LOW EARTH ORBITER TERMINAL (LEO-T)

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ABSTRACT

The Low Earth Orbit Terminal (LEO-T) developed by AlliedSignal for NASA Wallops is a fully autonomous satellite tracking system which provides a reliable, high quality, satellite data collection and dissemination service. The procurement was initiated by NASA, in an effort to provide more tracking capacity with a decreasing budget. A large mission set of NASA satellites in the next decade will not require the performance of existing large aperture systems. NASA is planning to use the larger aperture antennas to only support those missions needing the higher performance. The remainder of the missions will be supported with the smaller LEO-Ts, which are smaller, significantly less expensive, and fully automated. The procurement is also an attempt at a first step towards fostering commercialization and privatization of small station acquisition and services. The system design features a modular architecture to simplify integration and to support affordable future expansion.

This paper begins with a brief summary of the LEO-T program, then provides the design details and capabilities of the LEO-T system.

KEY WORDS

Autonomous, Front End Processor, CCSDS and TDM Telemetry, Low Earth Orbit

INTRODUCTION

The emerging small satellite programs have a substantial percentage of near-polar missions with frequent downlinks of sizable quantities of data. Typically, the period of time from conceptual design to satellite launch for these programs is on the order of three years. Additionally, these missions will not always be under a NASA Center’s project management and control, and may desire to implement their own distinct operational practices without being burdened by significant bureaucratic interfaces. NASA recognized that an infrastructure of small ground stations would prove to be operationally effective, flexible and provide additional costs benefits. The LEO-T program is in response to NASA's need for a system design that provides a flexible, tailorable, communications link between designated flight mission centers and their satellites without manned intervention, while facilitating ease of operation and maintenance.

LEO-T DESIGN OVERVIEW

The LEO-T is a small autonomous terminal tracking low Earth orbiting spacecraft. The antenna is an elevation over azimuth with a 7 degree tilt program tracking pedestal with a 5 meter reflector. The complete antenna subsystem is housed within a 28 foot sandwich type radome. The LEO-T supports the 2025 to 2120 MHz uplink band and the 2200 to 2300 MHz receive band with 8 to 8.5 GHz receive available as an accessory. The RF subsystem employs a polarization diversity feed with optimal ratio combining and supports FM, PM, BPSK and QPSK modulation types with up to 8 MBps data rates. The Autonomous Control and Processing subsystem (ACPS) supports Consultative Committee for Space Data Systems (CCSDS) compliant and Time Division Multiplexing (TDM) telemetry processing with over 9 gigabytes of telemetry data storage capacity. Telemetry data transfer to users is performed either real-time or post-pass via File Transfer Protocol/Internet Protocol (FTP/IP) or User Datagram Protocol (UDP). Real time and 'store and forward' spacecraft commanding is supported. Complete telemetry and command simulation capability is available to users pre-pass and via schedule request for system validation and user system's check out. The LEO-T will autonomously support up to 100 different configuration setups. The high-level design for the LEO-T is shown below Figure 1.

AUTONOMOUS OPERATION

The LEO-T is designed to function reliably in a fully autonomous environment. LEO-T autonomy relies on a robust schedule that may be modified by remote users and the system administrator. Spacecraft in the mission set are scheduled for normal operations according to the priority they have been assigned by the system administrator. The station will operate for extended periods of time with no intervention other than periodic scheduling contacts. Schedule execution initiates equipment configuration, including establishing the communications link to the user, and automated testing and pass support activities. The LEO-T concept is depicted in Figure 2.

