RANGE SAFETY CASE STUDY: WESTERN RANGE CENTRALIZED TELEMETRY PROCESSING SYSTEM (WR CTPS), A LARGE DISTRIBUTED GROUND SYSTEM

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ABSTRACT

This paper presents a case study of the Western Range Centralized Telemetry Processing Subsystem (WR CTPS). This system was developed by Lockheed Martin Integrated Systems and Global Services and L-3 Communications Telemetry-West as part of the Range Standardization and Automation (RSA) IIA program. Requirements included real-time simultaneous acquisition of 16 PCM streams at rates of up to 30M bits per second; real-time processing; and data display on workstations connected over a gigabit Ethernet network. This system is designed for range safety and needs to be fault-tolerant while maintaining 100 percent data availability in the event of a single failure during an operation. The development of such a system demanded a rigorous Systems Engineering approach to ensure the successful upgrade and deployment onto the range infrastructure. This case study provides an overview of the system technical requirements and its architecture. The summary presents challenges encountered during the development and lessons learned while meeting them.

KEY WORDS

Client-Server;
Distributed Operations;
Ground Systems Architectures;
Range Safety;
Range Standardization and Automation;
INTRODUCTION

The United States Air Force adopted the Range Standardization and Automation (RSA) effort (Phase I, IIA and IIB) to improve and modernize the nation's Space Lift Range System (SLRS). The SLRS assets enable the safe and effective launch, command and control, and tracking of Department of Defense, civil, commercial, and international space-lift vehicles, Space Shuttle landings, space surveillance, and ballistic missiles from the Eastern Range (ER) at Patrick Air Force Base, Florida, and the Western Range (WR) at Vandenberg Air Force Base, California.

The prime purpose of the Western Range Central Telemetry Processing System (WR CTPS) is to support the real-time acquisition, decommutation, processing, and display of telemetry data during launch boost phase of Space Lift and Ballistic Missile Operations at the Western Range. This function is performed using dual redundant functional strings of equipment to prevent the loss of data in the event of a single failure in either hardware or software. This data is used by Range Safety systems to permit good vehicles to continue to fly during launch operations and to protect life and property from errant space launch vehicles and ballistic missiles. The WR CTPS is also used to support the collection and processing of telemetry data from Post Boost Vehicles (PBVs), satellites on orbit, and aircraft tests in conjunction with the Air Force Flight Test Center (AFFTC) and operations in the West Coast Off-shore Operations Area (WCOOA).

The WR CTPS includes sufficient quantity of hardware to support at least two concurrent Flight Operations with redundancy for prime and backup support of each of these operations. As well as supplying data to the Range Safety system, the WR CTPS collects and distributes data to the user community comprised of launch vehicle and vehicle component manufacturers. WR CTPS provides sufficient equipment to support 7 separate Quick Look Display Areas for user support.

WR TELEMETRY (TM) SOURCES AND BEST SELECTION

There are four geographically separated telemetry receiving sites in the WCOOA. Three receive primary and alternate feeds via separate antennas. Thus, dual redundancy begins well in advance of the WR CTPS. The telemetry receiving sites transmit the launch vehicle telemetry to the WR Range Operations Control Center (ROCC) through the Post-Detect Telemetry System (PDTS). It transports digital post-detect telemetry data from the telemetry receiving sites as multiplexed streams. As shown in Figure 1, the primary and alternate aggregate PDTS data streams from the telemetry receiving sites are demultiplexed by Wide Area Network Interface Units (WANIU) into separate PCM streams. Isolation and decryption is applied to the demultiplexed PCM streams as required.

