HIGH PERFORMANCE CCSDS PROCESSING SYSTEMS FOR EOS-AM SPACECRAFT INTEGRATION AND TEST

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ABSTRACT

The Earth Observing System-AM (EOS-AM) spacecraft, the first in a series of spacecraft for the EOS, is scheduled for launch in June of 1998 . This spacecraft will carry high resolution instruments capable of generating large volumes of earth science data at rates up to 150 Mbps . Data will be transmitted in a packet format based upon the Consultative Committee for Space Data Systems (CCSDS) Advanced Orbiting Systems (AOS) recommendations.

The Data Systems Technology Division (DSTD) at NASA's Goddard Space Flight Center (GSFC) has developed a set of high performance CCSDS return-link processing systems to support testing and verification of the EOS-AM spacecraft . These CCSDS processing systems use Versa Module Eurocard bus (VMEBus) Very Large Scale Integration (VLSI)-based processing modules developed for the EOS ground segment to acquire and handle the high rate EOS data . Functions performed by these systems include frame synchronization, Reed-Solomon error correction, fill frame removal, virtual channel sorting, packet service processing, and data quality accounting.

The first of the systems was delivered in October 1994 to support testing of the onboard formatting equipment . The second and third systems, delivered in April 1995, support spacecraft checkout and verification . This paper will describe the function and implementation of these systems.

KEY WORDS

CCSDS Processing, VLSI, High Performance Telemetry Processing

INTRODUCTION

The Earth Observing System (EOS) is a NASA science research mission commissioned to provide a comprehensive understanding of global environmental change. The EOS-AM spacecraft is the first of over 15 spacecraft that will systematically measure and study global changes in the Earth's environment .

The EOS-AM spacecraft incorporates a number of high resolution instruments that will be capable of generating enormous volumes of science data . Science data from each instrument will be packetized, multiplexed, and downlinked at very high rates using standard Consultative Committee for Space Data Systems (CCSDS) protocols . The EOS-AM spacecraft will transmit in excess of one Terabit of data per day and at a peak down link data rate of 150 Mbps . In order to accommodate this volume of data, spacecraft integration and test systems will require performance and functionality far beyond those commonly implemented.

To meet this challenge, the Data Systems Technology Division (DSTD) at the NASA Goddard Space Flight Center (GSFC) has developed a new generation of functional components for data systems . These new low-cost subsystems include elements for frame synchronization, Reed-Solomon error correction, and spacecraft telemetry data simulation at sustained data rates up to 150 Mbps . These subsystems have been used in the development of three High-Rate Data Test Equipment (HRDTE) Systems for EOS-AM spacecraft integration and test . The systems support CCSDS telemetry formats and perform telemetry processing functions at rates from 1 bps to 150 Mbps . The systems also support six channels of instrument packet data simulation at rates up to 50 Mbps each. This paper discusses the functions and implementation of the HRDTE Systems.

FUNCTIONAL REQUIREMENTS

The HRDTE System is designed to perform standard CCSDS telemetry processing functions for the EOS-AM mission for spacecraft integration and test . It is being used to verify the functionality of the on-board formatting equipment and the recorder equipment. The HRDTE will also be used in support of spacecraft checkout before launch.

