DESIGN OF THE TOPEX-NFEP UTILIZING THE FUNCTIONAL COMPONENT APPROACH

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ABSTRACT

TOPEX/POSEIDON is a joint American/French Ocean Topography Experiment undertaken by the National Aeronautics and Space Administration (NASA) and Center National d'Etudes Spatiales (CNES) to acquire, process and verify altimetric sea surface height data so that mean and variable geotropic surface currents of the world's oceans can be mapped.

This paper describes the functions and the architecture of the proposed front end to the Telemetry, Command and Communication System (TCCS) used for monitoring the spacecraft health, real time analysis required for supporting satellite analysis, collecting the telemetry data, and commanding the satellite. The system uses specialized hardware developed (herewith called as NFEP) at Goddard Space Flight Center to offload the Host processing and to support the data acquisition in a stand alone mode even in case of failure of the Host machine. The NFEP utilizes the semi-custom and custom very large scale integration (VLSI) devices, microprocessor control, and programmable logic designed to provide a generic NASA Communication (NASCOM) block processing and telemetry frame synchronization.

1. INTRODUCTION

The Jet Propulsion Laboratory (JPL) is involved in performing the TOPEX/POSEIDON mission, a project to study ocean circulation from an orbiting satellite. One subsystem called the NASCOM Front End Processor (NFEP) is tasked with accepting spacecraft telemetry data relayed via the NASCOM Network, and performing certain functions before passing it to the Telemetry and Command (TLM/CMD) Host computers which are part of the TOPEX Ground System (TGS). The basic functions required of the NFEP are to accept inbound NASCOM block formatted data from NASCOM network circuits, identify it as TOPEX realtime (RT) or tape recorder playback (PB) telemetry data or non-telemetry data, process it, temporarily store it if necessary, and forward it to the TLM/CMD Host Computer. The NFEP also receives the outbound data from the Host computer and forwards it on the NASCOM Network. The primary acquisition of the telemetry data, and commanding of the TOPEX satellite, will be the TDRSS; DSN 26 meter ground stations will be used for backup purposes. The TOPEX satellite is capable of sending 2 telemetry data streams; one data stream having the real time engineering data and the other data stream consisting of the on-board tape recorder playblack data usually at 512 Kbps. This data is brought to the NFEP using the NASCOM ground communication facilities.

The minimum requirements for supporting the TOPEX/POSEIDON project for the NFEP is to process the following data items concurrently:

1. Receive the real time engineering data stream at rates up to 16 Kbps.

2. Receive the tape recorder data via the TDRSS or DSN stations at up to 512 Kbps.

3. Send the satellite command data via the TDRSS or DSN stations using a 9.6 Kbps communications link.

4. Support acknowledgement oriented file transfer protocol using the NASCOM block for transferring the file between the Host machine and the external subsystems.

Another unique feature of the NFEP is its ability to buffer the data on a local disc. The data stored on the local NFEP disc can be retrieved by the Host computer at any time via operator request. This allows the telemetry data capture function to continue on without any loss of data even in case of sudden failure of the Host machine

The Data Systems Technology Division (DSTD), at NASA's Goddard Space Flight Center (GSFC), over the last four years, has applied state of the art technology to enhance the performance and reduce the costs of NASA Communication Network (NASCOM) telemetry data systems. As part of this effort, the MicroElectronic Systems Branch of the DSTD, has designed and developed a variety of generic hardware and software processing elements used to capture, process, and distribute NASCOM data. These generic components are part of the functional components approach to the design and implementation of NASCOM data systems (1).

This paper describes the TOPEX-NFEP System to be developed by the Data Systems Technology Divisions for the JPL TOPEX/Poseidon Project and includes a description of the functional components used to greatly reduce the overall development effort and cost.

2. NFEP SYSTEM ARCHITECTURE

2.1 GENERAL

As shown in the Functional Block diagram, figure 1, the NFEP subsystem will accept spacecraft telemetry data relayed via the NASCOM Network, and perform certain functions before passing it on to the Telemetry and Command Computers (Host) which are part of the TGS.