The separated PCM streams are then input to primary and secondary Best Input Source Selectors (BISS). From RT Logic’s April 2005 press release, the primary function of the BISS is to assist range operators in identifying, at any given time during a launch, the “best” telemetry receiving site available and switching the telemetry from that site to the WR CTPS for decommutation and processing. Automated selection of the “best” telemetry source is based on the range count (time) and quality of the range safety link(s) from each telemetry receiving site. The BISS also accepts operator input to override its automated selection. Along with Range Safety data, information on the currently selected telemetry receiving site is sent to Flight Operations (FO) by the WR CTPS.
Figure 1: WR CTPS TM Source/BISS Configuration

Figure 2: WR CTPS TM Processing Configuration
WR CENTRALIZED TELEMETRY PROCESSING

Figure 2 shows the configuration of one WR CTPS system. It receives its telemetry data from the BISS (at left of Figure 2) and transmits Range Safety data to Flight Operations (FO) range safety workstations (at center of Figure 2). BISS and FO are the prime external interfaces of WR CTPS.

WR CTPS has been architected as dual redundant functional strings of hardware, referred to as “Side A” and “Side B”. Each side consists of one L-3 Communications Telemetry-West Vista 550 Telemetry Station (TS), one Range Safety Server, two Control Workstations, and one Data Consolidation Workstation. Common to both sides and connected by gigabit Ethernet switches are the Data Consolidation Server and nine Display Workstations for Range users. Common to both systems are three more Display Workstations for Flight Operation Project Officers (FSPOs).

The balance of this paper addresses the purpose and configuration of each of these categories of components. Before proceeding, however, note that Figures 1 and 2 taken together represent one dual-redundant configuration that supports a single Flight Operation. A quantity of hardware has been supplied sufficient to support at least two concurrent Flight Operations with redundancy for prime and backup support for each. Consider the full system then as Figures 1 and 2 taken twice.

WR CTPS TELEMETRY STATIONS (TS)

The role of the TS is to acquire, decommutate, process, and distribute real-time data for storage, display, limit processing, event detection, and command verification. It also replays stored data for subsequent review, analysis, simulation, and rehearsal. The telemetry is NRZ-L/-M/-S PCM of up to 30Mbps in Class I/II formats per IRIG 106-01, Part 1. Figure 3 shows TS configuration.

Each TS is a L-3 Communications Telemetry-West PRO550A Base System Chassis containing:

- 8 Bit Synchronizers (Model BSZ532) for up to 30Mbps NRZ-L/M/S telemetry streams
- 8 Decommutators (Model DCZ534) for Class I and II formats per IRIG 106-01, Part 1
- 4 real-time processors (Model FPP5) for manipulation, EU conversion and distribution of data from full-rate vehicle streams using libraries of standard and custom algorithms
- 1 Multi-format Dynamic Simulator (Model XDS541) for dynamic PCM simulation
- 3 Time Code Generator/Translators (Model TCM542) for IRIG A, B, and G codes
- 1 hot-swappable SCSI storage for post-test review, analysis, simulation, and rehearsal
- 1 System Controller (MVME2304) for asset status, setup, and fault detection/isolation

L-3’s PRO550A Base System Chassis accommodates up to 20 VME modules. The P1 and P2 connectors of the standard VMEbus backplane provide the means for module control and low-rate data passage, while P3 - the MUXbus II - merges very high-rate data to 16M samples per second. The Bit Synchronizers and Decommutators are PCI Mezzanine Card (PMC) modules which are attached to four 550 VME PCI Mezzanine Carrier modules. This explains how the total module count can exceed 20, i.e., not all are VME modules. The 550 System Controller and FPP5 processors are diskless nodes that use FTP to load their real-time VxWorks kernels from a workstation during boot and then use NFS to access file systems from the workstation.
WR CTPS WORKSTATIONS (WS)

WR CTPS workstations are PC’s in two configurations. Each runs Microsoft Windows 2000 SP4 and L-3 Communications Telemetry-West *Vista550* software. A designator M or Z accompanies workstation descriptions below to identify their configurations. PC configurations are as follows:

- IBM Intellistation M Pro 2D PC; 2.67GHz single P4; 533MHz FSB; 512KB cache; 64MB video; dual monitor; 1GB RAM; and 120GB removable HDD
- IBM Intellistation Z Pro 2D PC; 2.67GHz dual Xeon; 533MHz FSB; 512KB cache; 128MB video; one monitor; 1GB RAM; and 120GB removable HDD

**Range Safety Server (Z)**

The Range Safety Server receives real-time range safety data from the TS, stores it in Telemetry Data Element (TDE) format, and transmits this information, along with the current site selected by the BISS, to FO range safety workstations. The TS and Range Safety Server are critical real-time components per side. If either is not available, the side is not available. For this reason, the Range Safety Server is also the FTP boot/NFS file server for TS System Controller and FPP5’s.

