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George C. Marshall Space Flight Center
Marshall Space Flight Center. Alabama 35812

LIGHTNING IMAGING SENSOR

SOFTWARE REQUIREMENTS SPECIFICATION

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1.0 INTRODUCTION

1.1 Identification of Document

This is the Software Requirements Specification for the Lightning Imaging Sensor (LIS) Experiment.

1.2 Scope of Document

This specification establishes requirements for the LIS software. This document applies to the Flight Software, Electrical Ground Support Equipment (EGSE) Software and Calibration Software to be developed by Marshall Space Flight Center (MSFC) for the LIS Experiment.

Flight software will be developed and tested as specified in the LIS Software Management, Development and Test Plan (Reference 1) for the Tropical Rainfall Measuring Mission (TRMM).

1.3 Purpose and Objectives of Document

The use of this specification will help promote efficient design and verification of the LIS software.

1.4 Document Status and Schedule

This document will be baselined at the Software Requirements Review (SRR), as specified in the LIS Software Management, Development and Test Plan (Reference 1), and will be used throughout the software life-cycle of the LIS experiment.

1.5 Documentation Organization

This document contains five sections. Section 1.0 is the introduction, section 2.0 contains related documentation, section 3.0 contains Flight Software requirements, section 4.0 contains Electrical Ground Support Equipment Software requirements and section 5.0 contains Calibration Facility Software requirements.

2.0 RELATED DOCUMENTATION

2.1 Applicable Documents

The latest version of the documents listed will be used as referenced where applicable:

Reference 1 - Lightning Imaging Sensor Software Management, Development and Test Plan, MSFC-PLAN-2025

Reference 2 - Tropical Rainfall Measuring Mission Spacecraft to Lightning Imaging Sensor Instrument Interface Control Document, TRMM-490-022

Reference 3 - Military Standard Fiber Optics Mechanization of an Aircraft Internal Time Division Command Response Multiplex Data Bus Specification, MIL-STD-1773

Reference 4 - TMS320 Assembler Guide for the TI TMS320C25

Reference 5 - Tropical Rainfall Measuring Mission SGSE/IGSE Interface Control Document, TRMM-490-TBD

2.2 Informational Material

The latest version of the documents listed will be used for information where applicable:

Info 1 - Tropical Rainfall Measuring Mission Command and Data Handling Subsystem Hardware Interface Control Document, TRMM-490-TBD

Info 2 - Tropical Rainfall Measuring Mission Electrical System Specification, TRMM-490-TBD

Info 3 - Tropical Rainfall Measuring Mission Specification, TRMM-490-001

Info 4 - LIS System Requirements Performance Document, MSFC-SPEC-TBD

3.0 FLIGHT SOFTWARE REQUIREMENTS

The LIS flight software is the Read Only Memory (ROM) resident code and data designed to run the onboard operation of the Texas Instruments TMS320C25 microprocessor controller. The LIS flight software shall interpret commands to the LIS instrument, receive and store digital data from both the Real Time Event Processor (RTEP) and the House-keeping Data Acquisition System (DAS) and also package data for transmission to the TRMM spacecraft's Flight Data System (FDS).

3.1 Hardware And Exception Generated Routines

3.1.1 Initialization Software

The LIS flight software shall be automatically executed upon system power-up or when the microprocessor is reset by the watchdog timer. The watchdog timer will cause a system reset if a software failure is detected. The initialization software will initialize the TMS320C25, the Bus Controller Remote Terminal (BCRT) and also the RTEP for operation of the LIS instrument.

3.1.2 Filter Temperature Monitoring

The LIS flight software shall exception monitor three filter temperatures when commanded. In the event the temperature exceeds nominally defined parameters the LIS flight software will reset both heater controllers and also enable the controller not operating during generation of the last exception.

3.2 Hardware Configuration

3.2.1 Primary Configuration

The primary configuration of the LIS flight software is the firmware that directs the orbital operations of the TMS320C25 microprocessor.

3.2.1.1 Operation Environment

The LIS software shall operate in the following environment: SCN001

TMS320C25 microprocessor
8k x 16 bits of external EPROM
16k x 16 bits of external SRAM

3.2.1.2 Interfaces

The LIS flight software will be written to control the hardware interfaces between the LIS instrument and the TRMM spacecraft. These interfaces shall conform to the TRMM Spacecraft to LIS Instrument ICD (Reference 2).