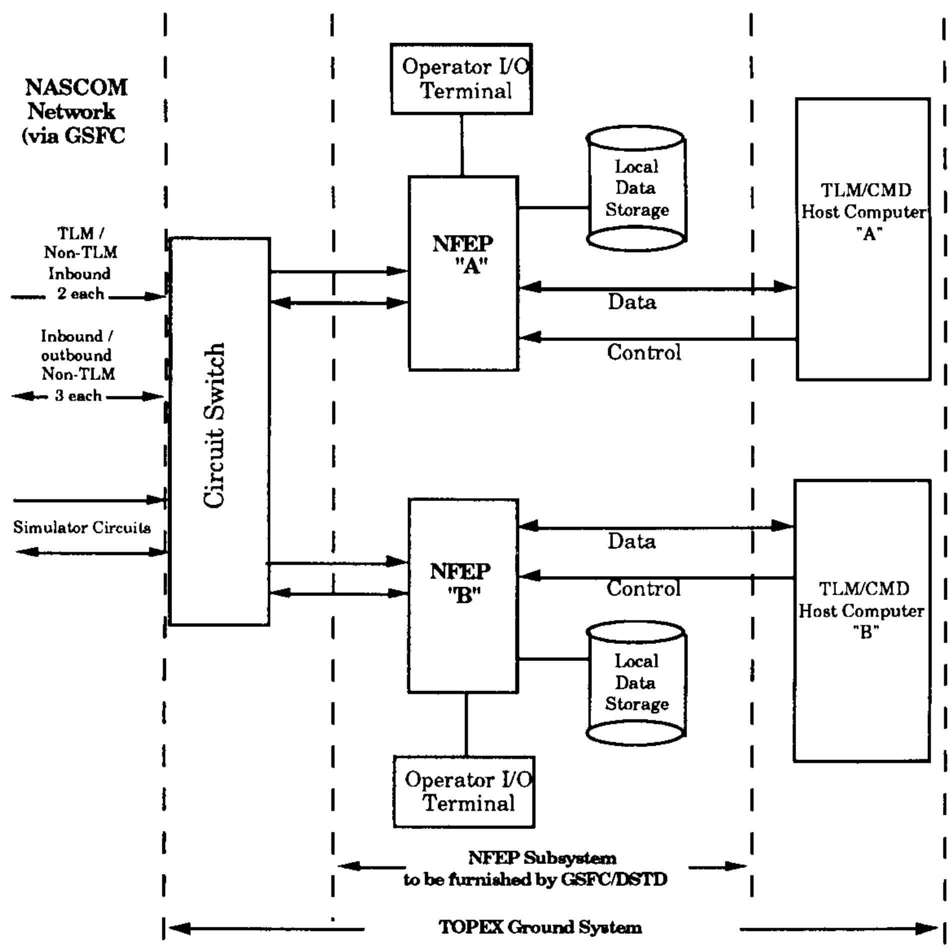

FIGURE 1. NFEP FUNCTIONAL BLOCK DIAGRAM

The architecture of the NFEP is based on the generic data system and subsystem elements developed in DSTD and used in such prototype efforts as the Telemetry and Command Prototype (TRAP)(4) system developed for the Multisatellite Operations Control Center (MSOCC). The generic software environment includes the Base Software Environment (BaSE) (2), used as the realtime development environment and the Multiprocessing Environment for Data Systems (MEDS)(2), used for the control and status monitoring of the system. Additionally generic commercial and custom hardware processing cards are used as the basis for the TOPEX-NFEP processing architecture. Both the generic software and hardware processing elements are all part of the functional components approach.

2.2 SYSTEM DESCRIPTION

The basic configuration of a single NFEP (two are required) consists of: 1) VME standard open bus enclosure, power supply, and a 21 slot backplane including a VME bus (J1 & J2) and a custom telemetry bus (J3); 2) a selection of commercial VME card modules including data buffering; 3) a selection of GSFC custom cards; 4) an operator's console; 5) a real-time, multi-processor operating system (OS) environment; and 6) application programs supporting specific TOPEX - NFEP requirements. The physical diagram of this configuration is shown in figure.2.