**Control Workstations (M)**

These dual points of setup and control for the TS on a given side enable WR CTPS operators to:

- Develop, retrieve, and monitor operation-specific configurations for BISS
- Build, store, and retrieve versions of operation-specific TS configurations
- Develop operation-customized algorithms, applications, and data displays
- Compile and load operation-specific configurations to Telemetry Stations
- Provide operators with graphical and numeric displays and local storage of real-time data and then post-test analysis of data from TS and local storage
Displays Workstations (Z)

These workstations are equipped with dual gigabit Ethernet NIC’s which enable access to both sides, providing Range users and Flight Safety Project Officers with the following capabilities:

- Enable users to build, store, and retrieve versions of customized displays
- Provide users with graphical and numeric displays and local storage of real-time data, then post-test analysis of data from TS and local storage
- Incorporate the enhanced capabilities offered by the Astro-Med Everest Visual Display (VDiS) strip chart display and analysis software package

Data Consolidation Server (Z)

This workstation is the repository for operation-specific configurations and customized displays. These are maintained in a central Database Management System (DBMS). As both sides require access to this information, the workstation is equipped with dual gigabit Ethernet NIC’s. Should the DC Server not be available, neither will the DBMS. Therefore, it is a critical resource. Once an operation is up and running, however, real-time processing does not require access to DBMS.

Data Consolidation Workstation (M)

This workstation is a standalone environment for developing operation-specific configurations and customized displays without access to a Vista550. These are stored in a local DBMS. They must be exported subsequently and imported into the central DBMS for checkout on either side.

L3-TW VISTA550 SOFTWARE

Telemetry applications on all WR CTPS TS and WS are performed by L3-TW Vista550 software. Vista550 is a versatile Java-based ground system which facilitates decommutating and processing telemetry data by managing Vista-compliant modules and monitoring event information. Modules are managed on a project basis, using a SQL-compliant database and a client-server architecture.

Because the Vista WS software is Java-based, it is supported on multiple platform types including Microsoft Windows, Sun Solaris, and Red Hat Linux. Several SQL-compliant databases are used: Microsoft Desktop Engine (MSDE), Oracle and PostgreSQL. Regardless of platform or database, key Vista concepts and services discussed below and depicted in Figures 4 and 5 remain the same.

Key Concepts

Module
- Any 550 hardware or WS software component which operates upon the telemetry data and passes it along to other Vista-compliant modules and/or to requesting applications.
- Operation-specific configurations are defined and stored with respect to module types. This enables a configuration to be assigned from a failed module to an operational one.
**Project**
- Identifies the modules and the specific configuration of each required for an operation.

**Database**
- Repository for module configurations and their operation-specific project assignments.

**Event**
- Notification regarding a significant occurrence detected by and conveyed within Vista.

**Client-Server**
- A network architecture, supporting distributed processing, in which one or more instances of client applications (often GUIs) send requests to single-instance servers that fulfill them.

**Key Services**

**Module Servers**
- A module server is instantiated for each of the 550 hardware and WS software components
- Each server is responsible for performing setup and control operations requested by client applications upon its module as well as for obtaining and reporting the status of its module

**Project Manager Server**
- In conjunction with Module Servers, manages ownership of modules delegated to a project
- Coordinates access to the project and module configurations in the SQL-compliant database

**Database Server**
- SQL-compliant Java Database Connectivity serves the Project Manager Server data requests
- While Vista requires DBMS services, the DBMS is a third-party product (not part of Vista)