3.2.1.2.1 Command And Control Interfaces

Data transfers between the LIS instrument and the TRMM spacecraft will be accomplished via a 1773 fiber optic data bus conforming to the protocol defined by MIL-STD-1773 (Reference 3). The LIS flight software shall initialize the bus controller remote terminal (BCRT) hardware to send data and housekeeping packets and receive command and data packets on the 1773 layer, as a remote terminal, in accordance with the protocol defined in the TRMM Spacecraft to LIS Instrument ICD (Reference 2). LIS flight software constructs the data packets for transmission. SCN001

In response to a data transfer command from the TRMM flight data system (FDS), the BCRT can operate by performing a direct memory access (DMA) and/or interrupting the microprocessor. When in the DMA mode, the microprocessor is placed on hold, and cannot access memory or data. Instrument commands and time updates will produce a BCRT interrupt of the microprocessor. All other transfers will be accomplished by the BCRT, via DMA.

3.2.1.2.2 Time Mark Interface

The LIS flight software shall receive the coarse time from the TRMM spacecraft via the MIL-STD-1773 fiber optic bus in conformance with the TRMM Spacecraft to LIS Instrument ICD (Reference 2). A 1 Hz time mark signal will be received over a RS-422 interface and will generate an interrupt to the LIS microprocessor. The LIS flight software will replace current time with the new coarse time upon receipt of the time mark signal.

3.2.2 Watchdog Timer

In the event the LIS flight software tries to execute out of program memory or the LIS flight software becomes locked in an endless loop the watchdog timer will reset the TMS320C25. The LIS software shall reset the watchdog timer every 1.2 seconds to indicate successful code execution.

3.3 Commands

The LIS software shall recognize and decode the CCSDS packets sent to command the LIS instrument. The format of these packets is described in section 2.3 of FDS Appendix of the TRMM Spacecraft to LIS Instrument ICD (Reference 2).

3.3.1 Instrument Command List

The LIS flight software shall recognize and implement the LIS instrument commands. A list of commands and a description of the action required are in Appendix A.

3.3.2 Command Constraints

Construction of LIS instrument commands shall be subject to the constraints of the TRMM Spacecraft to LIS Instrument ICD (Reference 2), section 8.2 and the FDS Appendix of the TRMM Spacecraft to LIS Instrument ICD (Reference 2), section 2.3.1.

3.3.3 Timing Constraints

The following timing constraints shall be observed:

a. 1773 commands will be read within 32 milliseconds to prevent over writing of the command buffer.

b. The BCRT requires DMA control within 1.9 microseconds after command receipt. The software will not execute any code that prevents the microprocessor from relinquishing control of the memory to BCRT DMA.

3.4 Operational Modes

The LIS instrument will operate in three modes and have differing bandwidth allocations. These modes are defined by the TRMM Spacecraft to LIS Instrument ICD (Reference 2).

3.4.1 System Test Mode

The system test mode will consists of an instrument self-test that determines the operational health of the LIS. The LIS data output during the system test mode shall be within the bandwidth allocation as assigned by the FDS Appendix of the TRMM Spacecraft to LIS Instrument ICD (Reference 2).

3.4.2 Background Send On Mode

In the Background Send On Mode background data shall be appended to the event data in the science data packets. The LIS data output shall be within the bandwidth allocation as assigned by the FDS Appendix of the TRMM Spacecraft to LIS Instrument ICD (Reference 2), sections 2.2.4 and 2.2.5.

3.4.3 Background Send Off Mode

In the Background Send Off Mode no background data shall be included in the science data packets. The LIS data output shall be within the bandwidth allocation as assigned by the FDS Appendix of the TRMM Spacecraft to LIS Instrument ICD (Reference 2), sections 2.2.4 and 2.2.5.

3.5 Interrupts

The TMS320C25 has three external maskable user interrupts available for external devices.

3.5.1 Real Time Event Processor Interrupt

The RTEP will set a flag to interrupt the TMS320C25 at the end of each video frame lightning occurance or when the 512th video frame occurs. Video frames are processed by the RTEP at a rate of one video frame every 2 milliseconds. The LIS flight software shall acknowledge the interrupt and initiate the science packet formation algorithm.

3.5.2 Command and Control Interrupt

The command and control interrupt is generated by the BCRT in response to a valid LIS command requiring microprocessor interaction. The LIS flight software shall respond to the command and control interrupt by acknowledging the interrupt, reading the command buffer and also executing the received LIS command.

3.5.3 Time Mark Interrupt

The time mark interrupt is generated by the LIS hardware upon reception of the 1 Hz RS-422 time mark. The LIS flight software shall respond to the time mark interrupt by acknowledging the interrupt and swapping the 'new' and 'old' coarse time memory pointers.

