TIMELY UPGRADES TO COMPLEX SYSTEMS SUCH AS THE TELEMETRY PROCESSING SYSTEM AT PMTC

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ABSTRACT

The procurement of a new or upgraded data processing system doesn't have to take eons of time and result in a less than adequate system. The complexity of requirements definition and system development are not getting any easier, but well-defined methodologies and the use of proven capabilities are providing a means of controlling the process. Even though there are more and more demands being placed on telemetry processing systems and advancing technology offers a myriad of solutions from which to choose, the Government and contractor communities are becoming more effective in applying techniques to define and deliver adequate systems. One method of demonstrating this is to describe an example of a complex telemetry processing system currently being developed for the Navy.

INTRODUCTION

Depending on its size and complexity, a new system may take anywhere from five to fifteen years from the time a need was first identified until it becomes operational. This represents a significant investment in time and money for the procuring agency. The success of the new system depends on timely, cost-effective development, its ability to utilize the latest technology, and the degree to which it satisfies the user's requirements. The Government and contractors have developed successful methods for ensuring the success of new systems. The Government's main contribution has been the preparation of Military and Department of Defense standards (particularly DOD-STD-2167) that define the process of designing, developing and testing complex systems. The new guidelines also allow for the tailoring of the standards to fit the type of system and contract. And because many of the new contracts are fixed-price-oriented, many contractors have developed their own strict procedures for regimenting the entire process. Industry enhancements such as CASE tools, CAD/CAM packages and other off-the-shelf workstation products have also provided a means of reducing the effort and the unpredictable characteristics of system design and development.

The need for a considerable enhancement to the system being used to process telemetry data at the Pacific Missile Test Center (PMTC) was defined at the ITC in 1986 (1). Since that time, a top-level system specification was developed, a Request for Proposal was distributed, and a fixed-price contract to develop a new Telemetry Processing System (TPS) was awarded to Computer Sciences Corporation (CSC) on 1 August 1989. The system design has been completed, and CSC is well on its way to completing the development of not one but four of the systems described at ITC/86. Delivery is scheduled for the second quarter of 1991.

Throughout the process of requirements definition and system development, the Navy and CSC have been using the latest standards, tools and techniques to ensure the timely and cost-effective delivery of a fully functioning TPS.

REQUIREMENTS DEFINITION

Since a system developer is only responsible for satisfying the documented requirements, a key step for a successful system is correctly defining the system requirements. In establishing requirements for TPS, many objectives had to be taken into consideration. These objectives included not only system functionality and performance, but also the time and cost involved in developing and maintaining the system.

The major factor influencing the requirements definition was the utilization of as much previously developed hardware and software as possible. This type of specification allowed the procurement to proceed as a fixed-price contract. Using this vehicle provided for a stable system with minimal development risk.

The basic technical objective was to present the end user with as much data as possible in the most comprehensive format. The individual user is uniquely interested in obtaining information useful in the decision making process based on an accurate representation of the telemetered parameters during real time or from analog tape playbacks.

The equipment operators have a different set of priorities for the system requirements. The operators arc responsible for ensuring that the system is working correctly so that it can provide the end users with quality data. The total system complexity must be kept within the maintenance and operational capabilities of a small complement of technical personnel. System design must take into account the skill levels required to maintain and operate the system, as well as the training required of these groups.

The software maintenance of modern computer systems can be one of the largest cost factors in the life cycle of the system. To reduce the cost burden of original software development, as well as the software maintenance, extensive use of off-the-shelf software was required. The use of CASE tools is gaining industry recognition as a means of improving the visibility into software design. Requiring an off-the-shelf CASE tool to be used for software development was also intended to enhance software maintenance. As a standard product, use of such a tool is fairly easy to master and thus allows maintenance personnel to quickly understand and modify the software design.

The display of telemetry data has traditionally been through the use of the strip chart recorder (SCR). While providing an accurate, real time display of each data sample for selected parameters as well as a hardcopy report, SCR's are severely limited in the number of parameters and the display format. The flexibility of data selection via menus on a CRT gives the end user the ability to analyze multiple parameters in many different presentation formats. The advantages of these two capabilities were combined in TPS through the requirement for both SCR's and real time graphics displays using the workstation concept.