**Event Server**
- Events are transmitted to a central hub from which they are distributed to client applications

**Processing Engine**
- Processing module to which clients connect to transfer parameter values to/from a data bus

**System Manager**
- Vista’s highest-level graphical user interface is configured by “properties” file to control and manage standard, optional, and user-created Vista, as well as non-Vista, applications
- While not itself a service, the System Manager provides the means by which to connect Vista apps to a DBMS, Project Manager Server, Module Servers and Processing Engine

**Mapping L3-TW Vista Services to WR CTPS WS**

The architectures shown in Figures 4 and 5 are generic, representing the services to which Vista clients require access without specifying where those services execute. Figures 6 and 7 identify where the Vista services execute with respect to WR CTPS workstations. They illustrate Vista’s client-server, distributed processing architecture at work. The determination of this final service architecture and differentiation in capabilities of the workstation types was facilitated by Vista’s ability to be configured via application “properties” files, a critical aspect of this COTS product.
Figure 4: L3-TW Vista Service Architecture

Figure 5: L3-TW Vista Event Architecture
Figure 6: WR CTPS L3-TW Vista Server Processes

Figure 7: WR CTPS L3-TW Vista Display Processes
The Data Consolidation Server, ABDATASV at the center of Figure 6, runs no Vista services. It provides the Microsoft Desktop Engine (MSDE) DBMS service which is accessed by both sides.

The Range Safety Servers, {A|B}SAFETY adjacent to the DC Server in Figure 6, were intended originally to run only the LM Range Safety Interface (RSI) application which was developed by using Vista’s API. As its critical nature became evident, the Range Safety Servers’ functionality were extended to include FTP boot/NFS file server for each TS, {A|B}550, as shown in Figure 6.

The Control Workstations, {A|B}CONTROL{1|2} in Figure 6, operate ordinarily in a primary-backup mode with regard to setup and control of the TS on a given side. They are also capable of running separate independent projects. That is, {A|B}CONTROL1 may run a project which requires a subset of the modules in TS {A|B}550, while {A|B}CONTROL2 runs a project that requires any of the remaining modules in the TS. In the former role, they require access to each other’s Project Manager Servers. The latter role requires independent Project Manager Servers. In both cases, common access to the Module and Event Servers is required. Redundancy of the Control Workstations determined that all of these services must run on the Range Safety Server.

The Display Workstations, ABDISPLAY{1|2|3}{A|B|C} and ABFSPO{1|2|3) in Figure 7, and the Control Workstations run Vista GUI’s to access the Vista functionalities allotted to them. In particular, this means that each runs the System Manager application, Vista’s highest-level GUI, locally. Connections to a DBMS, Project Manager and Module Servers, and Processing Engine are established by the System Manager and passed to Vista applications, such as Data Displays, started from it. Either Project Manager Server is accessible to a Control Workstation on its side only and to Display Workstations on both sides as indicated by the red nodes in Figures 6 and 7.

CHALLENGES AND LESSONS LEARNED

Challenges presented by WR CTPS involved the large number of workstations, specialization of the functions assigned to each, and allocation of L3-TW Vista services to support fault-tolerance.

Simply installing L3-TW Vista software on the workstations was time consuming because of the number. This process was aided by L-3’s development of configuration overlays, customized by workstation, that were applied after a standard L3-TW Vista release was installed. Each overlay contains the Vista application “properties” files customized for that workstation, eliminating the need to re-apply customizations manually which can be both time-intensive and subject to error.

The properties files perform the dual critical roles of assigning which functions a workstation can execute as well as identifying to which specific workstations L3-TW Vista services are allocated. The files are processed by the L3-TW Vista applications during initialization. So, behavior of the system is customized through the files, not by customization of the applications themselves. This enables future standard L3-TW Vista releases to be installed without loss of existing functionality.

Determining the allocation of L3-TW Vista services to the WR CTPS WS was the chief challenge. Initially assigned to the Control Workstations, they migrated to the non-Vista Range Safety Server as L-3 and LM realized that a side is non-functional without this node and its TS. These nodes are now the heart of the system, sending range safety TDE’s to FO and hosting L3-TW Vista services.