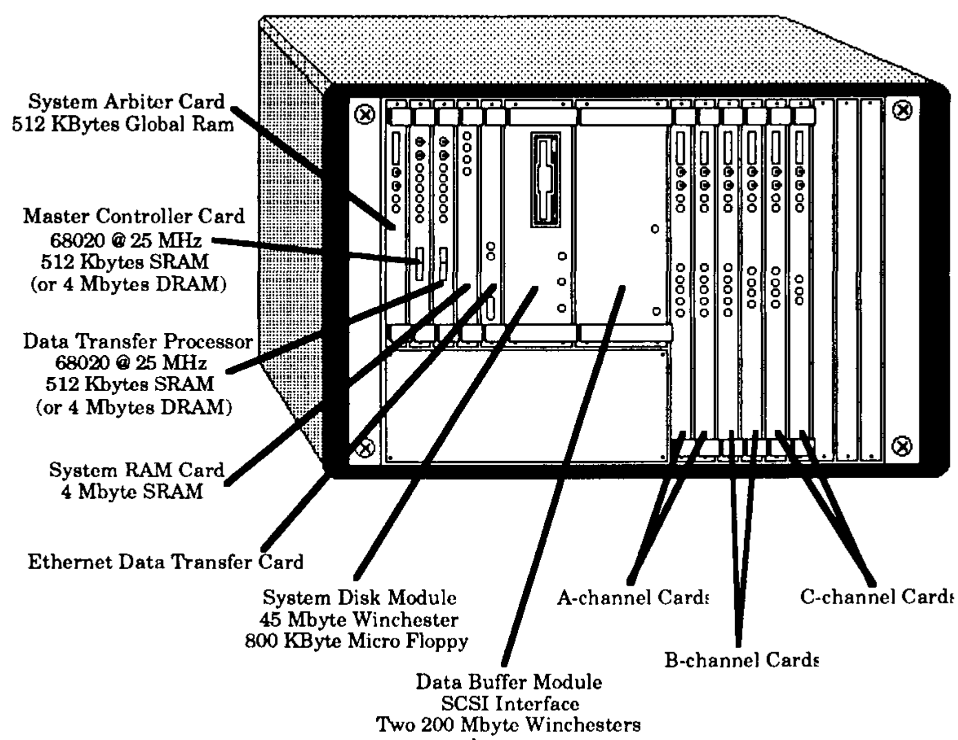

FIGURE 2. TOPEX NFEP SYSTEM CARD CAGE

The VME environment and commercial cards are used to support the general exchange and storage of control, status, and quality data required for local and remote operator console and control operations. These elements provide the general CPU processing, storage, and I/O functions required by the overall system application. They also initiate diagnostic tasks and format test results for presentation as required.

Custom cards and the third bus connector (9U VME card cages are used) comprise the telemetry data pipeline. This pipeline allows both incoming and outgoing telemetry data to be processed and transferred through the system without overburdening the VME bus with every data word transfer. This “pipelined” technique allows great flexibility in the processes performed on the telemetry data and allows for increased data bandwidth. The custom cards directly support the CCSDS standards for telemetry data acquisition and processing through the extensive use of NASA VLSI Application Specific Integrated Circuits (ASIC) developed at GSFC. Each custom card (see FIG. #3) is composed of a custom hardware section especially designed to implement a particular NASA communication functions) and a commercial CPU section used for local and global control/status exchange. These components and card systems provide programmability to support format or operation variations normally encountered during data capture and process operations.

3. TOPEX - NFEP CONFIGURATION

The configuration of a single TOPEX data system NASCOM Front End Processor (NFEP) is shown in FIG. #4. The hardware design of this system will be able to use generic commercial and custom hardware used in the previously developed Telemetry and Command Prototype System (TRAP) System.

Similar to the TRAP System, the TOPEX-NFEP will provide a standard VME platform using commercially available processors, Ethernet communication, disk controllers and storage components coupled with custom logic cards. All cards, both custom and commercial, will run under the PDOS realtime operating system. Generic software elements which include the BaSE and MEDS environments will be used to reduce software development effort and to allow for the integration of the commercial and custom processing cards.