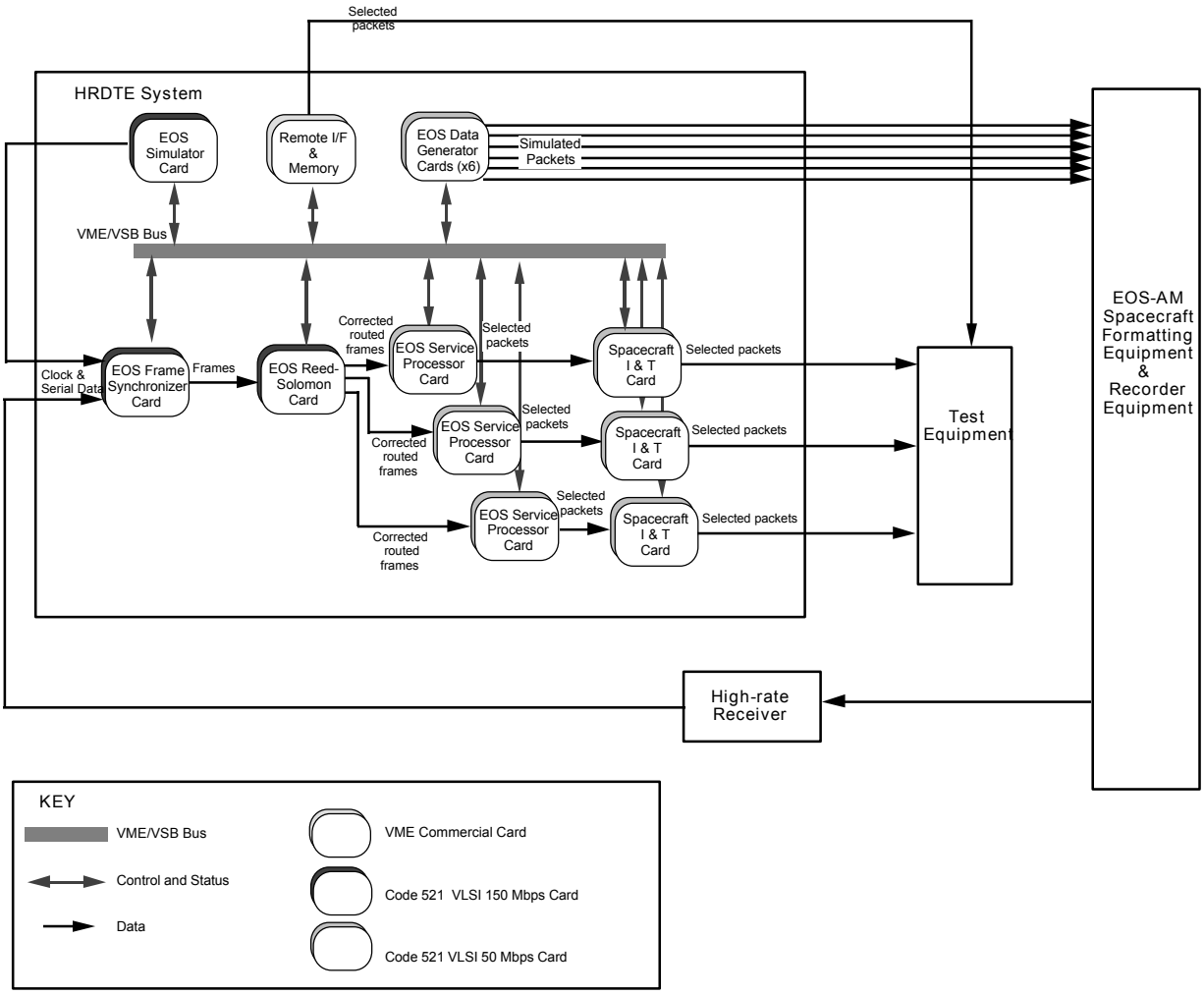


Figure 1: HRDTE System Context Diagram

The HRDTE, shown in the context of testing on-board spacecraft equipment, provides both Instrument Data Simulation and Return Link Processing functions . These processing functions include:

- Provides six independent streams of simulated Transparent Asynchronous Transmitter/Receiver (TAXI) Interface serial packet data for input into the onboard formatting equipment at rates up to 50 Mbps.
- Provides one stream of simulated serial frame data for system loop back self-test at rates up to 150 Mbps.
- Synchronizes to CCSDS frame streams at rates up to 150 Mbps each.
- Detects and corrects errors using CCSDS-recommended Reed-Solomon processing.
- Filters fill, invalid, and/or user-selected frames according to the Spacecraft Identifier (SCID)/Virtual Channel Identifier (VCID).

