EOSDIS TEST SYSTEM (ETS) HIGH-RATE SYSTEM (HRS)

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ABSTRACT

NASA's use of high bandwidth packetized Consultative Committee for Space Data Systems (CCSDS) telemetry in the Earth Observing System (EOS) mission presents a great challenge to ground data system developers. The EOS mission calls for high data rate interfaces and small packet sizes which would dramatically increase the real-time workload on ground packet processing systems.

NASA's Goddard Space Flight Center (GSFC) has been developing packet processing subsystems for over a decade. This paper will discuss the design of a high-rate telemetry test system and a simulation software package. The system will support CCSDS telemetry formats and perform frame synchronization, error detection and correction, packet reassembly and sorting, error checking, and data set creation. In addition, a highly automated operation environment is designed to minimize human intervention in control and monitoring, and data distribution. The design is based on a Very Large Scale Integration (VLSI) Level Zero Processing (LZP) System technologies, VLSI telemetry data simulation and processing functional components, Object-Oriented Design methodologies, C++ programming environment, shareware and Open Software Foundation (OSF)/Motif-based Graphical User Interfaces (GUI).

KEY WORDS

Telemetry Protocol Processing, Real-time Processing, Test & Simulation.

INTRODUCTION

The EOS Data and Information System (EOSDIS) Test System (ETS) High-Rate System (HRS) was developed by the GSFC Data Systems Technologies Division (DSTD), as a part of the ETS project to support EOSDIS system integration, testing, verification, and

validation. ETS HRS was built on existing configurations and most of its components are reused from other DSTD systems. In addition to the reuse, enhanced capabilities such as new high performance mass storage devices, test data update capabilities at 150 Mbps, and high bandwidth requirements, had to be developed. Through prototyping efforts, the team was able to quantify the risk, identify additional development, and select Commercial-off-the-shelf (COTS) components that could meet the requirements at the lowest cost.

The ETS HRS consists of three subsystems: a VME High-rate Subsystem (VHS), a Tape Recording Subsystem (TRS), and a Control and Display Subsystem (CDS). The VHS is mainly responsible for data transmission, capture, and processing functions; the TRS for spacecraft test data storage and playback; and the CDS for user interface and operations control, as shown in Figure 1.

Together, these subsystems will support tests for EOSDIS return link science data processing functions. The Integration, Verification, and Test team for ESDIS also required ETS HRS to have the capability to create simulated spacecraft data and the simulated data products from the ground processing systems. To meet these requirements, a new data simulation tool, known as the Simulated CCSDS Telemetry Generator (SCTGEN) was developed. SCTGEN is based on an architecture that provides a modular and flexible environment. This environment not only supports current data simulation requirements but also allows future development of new data formats and a range of data scenarios.

INTENDED APPLICATIONS FOR HRS

The ETS project is required to support EOSDIS test activities in various test configurations, as defined in the ETS Operations Concept. The HRS will be used to test some of these configurations. The following paragraphs outline the typical usage of the HRS in the test configurations.

ETS HRS SIMULATED RETURN-LINK DATA STREAM

The HRS will simulate the Tracking and Data Relay Satellite System (TDRSS) Ground Terminal (TGT) high-rate interface with EOS Data and Operations System (EDOS) by transmitting up to two channels of serial data and clock at user selectable rates up to 150 Mbps each (Figure 2). The serial data stream will contain Channel Access Data Units (CADU) or Version 2 Transfer Frames (TF) with or without errors. These CADUs may be provided by ETS users, or simulated by SCTGEN, and stored as test data files on disks or tapes. Prior to a test, the user will generate/select test data files. During the test the HRS will transmit the test data and clock at user-selectable data rates up to 150 Mbps.

Figure 2. ETS HRS Simulation Data Flow

One option of simulating this serial data stream utilizes the ETS VHS. In this simulation mode, SCTGEN generates the test data in the form of a 'base' and 'update' file. The 'base' file is loaded on to the Simulator card when the system is set-up for simulation. The update file is previously loaded in to the system disk on the ETS VHS. The test data is output via the front panel data and clock output terminals on the VHS Simulator Card.

The other option of simulating the serial data stream is to use the ETS TRS. In this simulation, SCTGEN generates the test data in the form of a 'plain' file. This plain file is previously recorded on tape media on the TRS. The ETS TRS GUI on the CDS permits the selection of the file to be transmitted at a selected data rate. The tape drive will playback test data at rates up to 150 Mbps.