3.1 NFEP COMMERCIAL CARDs

The following is a list of the commercial cards which be used in the NFEP System and a brief description of the function to be performed by each card. All of the commercial cards used in the TOPEX-NFEP are used as generic functional components. While specific vendor cards and modules for this project are referenced in this paper, any VME

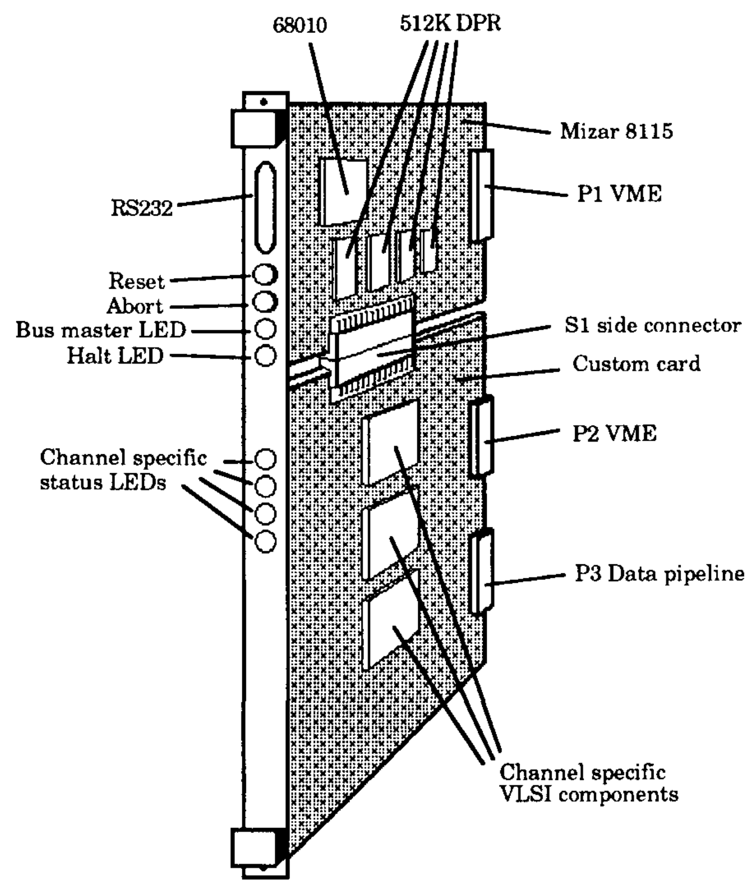

FIGURE 3. TYPICAL CHANNEL CARD

compatible products may be integrated and used to support required system functions. Software development of each commercial card is provided by the BaSE environment while integration with the custom cards is provided through integration with the MEDS environment.

3.1.1 SYSTEM ARBITER CARD

This function is performed by a Mizar CPU card (Model MZ8115) containing 512 KBytes of global RAM, Motorola 68010, and a prioritized or round robin 4 level system arbiter. Approximately 64 KBytes of global RAM on this card will be utilized by the operating system for global disk drive parameter tables. The rest is not specifically allocated.

