A PC WORKSTATION FOR SPACECRAFT FACTORY INTEGRATION & TEST

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ABSTRACT

PC technology has progressed to the point that it can very effectively support commercial geostationary spacecraft design, manufacture, test, launch, ground station, and on-orbit mission control activities. Many of the manufacturers that provide VME spacecraft test hardware and software are now providing the same functions and performance for the PC. A PC workstation equipped with single and multiple Pentium processors and Windows NT software can support single and multiple uplinks/downlinks and provide client/server capabilities that perform traditional UNIX client/server operations. Such a PC workstation can provide the functionality, features, and performance necessary for commercial spacecraft board-level test, unit-level test, subsystem-level test, spacecraft bus and payload integration, and ground station monitoring and control, as well as on-orbit mission control activities.

KEYWORDS

Integration, Test, Spacecraft, Satellite, Commanding, Telemetry, GUI, Test Consoles, Commercial Satellites, Communications Satellites, Commercial Space

INTRODUCTION

Commercial communications satellites and satellite constellation companies are cost-driven. Commercial spacecraft builders must implement cost-effective approaches to meet satellite manufacture, test, and delivery schedules. The size and complexity of commercial communications satellites continue to grow, and delivery schedules are getting shorter. Deliveries of new, larger, more powerful commercial spacecraft are now on a 12-18 month schedule. These accelerated time frames mean spacecraft test equipment must be continuously available and easy to use.

Since 1984, when the PC was invented, companies that manufacture test equipment for flight testing and spacecraft factory testing have recognized the suitability of the PC as a low-cost computer platform able to receive, process, and display telemetry. Many manufacturers of telemetry test equipment went on to design PC-based products from existing rack-mount units and VME boards to provide the functions, features, and interfaces needed for spacecraft integration & test (I&T). One of these companies, Telemetry & Instrumentation, developed PC test equipment (called NeTstar) to meet the needs of commercial, NASA, and military spacecraft I&T applications.

Telemetry & Instrumentation merged state-of-the-art PC technologies from two of its products, the Telemetry and Command Board Set (TCBS) used on Globalstar, and the Visual Test System (VTS), to create NeTstar. The TCBS is a three-board set that integrates an RF transmitter, RF receiver, and a digital signal processing (DSP) board for modulation/demodulation. The VTS is a PC-based data acquisition and display system that combines telemetry acquisition, processing, display, and analysis tools in Windows software. Figure 1 illustrates the evolution of the PC for space applications.

