercial Off The Shelf		MSB	Most Significant Byte
DOS	Disk Operating System		NASA	National Aeronautics and Space Administration
DQ	Data Quality		NRZ-L	Non Return of Zero Level
DRT	Data Receive and Transmit		PC	Personal computer
GDP	General Data Products		PCM	Pulse Code Modulation
GPS	Global Positioning System		PCDQS	PC Data Quality System
GSFC	Goddard Space Flight Center		PPS	Points per second
HF	High Frequency		RCC	Range Control Center
Hz	Hertz		RS	Range Safety
IIP	Instantaneous Impact Prediction		SGI	Silicon Graphics, Inc.
IMU	Inertial Measurement Unit		TCP	Transmission Control Protocol
INS	Inertial Navigation system		TDP	Telemetry Data Processor
IRIS	Integrated Range Information System		TELPro	Telemetry Ethernet LTAS Processor
LCD	Liquid Crystal Display		TL	Talton Louley
LSB	Least Significant Byte		TM	Telemetry
LTAS	Launch Trajectory Acquisition System		VHF	Very High frequency
MDDF	Minimum delay data Format		WFF	Wallops Flight Facility
MINISAT	Miniature Satellite		Y2K	Year 2000