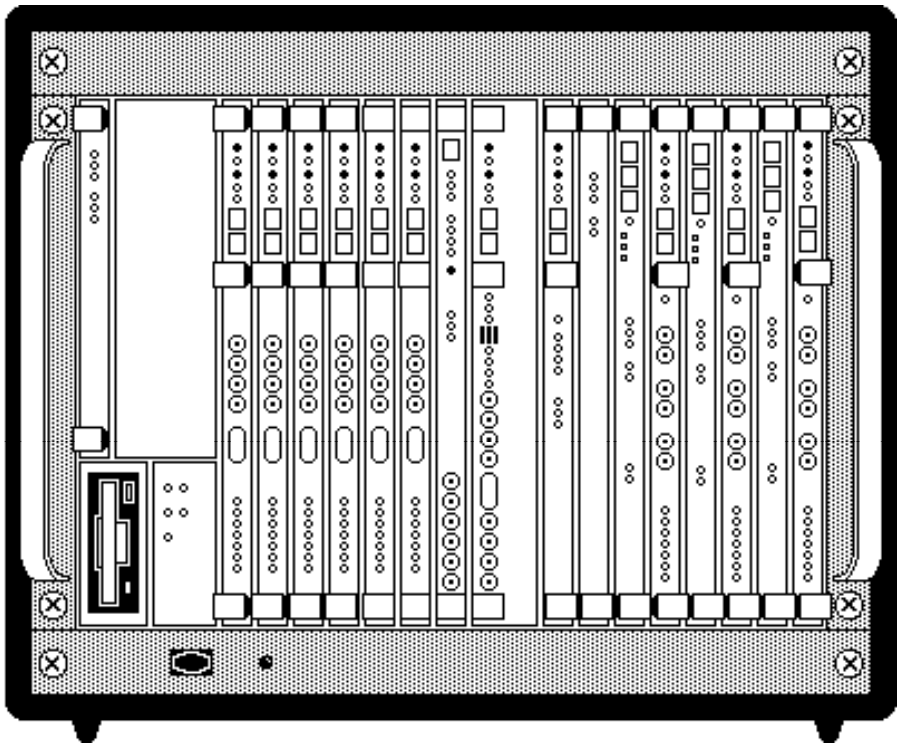
- Routes composite frame stream, with user-selectable SCID/VCID combinations, for packet reassembly and service processing.
- Extracts and reassembles CCSDS Version 1 packets embedded within the frames received.
- Transfers user-selected stream of reassembled packets through an Ethernet link using Transmission Control Protocol/Internet Protocol (TCP/IP) to a user workstation.
- Performs byte-error detection on data field of reassembled packets against a stored data pattern up to 8k in length.
- Forwards selected packets to Instrument Ground Support Equipment via TAXI Interface.

HRDTE IMPLEMENTATION

The implementation of HRDTE emphasizes the use of VLSI technology and industry standard interfaces. Over the past 9 years, the DSTD has developed a set of VLSI Application-Specific Integrated Circuits (ASICs) that perform standard telemetry processing functions. These chips are integrated into a set of custom-designed, reusable cards based on the industry standard VMEBus . Each card performs one or more generic telemetry processing functions, such as frame processing, packet processing, and data simulation. Through the use of high-level integration ASICs and cards, the system achieves high performance, high reliability, and low replication cost.

The integration of custom cards with other Commercial-Off-the-Shelf (COTS) VMEBus components is facilitated by a modular software platform based on a commercial real-time operating system . This platform, known as the Modular Environment for Data Systems (MEDS), allows for generic system level functionality including card configuration and interprocessor communications . With this platform, a system designer can easily select and configure any number of VMEBus processing cards to instantiate a system for mission specific processing requirements . This software platform enables a high-level configurability, reusability, and upgradability in the system.