In this manner, each type of user associated with TPS and each functional discipline was analyzed as to the best way to structure the system requirements. The intent was to ensure that the system would not be designed to suit one group of users, while making the job harder on another group. User acceptability is a major factor in the success of a new system.

The following overview describes the system being developed to satisfy the Navy's requirements.

TPS SYSTEM OVERVIEW

Figure 1 shows an overview of TPS and its subsystems. As shown, there are four identical strings of equipment receiving data from the Input Data Distribution Patch Panel (IDDPP). Each of these strings contains a Telemetry Front End Subsystem (TFESS) that provides data to a Telemetry Processor Subsystem (TPSS) through a Universal Memory Network (UMN). Data from each TPSS is routed through the Telemetry Graphics Network (TGN) patch to any one of four Telemetry Display Subsystems (TDSS). The Navy's two Range Central Site Computers (RCSC) can pass data to and from any TPSS over the high speed Telemetry Data Network (TDN). The transfer of setup files and other support data is done over the Local Communication Network (LCN) between the TPSS's, the Software Development Station (SDS), and the Navy's Telemetry Decommutation and Processing System (TDAPS).

1. IDDPP

The IDDPP contains the equipment that provides a centralized distribution for the incoming PCM, PAM and FM data to each of the four TFESS's. It also contains test equipment that may be used to evaluate the signals and help the operator respond to anomalies. The IDDPP is housed in five 19-inch racks that contain the test equipment, the patch panel for routing real time or playback data to selected TFESS's, two Honeywell Model 97 automatic magnetic tape systems for playback, a TRAK Model 8500 time code processor to support tape search, two AGC/Video Multicouplers from Apcom, and four Fairchild Weston Model 4142 tunable analog discriminators.

2. TFESS

The Aydin Computer and Monitor Division (ACMD) System 2000 is the major component used to satisfy the TFESS requirements identified in Table 1. The System 2000 configured for TPS performs frame synchronization, engineering units conversion, data compression, user-defined processing, and other basic data processing functions on up to four PCM stream, two PAM sources and two FM sources. As shown in Figure 2, the System 2000 has a modular, bus-based architecture that includes separate cards for decommutation (FSC019 and FSC005), Digital Signal Processing (DSP003), specialized processing (DSP002), analog data input/output (ICM003), monitoring data status (SSM002), data transfer to the host computer (CPI010), and receiving command and setup data from the host computer (IOC011). In addition, the System 2000 is configured with four sets of Simulator Modules (SIM004) and Serial Output Code Converter Modules (SOC001) to provide a controllable, simulated PCM data stream for system testing and data validation. The System 2000 is provided with data from four ACMD 3335 bit synchronizers, two Acroamatics Model 2410 PAM synchronizers/PCM converters, and two FM inputs through a Fairchild Weston 8470 Tunable Digital Discriminator and a Tustin 2315 A/D converter. A separate TRAK 8500 Time Code Processor allows the CPI010 cards to time tag the data to a resolution of 10 microseconds.

3. TPSS

The TPSS serves as the host computer for the TPS. It provides the central control over operations, allowing preflight setup, operation initiation, acquisition and routing for realtime and analog playback data, and post-test playback of recorded data. The TPSS processor is a DEC VAX 6220 super minicomputer system. In addition to the required memory, disk, tape, printers and other peripherals, the DEC 6220 is configured with two VAX Real Time Accelerators (RTA). The RTA's serve as an

Input/Output Processor for high speed data format conversions between the DEC and CDC Cyber processors (RCSC's) for data transferred over the TDN.

4. TDSS

The TDSS provides the real time user interface to TPS. Each of the four TDSS's supports a separate display room that includes four Graphics Display Stations (GDS), eight strip chart recorders, two remote color display monitors, and a large screen display provided by the Navy. Each GDS is configured with a printer/plotter for graphics hardcopies and its own disk for recording and recalling display data. The GDS is a DEC VAXStation 3200 processor configured with a GPX coprocessor that provides high-performance color graphics. The GDS is an intelligent workstation capable of processing and displaying real time data from the TPSS or recall data from its own local disk. The strip chart recorders are Astro-Med's Model MT-95000R configured with a digital interface.