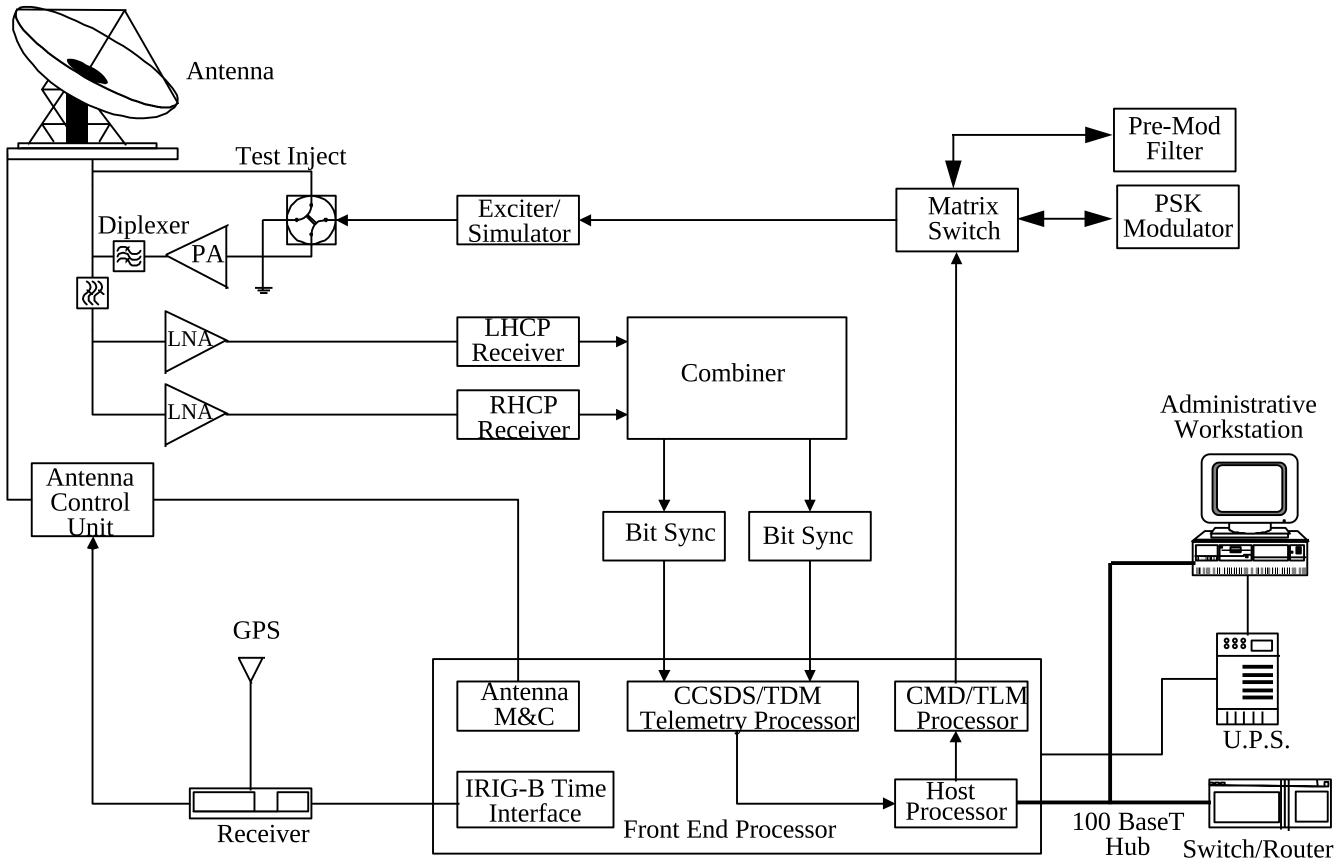

FIGURE 1 LEO-T High Level Block Diagram

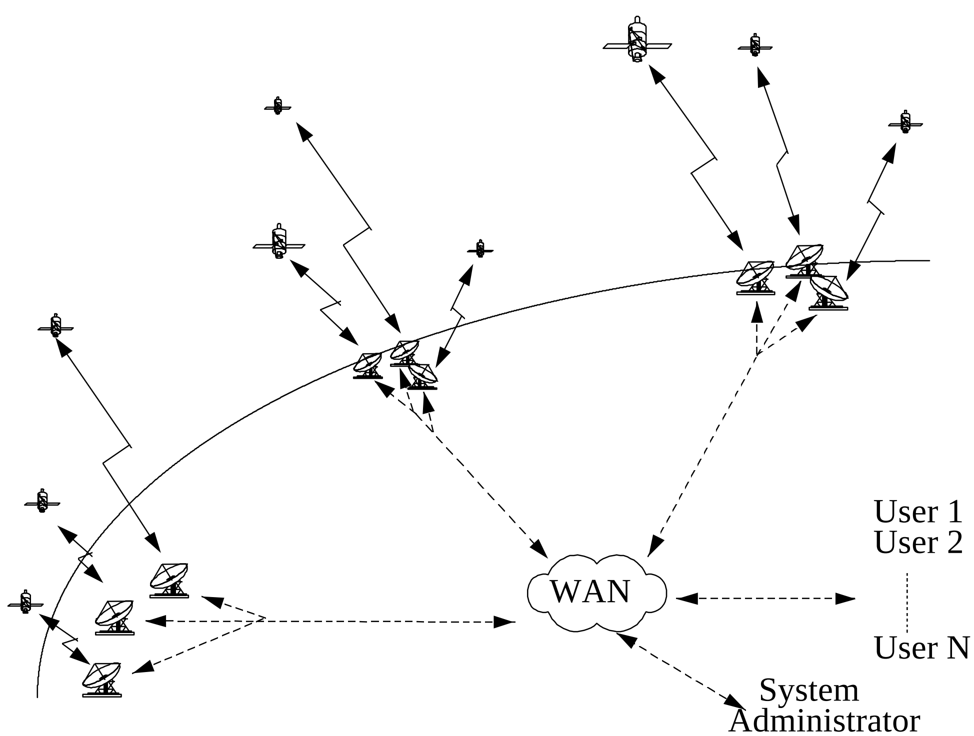

FIGURE 2 LEO-T Concept

AUTOMATED CONTROL AND PROCESSING SUBSYSTEM

The heart and soul of the LEO-T is the Autonomous Control and Processing Subsystem (ACPS), depicted in Figure 3. The ACPS utilizes a distributed architecture consisting of a UNIX based Pentium PC Administrative Workstation (AWS) running a SUN Solaris Operating System and a VME based Front End Processor (FEP) running REAL/IX Real Time UNIX Operating System. Both computers are interconnected via a LAN. All hardware and software components conform to industry standards for open systems and consist of commercial-off-the-shelf products.

The FEP performs the real-time processes while the AWS handles off-line or non-real-time processes. The segregation of real-time and non-real-time functions helps to maximize real-time responsiveness while eliminating interference of off-line administrative functions with real-time data processing. Separation of these processes is transparent to local and remote users, providing a look and feel of a single, unified system. Control directives received from the users are transferred automatically by the AWS to the FEP for execution. Similarly, equipment status is transferred from FEP to AWS for local/remote display.