The HRDTE shown in Figure 2, consists of three commercial and 15 custom VMEBus modules incorporating 22 microprocessors running concurrently . The custom modules perform both Data Simulation and Return Link Processing functions . The Data Simulation functions simulate both payload data and telemetry frame data . The Return Link Processing functions perform frame processing, packet extraction, and data comparison. The detailed description of each module is given in the following section.



Master Controller Card	Global Memory
SCSI Floppy Disk Module	EOS Service Processor Card
SCSI System Disk	EOS Spacecraft Integration and Test Card
EOS Data Generator Cards	EOS Service Processor Card
EOS Simulator Card	EOS Spacecraft Integration and Test Card
EOS Frame Synchronizer Card	EOS Service Processor Card
EOS Reed-Solomon Card	EOS Spacecraft Integration and Test Card

NOTE: Cards are read from left to right.

Figure 2: HRDTE Chassis

DATA SIMULATION

Data Simulation functions are performed by the EOS Simulator Card and six EOS Data Generator Cards designed and built by the DSTD . Their functions are illustrated in Figure 3 in the context of the system data flow diagram.

The EOS Simulator Card provides high-rate telemetry frame data for system self-test and diagnostic purpose. The EOS Data Generator Cards provide up to six TAXI streams of simulated serial instrument packet data for input into the EOS-AM formatting equipment. Simulated data sets for the EOS Simulator Card and EOS Data Generator Cards are generated off-line using a CCSDS data simulation software package developed by the DSTD.

Simulated data sets for the EOS Simulator Card consist of a stream of CCSDS Version 2 Virtual Channel Data Units (VCDU) containing variable length Version 1 Source Packets. These data sets can be up to four megabytes in length and are