5. SDS

The SDS is not part of the real time processing configuration. It serves as the primary setup file development and applications software development station. The SDS also provides the storage space and connectivity to serve as the archival system for the TPS setup files. The SDS processor is a DEC VAX 6210 super minicomputer system configured with the required memory, tape and disk peripherals. It also has a graphics unit to allow for development of real time displays.

6. UMN

The UMN is an ultra high speed, inter-computer communication network which allows dissimilar computers to access common memory at transfer rates of up to 40 megabytes per second. In the TPS configuration, the UMN is used to pass the high speed real time data from the TFESS to the TPSS. The UMN configuration, as shown in Figure 3, consists primarily of the SMI-32 bus with an Intelligent Data Interface (IDI) module, a controller module, memory cards, and a computer interface module. For TPS, the computer interface is a connection to the VAX BI Bus. Also included are data transfer cards (FDT3001 and FDT7002) that provide two separate data paths from the System 2000 into the IDI, as well as an output path from the IDI to the digital-interface strip chart recorders. The IDI provides an additional level of preprocessing easily modified by downloading programs from the TPSS host processor.

7. DATA NETWORKS

As shown in Figure 1, there are three data networks within TPS: the LCN, the TGN and the TDN.

a. The LCN links each TPSS with the SDS and the TDAPS. This network consists of an Ethernet connecting the processors.

b. The TGN provides the data path from each TPSS to selected TDSS's. The TGN is a thin wire Ethernet Local Area Network, where each TPSS and each TDSS has an Ethernet interface. The system is configured with a TGN patch panel that allows any TPSS to be patched to any TDSS, or any two TPSS's to be patched to a TDSS, or one TPSS to be patched to all four TDSS's. Up to 50,000 samples per second can be transferred across the TGN for display.

c. The TDN connects each TPSS to the Navy's two RCSC's. Because of the high data transfer rates required (100,000 samples per second), the TDN is implemented with a Network Systems Corporation HYPERchannel. This network has a trunk transfer rate of 50 megabits per second, and provides an effective transfer rate sufficient to support the requirements.

DESIGN APPROACH

The design of a new system plays a significant role in its success. The approach to designing TPS consisted of matching the functional requirements to the appropriate system component or subsystem in a way that enhanced such system capabilities as real time performance, flexibility, ease of use and reliability. This was done as much as possible with modular, proven, available, and state-of-the-art hardware and software products. It was also done with an eye towards retaining the basic system architecture used on previous projects (2). For although a certain amount of development is almost always required for a new system, a primary objective should be to restrict development to new or enhanced capabilities. In other words, eliminate the need to redevelop existing capabilities due to changes in the system configuration or architecture.

The TPS design follows the industry trend over the last few years of allocating as many functions as possible to the front end subsystem which consists primarily of high speed microprocessors and built-in firmware. The performance and modularity of today's front end hardware provides an extremely flexible way to significantly enhance system performance without the inherent problem associated with upgrading the hardware and software of a host processor. TPS takes this concept one step further by also including an intelligent interface between the front end subsystem and the host processor. In addition to providing the necessary high-speed data interface between the two subsystems, added capability is provided by a microprocessor programmable from the host computer and by specialized digital interfaces to such devices as strip chart recorders.

The TPS design further minimizes the workload of the host processor and takes advantage of the advances in minicomputers by allocating the data display and recall processing functions to multiple intelligent workstations. The host processor is used primarily to collect and buffer the real time data for transmission to the workstations, for conversion and transfer across the network to other processors, for output to the data recording function, and for input to user application code running within the host processor.

The following section identifies the specific factors used to provide TPS with the development, integration and test advantages that contribute to the probability of success.

TPS SYSTEM DESIGN FEATURES

The TPS design takes advantage of several factors to help assure a successful development. The design of each TPS subsystem was carefully constructed to take advantage of off-the-shelf hardware and software with proven capabilities.

1. Similar Architecture

   Since the basic data flow and system architecture does not vary considerably from other telemetry systems, much of the required TPS support software has already been developed (3) and can be reused with minimal modifications. A similar architecture also allows for the use of proven capabilities and provides developers with a head start in understanding the most critical areas of the system. Thus the selection of subsystem components and interface definitions can be made more intelligently.