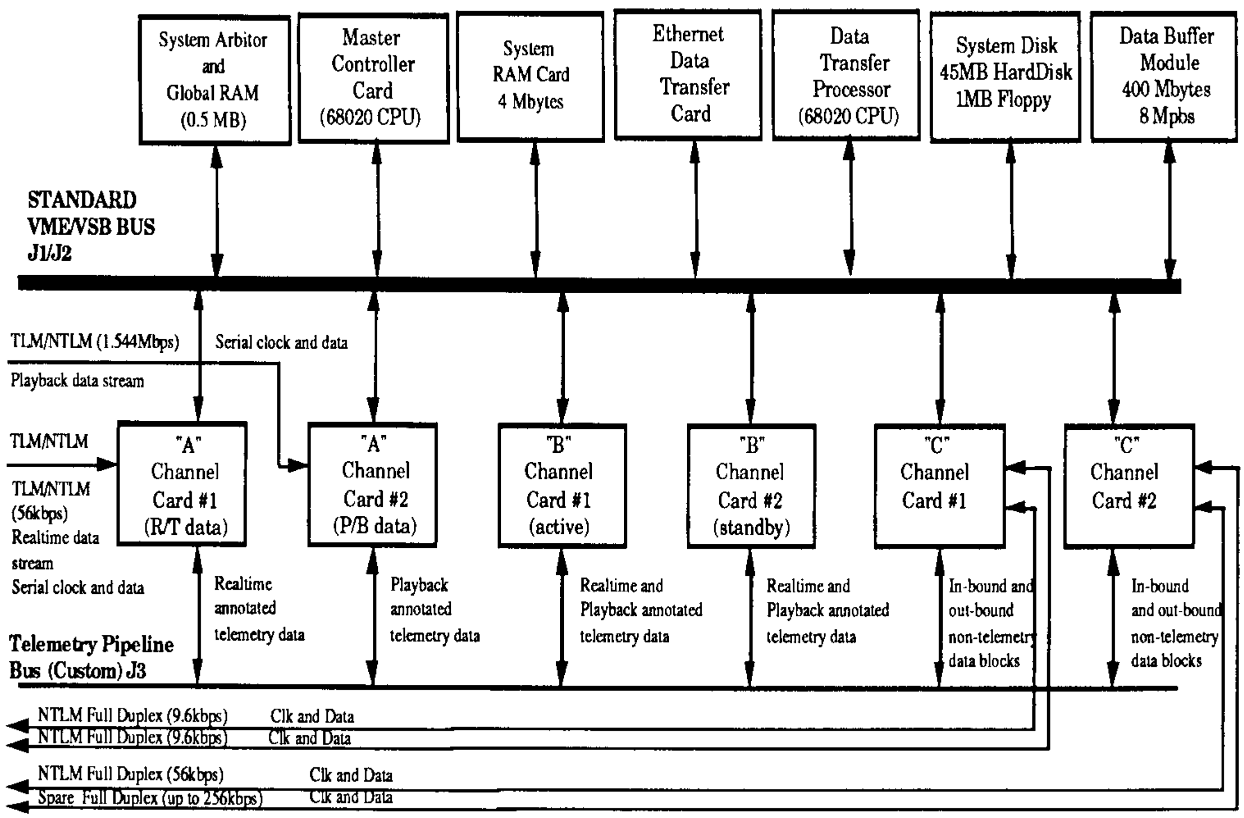

FIGURE 4. TOPEX DATA SYSTEM NASCOM FRONT END (NFEP)

3.1.2 MASTER CONTROLLER CARD

A General Microsystems CPU card (Model GMS-V07), containing a 5 MIP, 25 Mhz Motorola 68020 microprocessor, 512 Kbytes of zero wait state RAM, single level VME bus arbitration, and two serial RS232 ports will act as the Master Controller Card.

The Master Controller Card will be programmed to handle the remote and operator terminal interface. It will handle the setup of all the custom logic cards and gather status at regular intervals for display on the operator terminal or transfer via Ethernet (tentative) to the TOPEX host computer.

3.1.3 DATA TRANSFER PROCESSOR

A General Microsystems CPU card (Model GMS-V07), containing a 5 MIPs 25 Mhz Motorola 68020 microprocessor, 512 Kbytes of zero wait state RAM, single level VME bus arbitration, and two serial RS232 ports will act as the dedicated Data Transfer Processor.

The Data Transfer Processor will be programmed to handle the in-bound and out-bound transferring of telemetry and non-telemetry data through the Ethernet Data Transfer Card (tentative). Additionally the Data Transfer Processor will provide for the temporary buffering of in-bound telemetry data for deferred delivery to the TOPEX (TLM/CMD) Host.

3.1.4 SYSTEM RAM CARD

A Micro Memory 4 Mbyte SRAM (Model MM6704CX) with VME bus transfer rate of 38 Mbytes/s, will be used as the system RAM card. This card will primarily be utilized by the Data Transfer Processor for temporary data buffering.