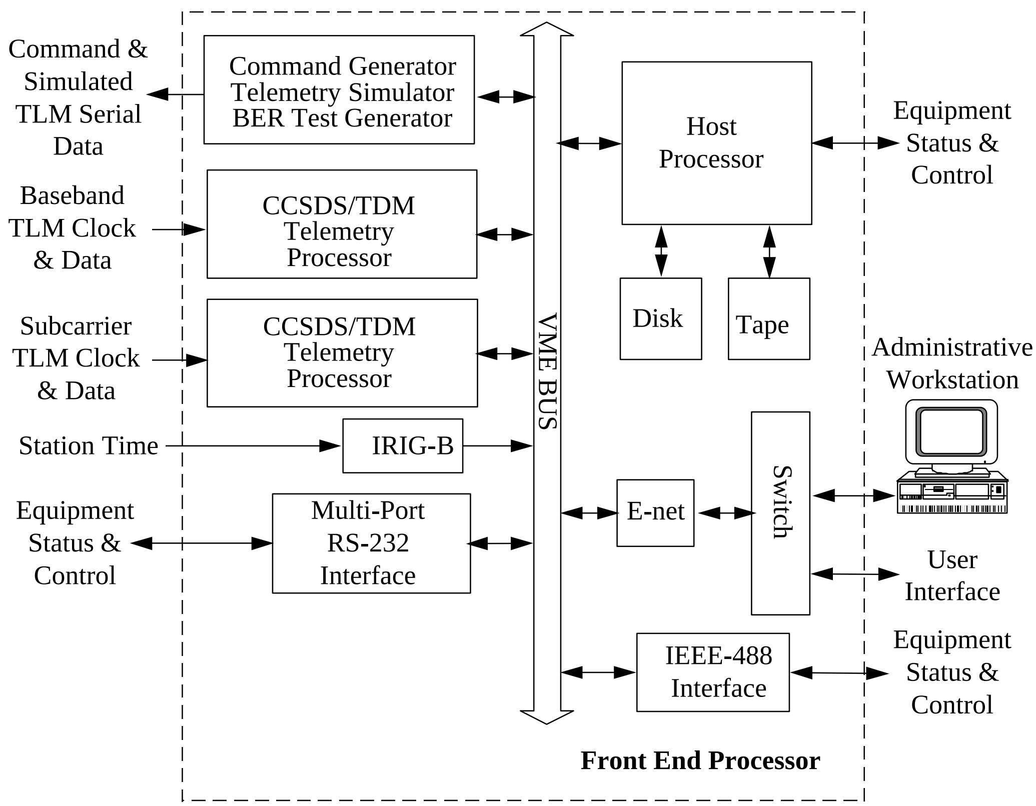

FIGURE 3 ACPS Block Diagram

TELEMETRY PROCESSING

The LEO-T supports both CCSDS and TDM formats using the same software and hardware. Figure 4 provides the basic structure for telemetry processing. All configuration operations may be accomplished either from the Administrative Workstation or via an X-Windows interface.

Initially, the pass configuration is retrieved from the stream database. Separate database definitions are kept for each mission supported allowing up to 5 different configurations for 20 or more missions. The database parameters define the equipment setup and routing characteristics while real-time control is performed by the stream manager. By design, no operator intervention is required because schedule execution plus database definitions provide full automation. User interface functions, however, are provided for monitoring and controlling the telemetry processing operations, responding to anomalies, performing analysis and troubleshooting, and overriding default schedule activities.