2. Proven Capabilities

   The ACMD System 2000 has been used by CSC to support several other real time telemetry processing systems (4,5). Its proven performance and its high degree of modularity is ideally suited to satisfy the PMTC requirements with minimal modifications.

   The GDS is based on CSC's Telemetry Work Station, which was developed as a small, standalone system with all the basic telemetry data processing capabilities.

CSC's use of NSC's HYPERchannel in three previous system configurations assures more than adequate experience and available software to quickly implement the TDN.

3. Off-the-Shelf Hardware

The IDDPP is configured with readily-available, off-the-shelf equipment. Construction of the specific racks and patch panels for TPS is a standard process that uses catalog components.

The DEC processors were an excellent fit to the specified TPS requirements, and their use throughout TPS permitted the use of common interfaces and software.

Since the TPS data transmission requirements are not excessive, the data networks selected are all standard off-the-shelf products. The use of DECnet on the LCN ensures compatibility among the processors and data transfers, as well as compatibility with existing hardware and software. Setup files are transferred over the LCN using standard DECnet file transfer protocols. The only development item on the TGN is the switching network, which is a simple patch panel.

4. Development Configurations

Off-the-shelf hardware, such as the DEC processors and the NSC equipment, was ordered early to allow a development system to be configured for use by the completion of the critical design review.

Modifications to the System 2000 prevented early delivery of the actual TPS components. Therefore, an interim unit was configured using only off-the-shelf components to provide as much functionality as possible. Existing software modules were available to support these off-the-shelf items, thus providing a means of ingesting data into the system.

The UMN is the closest thing to a new development item in the TPS configuration. Although a version of the UMN is currently being used operationally by NASA at their Dryden Flight Research Facility (6), many of the modules had to be developed for the first time to fit the specific TPS interfaces. For this reason, a simplified version was built with existing components for use during the early development phases. The intent was to assure that functional development could continue without the risk associated with a delay in receiving this vital component.

5. Off-the-Shelf Software

The type of processor has the greatest effect on development time if existing code has to be redeveloped to run on the new processor. Of course, redevelopment can be minimized if the code is in a standard high order language, such as FORTRAN or C. Due to its similar architecture, the library of existing FORTRAN code currently being used to support other telemetry processing projects satisfies most of the TPS functional requirements. The use of this existing code considerably reduces the development and debug time on 'IPS.

A significant feature of this software is that it was designed using CASE. CASE provides the software designers with online access to the data flows and data structures of the entire software configuration (7). Modifications for TPS-specific functions were easily made, and the CASE tool automatically verified that the changes balanced with higher and lower level structures (i.e., functions and data interfaces were correctly defined).

The TPS setup file software (i.e., the software that establishes the run time environment and processing to be done) requires limited development, since the TPS front end, host processor and display configurations are very similar to those used on previous CSC projects. What originally took ten to twelve manyears to develop on initial telemetry systems, now requires less than three manyears to modify for TPS.

The TDSS design also takes advantage of an off-the-shelf software package developed by V.I. Corporation to support graphical requirements on the workstations. This eliminates the need to develop a significant amount of graphics software to support TPS.

6. Economy of Scale

The most cost-effective TPS integration feature is the concurrent development of the expansion options (i.e., four systems rather than one) with the basic system. Although this may appear to add complexity to the situation, it actually allows many of the integrated system design problems to be resolved during the early development phases rather than later when modifications are much more difficult and costly. It also provides for the most cost-effective use of labor to complete the entire system in a shorter period of time. In addition, the ability to order four systems worth of equipment makes quantity discounts available and simplifies receiving by preventing deliveries from being spread out over several years. The advantage to the

Navy is obvious. They get a complete system that is fully checked out in a much shorter period of time for less cost.

SUMMARY

The successful development of systems such as TPS is no longer a rare occurrence. Many of the areas that used to cause wide variations in schedule and cost have been brought under control through the use of modular systems, proven capabilities, and well-defined procedures. The availability of off-the-shelf hardware and software to satisfy many new or enhanced requirements should only increase. System developers and system integrators are getting better at applying the standards and procedures to build complex systems. Users should now expect to get new or upgraded systems in a reasonable amount of time and, because much of the capabilities are already proven, without much of the skepticism that normally accompanies the arrival of a new system.