3.1.5 ETHERNET DATA TRANSFER CARD

A Computer Machinery Corporation Ethernet Interface card (CMC Model ENP-10-plus) will transfer inbound data received by the NFEP to the TOPEX (TLM/CMD) host Computer in realtime or in deferred delivery mode. Also, this card will transfer outbound data from the TOPEX host computer to the NFEP. This card will be controlled by the Data Transfer Card which will initiate its setup and control the transferring of data both inbound and outbound.

3.1.6 SYSTEM DISK MODULE

A Technico disk module (Model TDM-801-45H-6U) will provide the storage of all development and operational programs, all setup catalogs, and the realtime operating system for the NFEP. This module contains a disk controller, 800 K-byte 3 1/2" floppy drive and a 45 Mbyte Winchester drive.

3.1.7 DATA BUFFER MODULE

A Technico disk module (model TDM-400-SCSI-2) with a Winchester disk drive capacity of 400 Mbytes unformatted will provide for high rate buffering of telemetry data and the deferred delivery of data if the TOPEX Host is not available. Transfer rates to and from the Data Buffer Disk will be a sustained rate of 8 Mbps. The data will be stored in sequential files and can be recalled by the host computer at any time file name and time of receipt.

3.2 CUSTOM LOGIC CARDS

Each of the custom cards (“A”, “B” and “C”) cards described below are generic processing elements used in the functional components approach. A brief description of the cards function as applied to the TOPEX-NFEP requirements is outlined. The PDOS realtime operating system, which runs on each of the Custom Logic Card Controllers, along with the BaSE development environment allows for the complete development of application programs on each custom card. The application programs of each custom card are linked to the commercial cards through the MEDS program.

Each of the six Custom Logic Cards will contain a commercially available Mizar 8115 Custom Logic Card controller which will be memory mapped to the VME bus system environment. Attached to the Custom Logic Card via a connector is the custom logic hardware. The Custom Logic Card Controller will control the setup and execution of the custom hardware on the Custom Logic Card and can directly control and interface with all of the other commercial components in the VME system.

Each Custom Logic Card Controller contains a 1 MIP, 12.5 Mhz Motorola 68010 microprocessor with 512 kbytes of zero wait state RAM and VME bus arbitration logic. Additionally two RS232 serial ports are available for development or debugging purposes.

3.2.1 N CHANNEL CARD

Two “A” Channel Cards will provide complete NASCOM 4800 bit block processing and telemetry frame synchronization for the two combined realtime and playback data streams.

In the configuration, two “A” Channel Cards are used to capture the TOPEX realtime and playback data streams. Each “A” Card handles the processing of both telemetry and non-telemetry data received from the NASCOM network. For non-telemetry data (network monitor data) the “A” Channel Card synchronizes to and quality checks the received non-telemetry block and outputs the received block through the VME control and status interface through normal status interrogation.

For telemetry blocks received, the “A” Channel Card synchronizes and quality tags each received telemetry block. In addition, it extracts the telemetry data bits from the block and outputs the telemetry data to the frame synchronization subsystem. After passing through a synchronization strategy and error checking in the frame synchronizer subsystem the telemetry frame is annotated with telemetry block and frame quality information and a received timecode stamp. The quality annotated telemetry frame is then output to the “B” Channel Cards.

Additionally, the “A” Channel Card accumulates statistics on the quantity and quality of telemetry data received over the NASCOM network and, periodically, formats and transfers this information to the Master Controller Card to be displayed on the local operator console or transferred to the TOPEX (TLM/CMD) host computer.

3.2.2 B CHANNEL CARD

The two “B” Channel Cards provide for the multiplexing and buffering of up to three separately received telemetry data streams into a single composite data stream. From each “A” Channel Card, the “B” Channel Card maintains a separate 16 kbyte cyclic buffer area and maintains control of data moving into and out of the buffers.