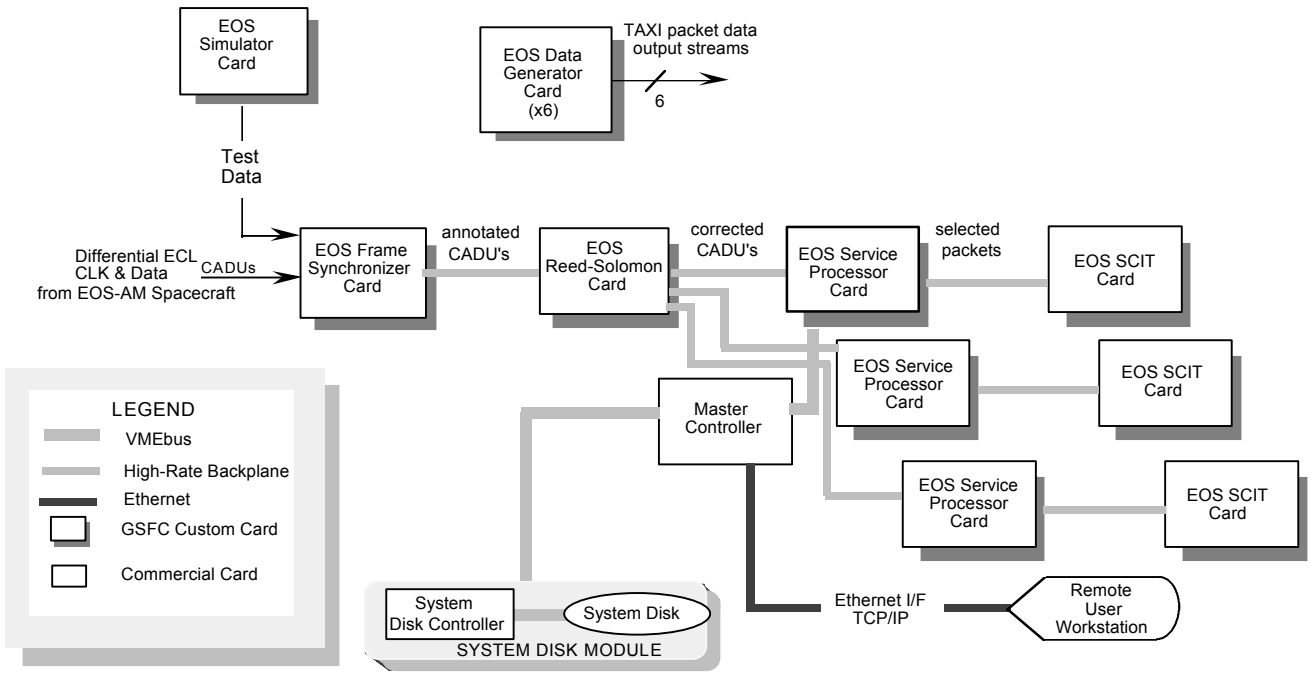


Figure 3: System Data Flow Diagram

repeatable continuously or for a programmable number of times . Simulated data sets for the EOS Data Generator Cards consist of variable length Version 1 Source Packets. These data sets are also up to 4 MBytes in length and are repeatable.

RETURN LINK PROCESSING

The Return Link Processing module consists of the EOS Frame Synchronizer Card, the EOS Reed Solomon Card, three EOS Service Processor Cards, and three EOS Spacecraft Integration and Test Cards . All processing modules are developed by the DSTD. Their functions are illustrated in Figure 3, the system data flow diagram.

The EOS Frame Synchronizer Card receives telemetry clock and serial data and frame synchronizes according to a programmed synchronization pattern and strategy . The EOS Reed-Solomon Card performs Reed-Solomon error detection and correction on the frames. It then routes frames based on SCID/VCID to one of three EOS Service Processor Cards. The EOS Reed Solomon Card also maintains buffers of up to eight frames with Reed-Solomon errors and up to eight frames with invalid SCID/VCID . These buffers can be accessed via Ethernet.

The EOS Service Processor Cards extract packet data pieces from the frames, reassemble source packets, and check for packet errors . They also maintain 32 records of packet/frame errors and detect processing overload conditions . The EOS Service

Processor Cards also route selected packets based on SCID/VCID/Application Process Identifier (APID) to either Ethernet or one of the EOS Spacecraft Integration and Test (SCIT) Cards . The EOS SCIT cards perform byte error checking on selected packet data and outputs selected packets to IGSE via front-panel TAXI interface . They also maintain a 4-MByte snapshot ring buffer of all packet data that enters the card which can be accessed via Ethernet.

CONCLUSION

The function and implementation of the HRDTE used for EOS-AM spacecraft integration and test has been discussed . The HRDTE supports CCSDS telemetry formats and perform frame synchronization, Reed-Solomon decoding, packet reassembly, and packet byte error detection at rates up to 150 Mbps . The systems also supports six channels of packet data simulation at rates up to 50 Mbps each.

The HRDTE are the first systems to use reusable low cost, high performance components developed by the DSTD at GSFC . These components offer unprecedented levels of system performance for CCSDS telemetry data systems . The reuse of these component designs is expected to achieve dramatic savings for EOS and other programs requiring hig data rate handling capabilities.

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NOMENCLATURE

AOS	Advanced Orbiting Systems
APID	Application Process Identifier
ASIC	Application-specific Integrated Circuit
CCSDS	Consultative Committee for Space Data Systems
COTS	Commercial-Off-the-Shelf
DSTD	Data Systems Technology Division
GSFC	Goddard Space Flight Center
EOS-AM	Earth Observing System-AM
HRDTE	Hight Rate Data Test Equipment
Mbps	Megabits per second
NASA	National Aeronautics and Space Administration
SCID	Spacecraft Identifier
TAXI	Transparent Asynchronous Transmitter/Receiver
VCDU	Virtual Channel Data Unit
VCID	Virtual Channel Identifier
VLSI	Very Large Scale Integration
VMEbus	Versa Module Eurocard bus