ETS VHS SIMULATED EDOS BACK-END OUTPUT TO DAAC

The HRS will simulate the EDOS interface with the Distributed Active Archive Center (DAAC) by transmitting Expedited Data Sets (EDS) and Production Data Sets (PDS) through EOSDIS Backbone Network (EBnet) to a DAAC at rates up to 34 Mbps. Prior to a test, the user will select test data sets and the order in which they will be transferred. During the test, the HRS VHS will transfer these data sets to a DAAC. Each data set may consist of multiple files of up to 2 GB each.

ETS VHS SIMULATED DAAC FRONT-END INPUT FROM EDOS

The HRS will simulate DAAC front-end interface with EDOS by capturing EDS and PDS output from EDOS via Ebnet at data rates up to 34 Mbps. The HRS VHS will receive and store these data sets during the test. At the end of a test session, the user will be able to retrieve the received data sets for analysis and verification.

GENERATING DATA SETS FROM S/C TEST DATA

The HRS will perform EDOS-compatible return link processing on user provided test data (CADU) to generate EDS and PDS. The spacecraft developer generates test data during spacecraft testing at the Spacecraft Integration and Test Facility (SCITF) and records the data on AMPEX tape media. The HRS TRS will playback these tapes for the HRS VHS to ingest the data and generate EDSs and PDSs. The ETS CDS retrieves and stores the EDSs and PDSs for analysis and testing.

GENERATING FRAME DATA FILES FROM S/C TEST DATA

In other cases, a user may want to insert errors into spacecraft test data stored on a tape in serial data format. The HRS supports this requirement by performing frame synchronization on the serial data and saving the synchronized CADUs into a frame-aligned data file. The user will then transfer the CADU data file over to the CDS and edit the file using the SCTGEN.

LEVEL ZERO PROCESSING FUNCTIONS

One of the VHS functional requirements calls for generation of EDOS-like EDS and PDS from user-provided spacecraft test data. This requires ETS-HRS to perform Level Zero Processing (LZP) functions, including frame synchronization, Reed-Solomon decoding and error correction, packet extraction and reassembly, sorting and grouping, merging, time ordering, overlap deletion, quality and statistics generation, and data set generation. Figure 3 depicts the required ETS-HRS subsystems during the LZP operation.

The Channel Access Data Units (CADUs) are input into Frame Synchronizer from either Simulator (SIM) card or TRS. After passing the frame synchronization strategy, CADUs are passing on to Reed-Solomon card for error detection/corrections. All good frames are then passed on to Service Processor card for sorting. All sorted packets are passed on to Annotation Processor and Data Set Processor for generation of EDS and PDS.

The design of the ETS VHS configuration was built on two existing systems: the EOS AM-1 Integration & Test system, and the VLSI LZP-II prototype. The former was an high rate grow support system developed for and delivered to the AM-1 spacecraft developer to support spacecraft integration & testing. It features 150 Mbps data simulation and return link processing capabilities. The VLSI LZP-II was a prototype system developed to demonstrate the high rate CCSDS telemetry level zero processing functions using the VLSI technology. Although a prototype, the VLSI LZP-II system architecture, and most of its software, including the core packet processing algorithms, are based on the operational Fast Auroral Snapshot Explorer (FAST) Packet Processing System (PPS) that provides LZP for the FAST Mission Science data. The combination of these two existing systems formed a solid basis for the ETS VHS. Most of their interfaces directly mapped to the ETS requirements. And 80% of hardware and software components were directly reused with minimal modification.

Hence the reuse of the VLSI LZP-II system architecture and software to meet VHS LZP requirements represented a low risk, moderate effort approach that best suited the VHS development.

USER INTERFACE

The ETS HRS uses the Telemetry Processing Control Environment (TPCE) which allows the operator to set up the ETS-HRS, flow data through the system, and monitor system status from a remote (or local) location through an Ethernet connection. TPCE runs on an HP-755 workstation using X-windows. Multiple windows can be open, which provide the operator with a versatile and efficient method to access information, monitor status, and perform tasks.

TPCE receives and sends setup, status, and data through the Master Controller of the ETS-VHS. Information is passed between the two systems packed in Modular Environment for Data Systems (MEDS) messages, which provide the translation of information in a format that ETS-VHS can process and produce.

Control of the VLSI systems is accomplished through editable configuration sets, which include parameters used to specify the nature of telemetry processing. Thus, a VLSI system can support various types of telemetry processing, simply by loading different configuration sets. The TPCE system provides graphical displays that present the current status of telemetry processing. These displays update dynamically to present data quality information for on-going telemetry processing sessions, present historical, summary data quality and accounting information for processed sessions, and present the status of VLSI subsystems. TPCE also automatically generates reports summarizing the quality and accounting information for completed telemetry processing sessions.