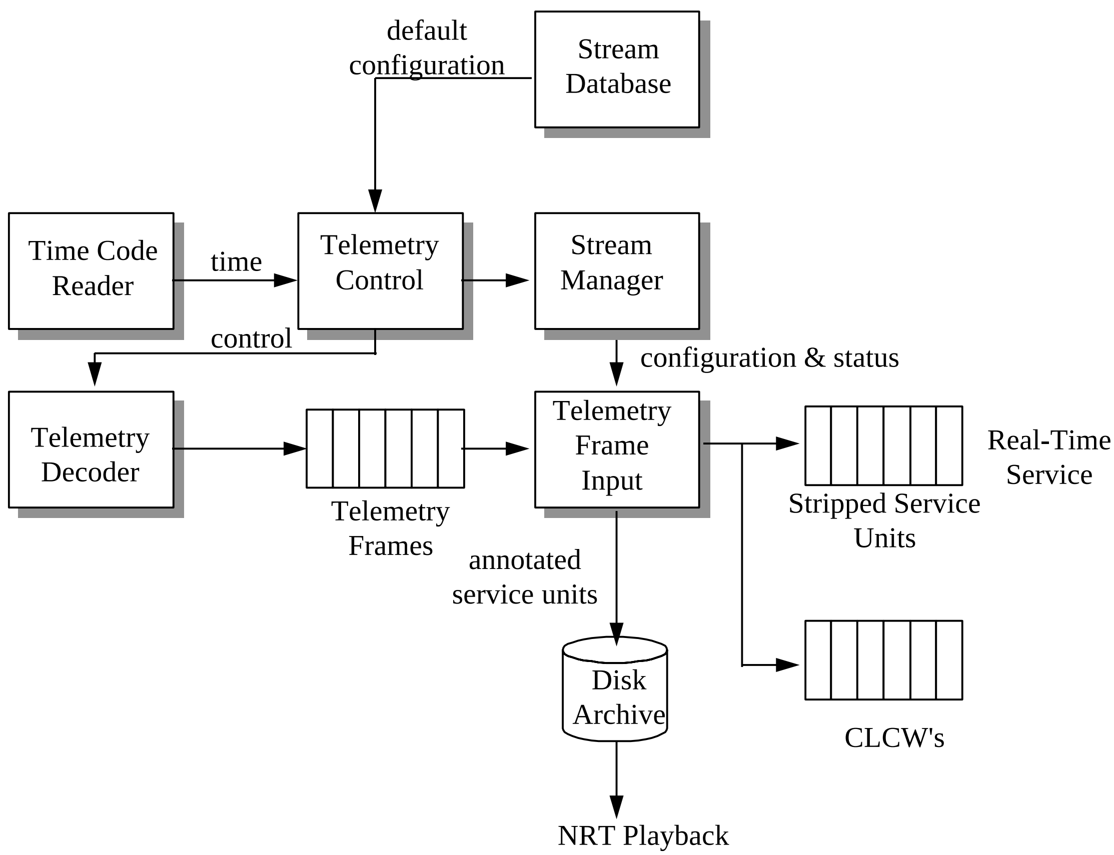

Figure 4 Telemetry Control

Run-time status and quality data are maintained in global variables and are accessible remotely via an X-Windows interface for real-time inspection. Errors and anomalies, such as data dropouts, decoding errors, and flywheeling, are written to an events log. Additionally, the system provides for data archiving, data strip and ship per configuration specification and Command Link Control Word (CLCW) output for CCSDS Command Operations Procedure-1 (COP-1) protocol verification.

SATELLITE COMMANDING

The LEO-T supports both real-time satellite commanding and store and forward commanding. Software controls command sequencing and serialization while the hardware supports CCSDS encoding and older TDM standards.

For real-time commanding, command blocks are received in real-time in TCP/IP packets. Each block is validated to ensure that the block header data matches the configuration per the database in terms of type, source code, and spacecraft code. Command frames are then extracted and transferred to the encoder for uplink. The software performs timing and sequencing of output via the serializer/encoder board. The uplink defaults to an idle pattern between transmission blocks.

MONITOR AND CONTROL

The LEO-T software provides the capability for automated monitoring and control of all the station equipment, including the antenna subsystem, RF, and baseband equipment. Communications to the equipment is performed by the FEP via IEEE-488 and RS-232 interfaces. Control directives, output bit patterns, and status return decoding are defined within the system database. Sampled status is output to a log and remotely via the TCP/IP status service. Control directives may be entered manually through the X-Windows interface or automatically via the scheduling functions. Figure 5 provides a high level overview of the monitor and control structure.

Devices are polled periodically for status. System globals are then updated based on the returned status. Globals are visible to all authorized users of the ground system while user defined values are written to a status log and reported to the users via the WAN. Out of tolerance values, whose limits are pre-defined within the database, result in the generation of alarms and events. Devices that fail to respond to status poll requests are marked as failed within the system globals and an alarm is generated. Event and alarm messages are written to the station log and may also be received in real-time by remote users. This log acts as the centralized record of all significant station activities. The log contents include error and event messages, equipment control directives and schedule execution steps. Each entry is time tagged to the nearest second and contains the source of the message. Specific