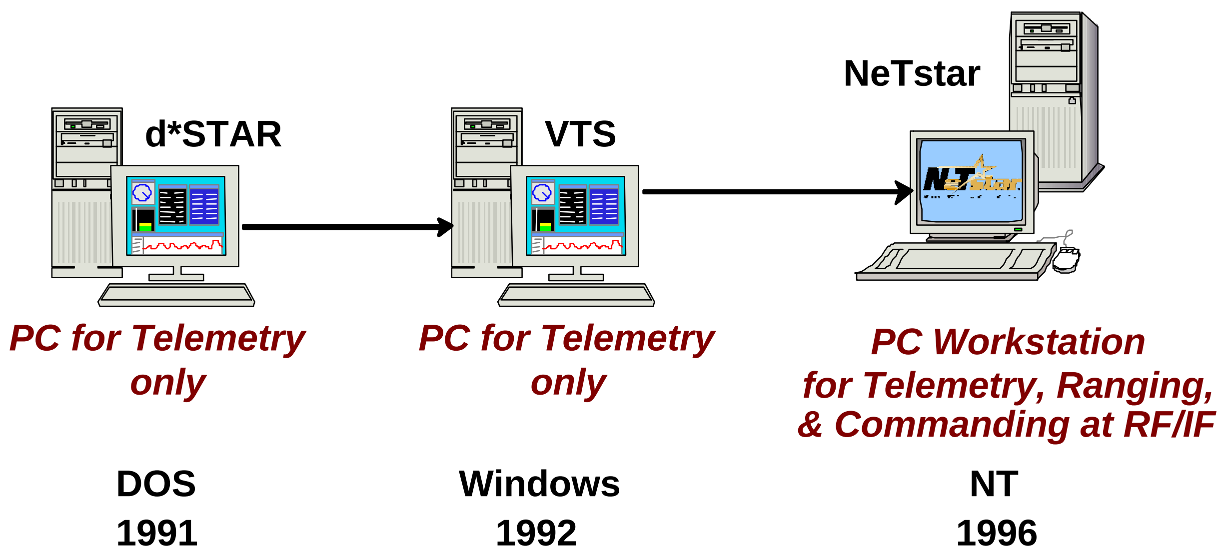

Figure 1. The PC's Development for Space

SPACECRAFT FACTORY INTEGRATION & TEST USING A PC WORKSTATION

Spacecraft I&T requires various electrical, mechanical, IF, RF, network, and data interface levels. PC workstations provide a cost-effective platform for providing the functions, features, and interfaces needed for spacecraft factory I&T. Their accessibility means that users can easily add program-specific interfaces. In addition, because PC technology continues to advance, users are guaranteed a built-in upgrade path.

PC I&T equipment can be networked with existing workstations running test executive software. The system can receive block command strings from the test executive software and convert them to any of the desired interfaces. RF telemetry can be received, processed, and routed to the workstation for final processing and archiving. Figure 2 is an example of a PC workstation networked to a host workstation and spacecraft during factory I&T.

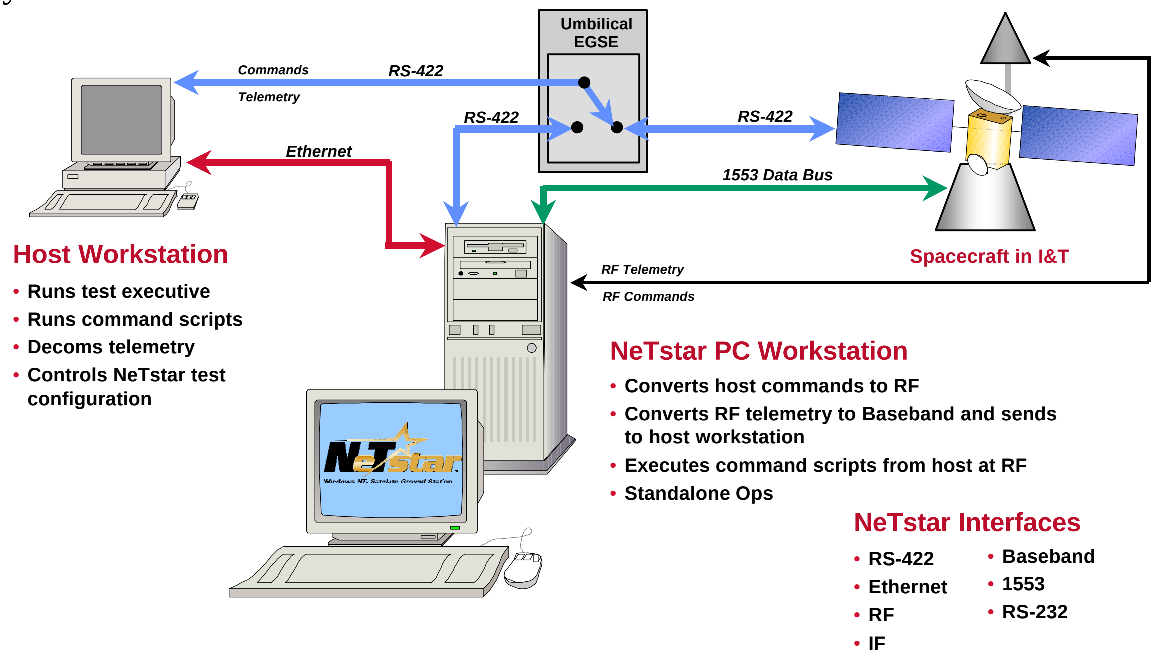

Figure 2. Spacecraft Factory I&T Test Equipment Configuration Using NeTstar for Spacecraft-Level Testing

Table 1 identifies typical commercial satellite factory spacecraft interfaces supported by commercially available PC hardware and software. More are possible with additional PC hardware tailored for specific programs.