In the configuration, only two of the three multiplexing buffers on the “B” Channel Card are needed. Realtime and playback annotated telemetry frames are input into the separate buffer on the “B” Channel Card. The “B” Channel Card Controller, can monitor the movement of data into each buffer. After realizing a complete annotated telemetry frame was received, it can initiate a Direct Memory Access (DMA) transfer of the annotated frame. The DMA transfer will move the annotated telemetry frame to separate larger buffer areas on the System RAM Card via the VME bus. The Data Transfer Processor, which monitors data transfers to the System RAM card, would initiate a transfer of the annotated telemetry data to the Ethernet Data Transfer Card for direct output to the TOPEX (TLM/CMD) Host computer and control the transfer of data to the Data Buffer Module (programmable) for deferred delivery to the TOPEX (TLM/CMD) Host computer.

Additionally, the “B” Channel Card will accumulate statistics on the quantity and quality of telemetry data received from the two “A” Channel Cards and periodically will format and transfer this information to the Master Controller Card for display on the operator console or transfer to the TOPEX (TLM/CMD) Host computer for remote quality analysis.

3.2.3 C CHANNEL CARD

Each of the two “C” Channel Card includes two full duplex non-telemetry interfaces. On inbound data, each accepted non-telemetry block is DMA transferred to separate buffer areas on the System RAM Card via the VME bus. As was the case in the transfer of telemetry data, the Data Transfer Processor maintains separate buffers for the non-telemetry data and transfers this data directly to the TOPEX (TLM/CMD) Host computer.

Outbound data, skeleton non-telemetry blocks received via Ethernet on the Ethernet Data Transfer Card are transferred to the “C” Channel Card for output on the NASCOM network. The “C” Channel Card modifies each outbound block with routing, sequencing and timecode information and (user selectable) append the outbound block with cyclic error code (standard NASA 22-bit CRC code) . Additionally, one of the “C” Channel cards can be configured to receive NASA36 standard timecode, decode it to binary coded decimal, and distribute this timecode to all of the custom and commercial cards in the system for ground time tagging purposes.

Additionally, the “C” Channel Card accumulates statistics on the quantity and quality of non-telemetry data received and transmitted (both in-bound and out-bound) for each of the two non-telemetry interfaces and periodically formats and transfers this information to the Master Controller Card for display on the operator console or transfer to the TOPEX (TLM/CMD) Host computer.

4. CONCLUSION

This paper describes a typical application of the functional component approach (1) to the design of a front end system (NFEP) for the TOPEX Project. The implementation described utilizes standard generic hardware and software processing components to handle common NASCOM data processing functions. Customization for the special functions and data formats required for the TOPEX Project is provided through the flexibility and programmability of the various system elements at both the hardware and software levels.

Because most of the generic software and hardware elements have already been developed, the use of the functional component approach allows for quick development time (schedule is for a development cycle of only 9 months) and reduced development effort and cost. The remaining major effort is focused on the application specific elements required for any specific project. Testing and integration effort is minimized because of ongoing testing and integration in other processing system (e.g.. TRAP).

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NOMENCLATURE

ASIC	Application Specific Integrated Circuit
BaSE	Base System Environment
CMC	Computer Machinery Corporation
CNES	Center National d'Etudes Spatiales
CPU	Central Processing Unit
CCSDS	Consultative Committee for Space Data Systems
DMA	Direct Memory Access
DSTD	Data Systems Technology Division
GMS	General MicroSystems
GSFC	Goddard Space Flight Center
JPL	Jet Propulsion Laboratory
Kbytes	kilo-bytes
MEDS	Multiprocessor Environment for Data Systems
MIP	Millions of operations per second
MSOCC	Multi-Satellite Operations Control Center
NASA	National Aeronautics and Space Administration
NASCOM	NASA Communication Network
NCC	Network Communications Center
NFEP	NASCOM Front End Processor
NTLM	Non-telemetry data
OS	Operating System
PDOS	Power Disk Operating System
RAM	Random Access Memory
RT	Realtime
PB	Playback
TDRSS	Tracking Data Relay Satellite
TOPEX	Ocean Topography Experiment
TGS	TOPEX Ground System
TRAP	Telemetry and Command Prototype
TLM	Telemetry data
TLM/CMD	Telemetry and Command Computer
VLSI	Very Large Scale Integration
VME	Virtual Memory Extended