SIMULATION

SCTGEN is used to simulate CCSDS and non-CCSDS telemetry for both forward and return link data streams. When used as a test tool for the EOSDIS it will also simulate EDOS-generated data products, such as EDOS Data Units (EDU), Rate-Buffered Files, EDS, and PDS. SCTGEN will be capable of simulating errored data via error insertion techniques.

DESCRIPTION

SCTGEN will be used as an offline tool to generate test data, and as such will not present a schedule conflict with operational systems. SCTGEN is written in C++ programming language and uses commercial-off-the-shelf compilers that run on all UNIX platforms. The Graphical User Interface (GUI) is based on graphical representation and has been enhanced with intelligence to ease the cumbersome burdens involved in test data specification. The object-oriented approach in developing SCTGEN has decreased the test generation time by two orders of magnitude. Not only can the data be generated faster, but the data can be viewed and corrected more easily and quickly.

DESIGN METHODOLOGIES

SCTGEN was developed using Object Oriented Methodology and using a commercial-off-the-shelf product for diagramming techniques. The choice of the tool was Software Through Pictures (STP) OMT diagramming techniques and rules. These tools use the Rumbaugh approach to object oriented design. In conjunction with the system design specifications for ETS, SCTGEN will reside on the CDS, which is the user-interface for the configuration, command and monitoring of all elements of ETS.

To support automated test operations, SCTGEN will provide a summary of expected results for each test data file generated. Expected results are stored in easily readable formats so that ETS data verification tools can read them in for comparison with actual test results.

SCTGEN LAYERING ARCHITECTURE

SCTGEN is composed of three layer functions as shown in Figure 4. The User will ingest the user's requirement for a data scenario via key strokes and mouse clicks, and in turn generate the scripts necessary to run the lower layers of the system.

The ETS Layer Functions implement the ETS specific processes to produce EDOS data products, i.e. EDS, PDS, EDU etc. The CCSDS Layer Functions are CCSDS specific that follow the CCSDS formats for return link and forward link data generation and manipulation. The Core Functions treat the data in a generic manner. These processes can fill, build and modify any field for any data structure.

There are seven basic Core Function Object Classes in the toolkits that CCSDS classes use to make and handle units such as packets and frames. All the drawings depicting the core functions object classes are OMT diagrams developed using a commercial development package Software Through Pictures. Two definitions are necessary to fully understand the terminology used in explaining the functions and products from the Core Classes.

- **Stream:** A stream can put a random, fixed, or user-specified pattern in to any data region. It can also fill using a file or input from another stream. Streams can either make units or can read complete units from files.
- **Fillers:** Are stream tools to fill data regions in units. For example, a packet stream uses a pattern tool to fill the packet's data region.

DATA GENERATION

The SCTGEN GUI is used to specify the data scenarios to be generated. The Menu Controller or command line input will start up the main panel of the SCTGEN GUI. The main panel or window will allow the user to select the various SCTGEN options. Some of these options are available only after the test data scenario has been designed and formatted as per the user's needs. Two examples of the types of simulated data are described in the following paragraphs.

RETURN LINK DATA GENERATION

The first step is to develop a scenario for data generation. Once the type of data is selected, which in this case is CADU, the scenario icon will open a window that accepts the user input. The information that is input at this stage is the Spacecraft Identifier (SCID), Virtual Channel Identifier (VCID), and Application Process Identifier (APID).

Figure 5. CADU Data Stream

Once these fields are selected the depression of the view button will pop up the next menu panel. From this point on each of the icons shown on the CADU stream menu, shown in Figure 5, open up more detailed windows.

FORWARD LINK DATA GENERATION

In this case the formats and recommendations set out in the standards for CCSDS Forward Link Data are followed to produce a Test Data File of Control Link Transmission Units (CLTU). Many Telecommand (TC) packet streams are multiplexed to create a TC Telemetry Frame (TCTF) stream, one per VCID for a SCID. Many such TCTFs, from more than one VCID, are multiplexed to produce a CLTU stream. The CLTU data stream is saved as a Test Data File for forward link. In some instances the CLTUs are grouped to create a Telecommand Data Stream.

SUMMARY

The ETS HRS and SCTGEN have demonstrated the versatility and flexibility in support of the EOSDIS system integration, testing, verification, and validation. Its unique capabilities to simulate realistic spacecraft CCSDS data streams at 150 Mbps proved to be invaluable for EOSDIS system integration and test.

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DISCLAIMER

The DSTD works with the GSFC Office of Commercial Programs to commercialize the technologies that it prototypes. The goal of the commercialization effort is to allow NASA to procure low cost/high performance ground acquisition systems for future space and earth science missions. The approach that DSTD uses is to license and commercialize technology prototypes, including chips, boards, and software, through the Office of Commercial Programs.

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