Table 1. Spacecraft I&T Interfaces Supported by the PC

Category	***Description***	***Item***	***Limits***
Power	D Subminiature or Circular Connector	Voltage	0 to +100 VDC
		Voltage Rise Time	50 - 200 msec
		Current	0 - 200 Amps
		In-Rush Current	~75 Amps within 1 sec
Bus Command	Multi-Pin D Subminiature	Serial/Pulse Commands	Uniquely defined protocols
		Pulse Voltage	-10 to +5 VDC
		Serial Voltage	+15 to +30 VDC
		Timing (rise/fall)	100 ns to 100 µs
		Command Rate	1 to 20 per second

Category	*Description*	*Item*	*Limits*
		Noise Immunity	Up to 50 pps with pulse width < 200 μs
Bus Telemetry	Multi-Pin D Subminiature	Serial/Bi-Level	Uniquely defined protocols
		Analog	0 to 6 VDC
		Bi-Level Voltage	-5 to +15 VDC
		Serial Voltage	+15 to +30 VDC
		Timing (rise/fall)	100 ns to 100 μs
		Telemetry Rate	16 Kbps
RF Signal	SMA, Type N, APC-7, and Others (varies dependent on signal frequency)	Frequency	1 to 40 GHz
		Power	-150 dBm to 10 dBW
		Signal Types	Pure or modulated carrier (FM, PM, digital)
IF Signal	SMA Connector	Frequency	40 to 200 MHz
		Power	-20 dBm to 10 dBW
		Signal Types	Pure or modulated carrier (FM, PM, digital)
Digital Interfaces	Multi-Pin D Subminiature	RS-422	Industry standard
		Data Rate	1 Hz to 20 MHz
		Termination	Single-ended or differential
		Signal Level	TTL or LVCMOS
Mechanical	¼-inch Pressure Fitting	Pressure	Up to 7,000 PSIG

PC WORKSTATION HARDWARE

PC Telemetry RF/IF Receiver/Demodulator

The Telemetry RF/IF Receiver/Demodulator receives the RF downlink signal, amplifies the low-level signal, phase-demodulates the carrier and PRN ranging tones, downconverts the demodulated carrier to IF, and demodulates the carrier and subcarrier with multiple telemetry subcarriers for real-time fast and slow or real-time and dwell data. The demodulator provides clock and data to the bit synchronizer. Viterbi convolutional decoding at rate ½, constraint length K=7 can be programmed on and off.

PC Telemetry Bit Synchronizer

The Telemetry Bit Synchronizer receives demodulated telemetry and synchronizes a clock to the incoming PCM data stream. The bit synchronizer conditions the input signals through analog and digital filters for signal conditioning and automatic gain, offset, frequency, and phase control. These techniques allow the module to make bit decisions while doing code conversion. The bit synchronizer module can extract data and clock from white noise and unwanted spectral frequencies. The output is low noise PCM telemetry and a synchronized clock for decommutation. A second Viterbi decoder decodes rate ½, constraint length K=7 encoded data with eight combinations of connection vector swapping and alternate symbol inversion. This capability allows a BER improvement of 5.2 dB @ 10^{-5} BER. Bi-phase-L encoding is also supported.

PC Decommutator

The Decommutator receives a serial data stream from the bit synchronizer. The decommutator's maximum rate is ~20 Mbps NRZ-L PCM with 32K words per frame. It provides frame and subframe sync functions. The decommutator utilizes a PCI bus, which is a 32-bit bus that operates at up to 33 MHz with a planned upgrade to 66 MHz.

PC Command and Range Tone Modulator

The Command and Range Tone Modulator is controlled by the command formatter and the command and range software. It modulates a command message as well as range tones onto the command subcarrier and range carrier/subcarrier. The modulator receives a TTL input from the command system. The output of the modulator is a complex IF signal consisting of modulated command and range tones on a 70 MHz signal.