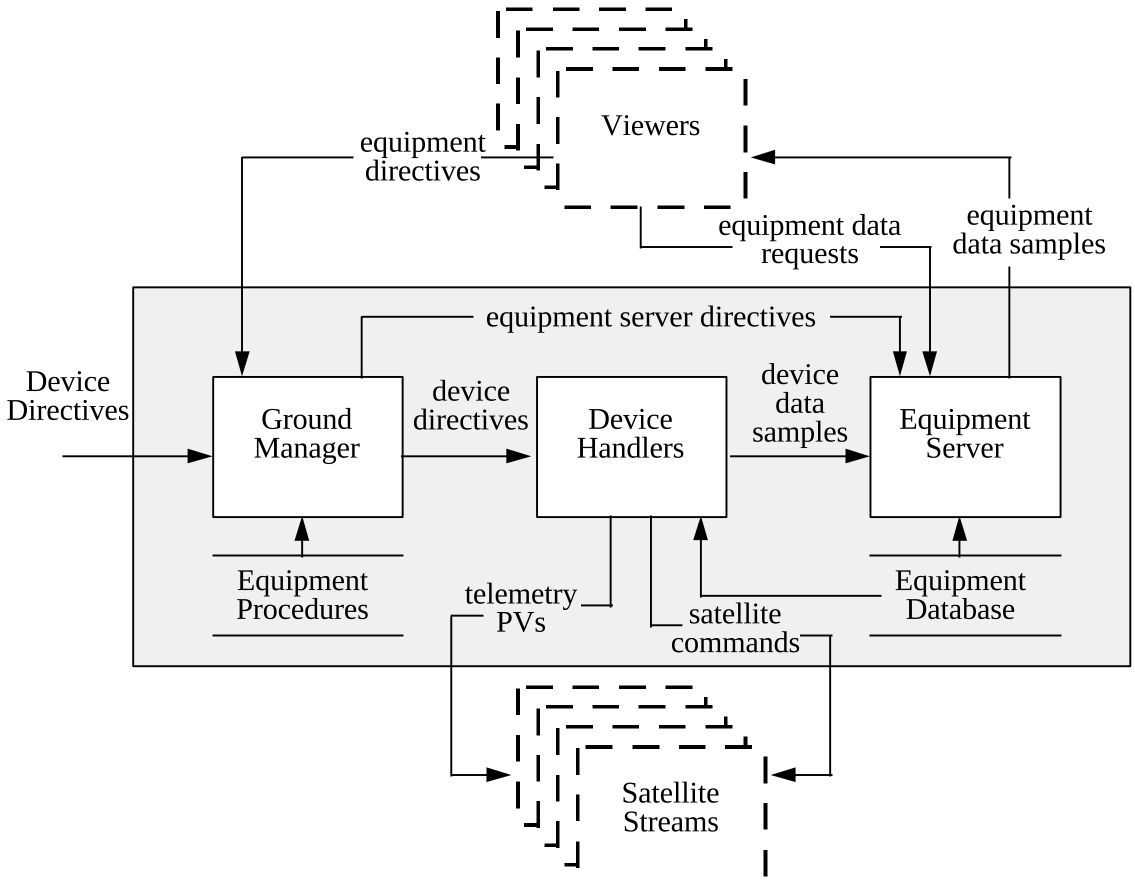

Figure 5 Monitor and Control

pass summary information will include items such as the antenna angles at AOS and LOS, total telemetry frames received, total bad frames received, total commands transmitted and total command re-transmissions. Additional trace information, recorded at 10 second rates, will include station time, antenna angles, receiver signal levels and receiver lock status.

AUTONOMOUS OPERATIONS

The key to the autonomy of the LEO-T is the system scheduler consisting of two components: schedule generation, and schedule execution. The output of the schedule generation process is a script file which is directly executable by the FEP. Upon execution, the schedule calls lower level procedures for performing standard operations. The scheduling script file controls the sequence of events while configuration details are maintained in the system database. Scheduling is accomplished nominally on a 7 day cycle but may be reconfigured by the system administrator for different cycles.

A contact display of all potential satellite contacts over the scheduling period is available to the user. Schedule requests are submitted in a pre-defined file format and are error checked with error messages being reported back to the user. Schedule conflicts are resolved on a strict priority base. New schedules are appended to old (active) schedules to prevent coverage gaps during the schedule transition as well as allow users to view history across the transition.

Once a schedule has been created, it may be edited and reconfigured remotely through an interactive X-Windows display. The display shows the satellite ID, configuration number, pass status (partial/entire), AOS date, AOS & LOS time, and command service requested. Control capabilities include additions and deletions of passes, pass parameter modifications such as AOS/LOS time, the configuration number, and the type of command service requested. Users may only modify scheduling parameters associated with their satellite. The system administrator has additional capabilities not available to the user, such as designating reserve periods for ground station maintenance, and controlling the schedule in real-time by performing schedule start, stop, and abort functions.

Each satellite pass is handled automatically via the system scheduler. Pre-pass operations include configuring the satellite and ground equipment streams, opening the pass log file, establishing user socket connections, configuring the ground equipment and performing a BER loopback test. Upon completion of the loopback test, the antenna is positioned to the predicted location for acquiring the spacecraft. Pass support activities include acquiring the spacecraft downlink, uplinking commands, and receiving, transmitting and archiving telemetry data. Post pass activities include the flushing of all buffers and temporary files, termination of real-time socket connections, and post pass FTP transfers.

CONCLUSION

The large mission set of NASA satellites forecast for the next decade does not require the performance of existing large aperture systems. The push is to provide ground systems which are smaller, significantly less expensive, and fully automated. The LEO-T developed by AlliedSignal for NASA Wallops is a state-of-the-art, fully autonomous satellite tracking system leveraging off recent advances in the commercial sector for computing, software, RF technology, and networking.