REFERENCES

1. Knight Paul, "Telemetry Processing System for the Pacific Missile Test Center", International Telemetering Conference, Vol. XXII, Instrument Society of America, Research Triangle Park, North Carolina, October 1986, pp 383-390.

2. Shelley, Larry and McCauley, Bob, "Accommodating Telemetry Data Acquisition Systems", International Telemetering Conference, Vol. XXIII, Instrument Society of America, Research Triangle Park, North Carolina, October 1987, pp 51-60.

3. Kendall, Richard A., "Unique Systems Through Reusable Software", International Telemetering Conference, Vol. XXV, Instrument Society of America, Research Triangle Park, North Carolina, October 1989, pp 583-589.

4. Quesenberry, David and Reed, Gary, "Telemetry Processing -- Reatime to Postflight", International Telemetering Conference, Vol. XXIV, Instrument Society of America, Research Triangle Park, North Carolina, October 1988, pp 237-246.

5. Shelley, Larry, "The Real-Time Telemetry Processing System III", International Telemetry Conference, Vol. XXIII, Instrument Society of America, Research Triangle Park, North Carolina. October 1987, pp 329-336.

6. Article in April 23, 1990 Electronic Engineering Times, "NASA Gets Memory-based Net", p 33.

7. Hill, Jerry, "Realtime Telemetry Processing System (RTPS) III -- A Preview of Software Development in the 1990s", International Telemetering Conference, Vol. XXIV, Instrument Society of America, Research Triangle Park, North Carolina, October 1988, pp, 257-266.