PC PCM Simulator

The PCM Simulator generates a user-defined PCM stream that can exercise frame/subframe modes of processing. Alternatively, the user can take advantage of a set of predefined wavetrains selectable through a point-and-click user interface. This feature is used for setup and checkout prior to use and for self-diagnostic routines. A simulated PCM wavetrain is available for self-test.

PC Time Code Reader & Generator

The Time Code Reader & Generator provides an effective tool for time-stamping, diagnostics, and data redistribution. Time capture is triggered by a pulse (event signal). The time code reader can read IRIG-A and -B time formats, and makes data available for use with third-party hardware and software.

PC Spacecraft Command Interface

The Command Interface accesses the command database and generates the command message. The complete command message goes to the command modulator for modulation onto a complex IF signal. The command database can be imported through spreadsheet-type applications or directly from a floppy disk.

PC WORKSTATION SOFTWARE

Windows NT Operating System

The PC workstation's Windows NT software provides system setup and monitoring, data archiving, and real-time satellite data acquisition, command generation, and ranging. The software uses an intuitive, graphical, point-and-click and menu-driven interface for configuring an array of hardware PC boards and PC software packages.

The PC workstation's software features a Heartbeat Page, shown in Figure 3, that launches the user into system functions. The Heartbeat Page also provides quick status of selected parameters and functions. PC workstation system and customer-purchased COTS software can be used for antenna control and status, command generation, telecommand processing, attitude determination, ground and satellite antenna pointing, ephemeris generation, client/server control, processing, and subsystem analysis, as well as PC local and remote control, command generation, telemetry processing, and local commanding.

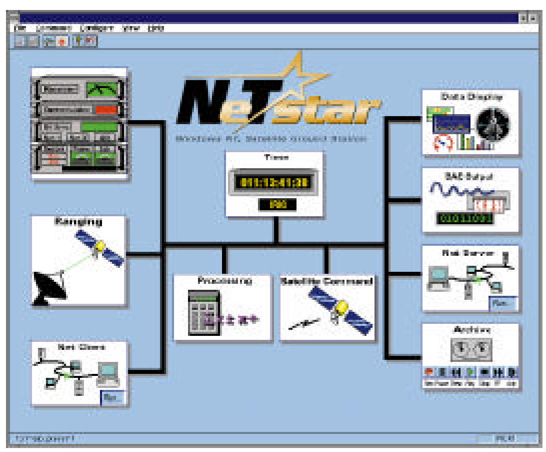

Figure 3. The PC Workstation's Reconfigurable Heartbeat Page

The PC's databases provide full command and control needs. In addition, the PC workstation receives command strings from host systems and sends frame-synched telemetry data back to the network. The command strings are taken off the network, converted, and transmitted to the spacecraft or to flight equipment.

The PC workstation software can handle multiple RF carriers, IF signals, subcarriers, data streams, and command links. The software provides real-time and post-pass data acquisition, analysis, and archiving in a true network-based environment where data can be distributed from a server to multiple clients. Analysis displays and tools include horizontal bar charts, vertical bar charts, strip charts, scope charts, range displays, tabular displays, scrolling text, alarm loggers, and dials. A set of standard telemetry processing algorithms is provided with the software. Custom algorithms are easily added using a template. Figure 4 is an example of the kind of screen display that can be produced using the PC's telemetry display and analysis tools.

Figure 4. Example of a Satellite Telemetry Display Page

PC Command Software

The Command Software stores satellite command databases and formats a command by adding the appropriate header. The Command Software is ideal for local and standalone test and system checkout, and for independent system use.

PC Ranging Software

The Ranging Software generates a range solution using discrete tones and/or a pseudo random noise (PRN) sequence. Ambiguity is resolved by using multiple tones.

CONCLUSION

The PC, with Windows NT software, can provide all the capabilities necessary for supporting spacecraft factory I&T. Telemetry & Instrumentation's NeTstar integrates hardware, software, and industry-standard network interfaces into a PC workstation that can operate as a standalone unit or be networked to a workstation environment and legacy test equipment. Using a common, low-cost, commercially available PC platform like NeTstar throughout all areas of the spacecraft factory (from systems engineering through final factory test) lowers costs and complexity, while increasing team efficiency.

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