Figure 1. Telemetry Processing System Configuration

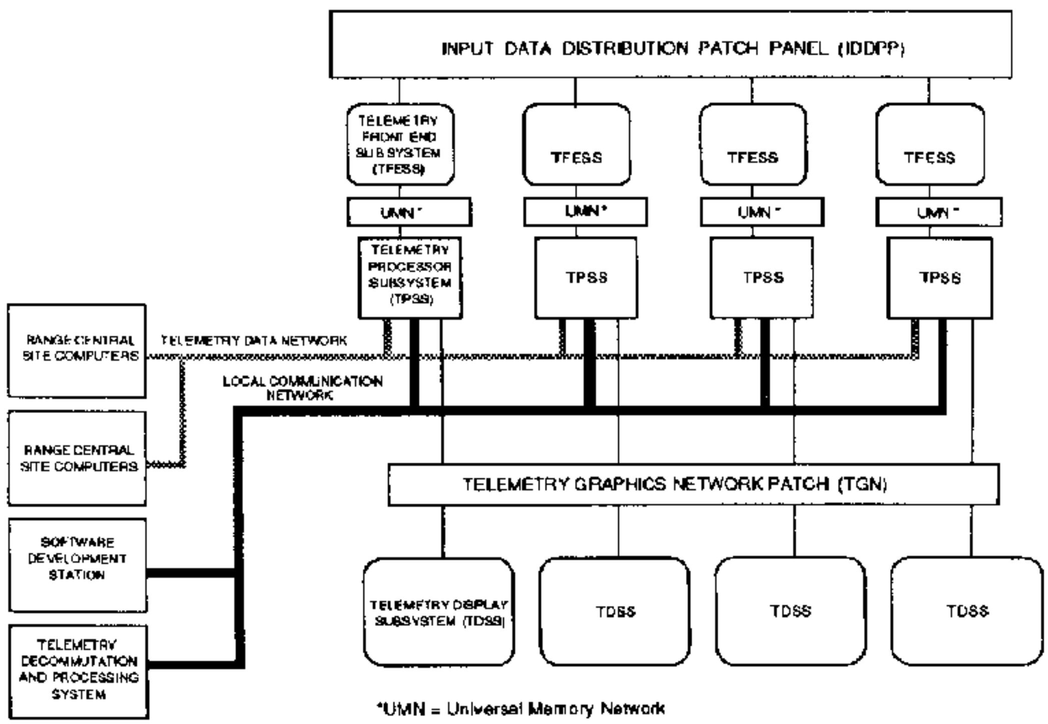

Table 1. TFESS Capacity Summary

TFESS Capability				Required Capacity
PCM:	Number of Input Streams			4
	Bit Sync Rate (Megabits / Sec.)			10
	Parameters / Source			4096
	Data Rate:	pps Sustained	/ Source	250,000
		pps Burst	/ Source	500,000
	Minor Frame			
	Subframe			
	Sub-subframe			
	Asynchronous Embedded Minor and Subframe			
	Repetitive Mode			
	(Subframe ID and Recycle)			
	Non-Repetitive Mode			
	Throughput (Direct Serial to Parallel) Mode			
PAM:	Number of Input Streams			2
	Channels / Frame			128
	Data Rate:	pps PAM NRZ		250,000
		Pps PAM RZ		125,000
Multiplexed FM:	Subcarrier Channels / Multiplex			20
	Analog to Digital Channels			32
	Simultaneous Stample w/in (Micro Sec.)			5
	Data Rate:	pps		300,000
Analog to Digital:	Data Rate	pps		500,000
Aggregate Data Throughput:	Pass through Rate:	pps		500,000
	Processed Rate:	pps		400,000
Strip Chart Recorder Outputs:	Channels			64
	Data Rate:	pps		200,000

Figure 2. Telemetry Front End Subsystem

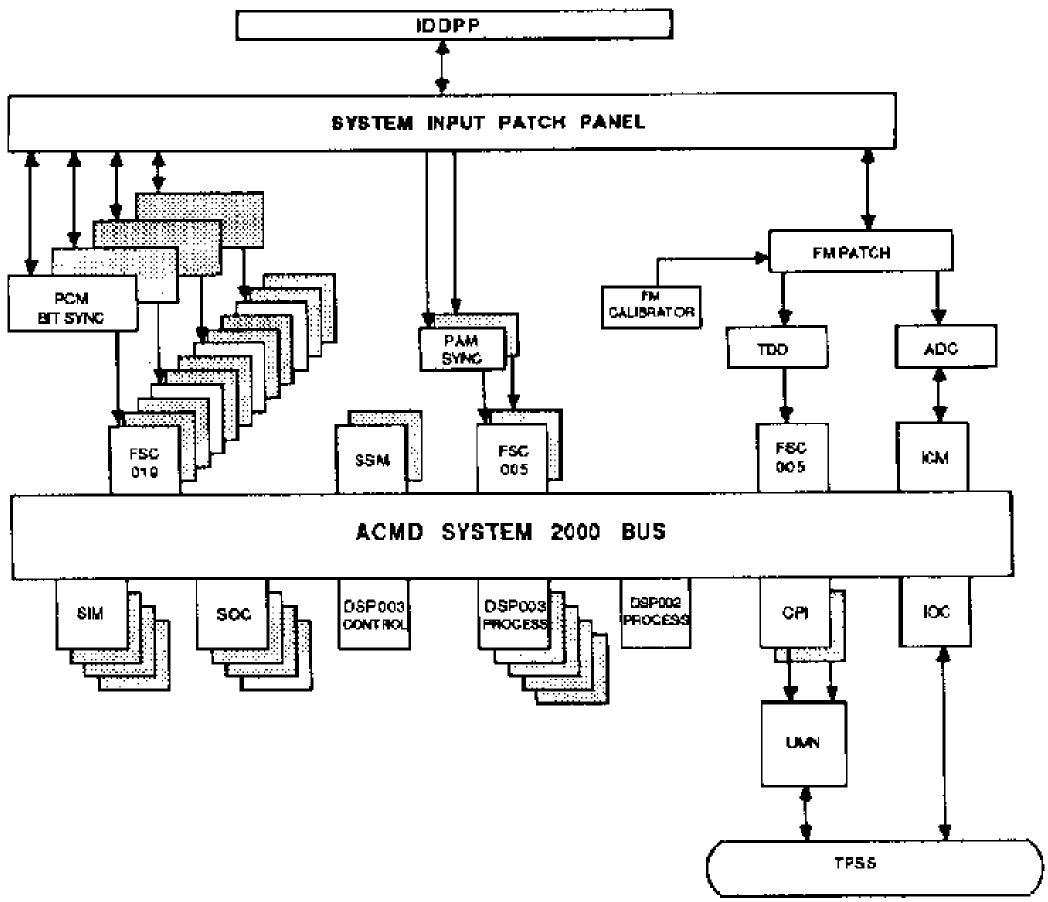

Figure 3. TPS UMN Configuration