3.6 Data Formats

3.6.1 LIS Data Formats

The LIS flight software collects, packetizes and also stores LIS instrument data for transmission over the TRMM 1773 bus. The time stamped LIS instrument data utilizes multiple 1773 subaddress reads as defined in the TRMM FDS Appendix of the TRMM Spacecraft to LIS Instrument ICD (Reference 2).

LIS data shall be formed into CCSDS packets. Each packet includes a primary and a secondary packet headers as defined in the FDS Appendix of the TRMM Spacecraft to LIS Instrument ICD (Reference 2) and also a time stamp to a resolution of 16 microseconds.

3.6.1.1 Science Data

The LIS science data consists of lightning event data (pixel location, intensity and time stamp to a resolution of 2 milliseconds). Background data will be added to the science packet if the number of events is low. LIS science data shall be compressed (by suppressing superfluous row, pixel, and time information) to maximize data within the allocated bandwidth. This compression algorithm will allow for recovery of background and event data on the ground.

3.6.1.2 Housekeeping Data

A LIS instrument housekeeping data packet shall consists of 16 housekeeping words from the housekeeping DAS and status word(s). The status word(s) show(s) error status and command verification returned from the LIS hardware.

3.6.1.3 Packet Structure

All LIS data transferred in FDS data reads shall be transmitted as CCSDS telemetry packets as defined in the FDS Appendix of the TRMM Spacecraft to LIS Instrument ICD (Reference 2), section 2.2.2, "Packet Communications".

The referenced section specifies the CCSDS options to be used, the protocol governing transmit requests, packet acknowledge and also error handling.

3.6.1.4 Packet Formation Format

The LIS flight software shall maintain two memory location pointers for science packets and also two memory location pointers for housekeeping packets. A completed data packet ready for transmission to the TRMM FDS will be stored in one area of memory. A second area of memory will contain the new packet information. Once the confirmation of the data packet transmission has occurred the LIS flight software will swap the pointer and form a new packet in the same location of the packet that has been confirmed.

3.6.2 Time Data Format

Coarse time data shall be transmitted by the FDS over the 1773 bus as described in the FDS Appendix of the TRMM Spacecraft to LIS Instrument ICD (Reference 2), section 2.2.6.

The LIS flight software will maintain pointers to two memory locations. One pointer will reflect the location of the current coarse time and the other pointer will reflect the location of the new coarse time.

3.7 Displays

None.

3.8 Engineering Development and Analysis Software

The LIS engineering development and analysis software shall support hardware development and testing. This software will be written on an as needed basis.

3.9 Implementation

The LIS flight software shall be written in assembly language for the Texas Instruments TMS320C25 microprocessor. This language is written as specified in the TMS230 Assembler Guide for the TI TMS320C25 (Reference 4).

The TMS320C25 has the following resources available:

1. 533 16-bit word on-chip RAM
2. 100 nanosecond instruction cycle
3. 10 MIPS
4. 16x16 I/O space

4.0 ELECTRICAL GROUND SUPPORT EQUIPMENT SOFTWARE REQUIREMENTS

The Electrical Ground Support Equipment (EGSE) is a design and test tool used to simulate the electrical interfaces and software activity of the TRMM space-craft. The EGSE software will operate the EGSE equipment and command the LIS instrument. The EGSE software shall have a user friendly interface to automate the control of the EGSE hardware and will also provide the ability to store, display and analyze LIS data.

4.1 Hardware And Exception Generated Routines

4.1.1 Initialization Software

The EGSE software shall begin execution following a run command from the operating system. Further execution will be driven by menus or sequences loaded from floppy disk.

4.1.2 Filter Temperature Monitor

None.

4.2 Hardware Configuration

The EGSE software will support a variety of simulation hardware configurations. In each configuration the EGSE software shall provide command and control capability that makes the hardware configuration transparent to the user. See Data Flow figures in Section 8.0.

4.2.1 MSFC TRMM Simulator Configuration

The EGSE software shall operate the TRMM interface simulators. The software shall control the interfaces of the MSFC TRMM simulator and also provide command and monitoring functions defined in section 4.4.2, utilizing the data format defined in section 4.6.4.

4.2.1.1 MIL-STD-1773 Interface

The EGSE software will implement the EGSE computer as bus controller to the LIS instrument using the MIL-STD-1773 command and control interface. The EGSE software shall drive a MIL-STD-1553 card used by the EGSE and implement the same command/response protocol (Reference 3).

4.2.1.2 Time Mark Interface

The EGSE software will control the time mark interface. The EGSE software shall have the capability to enable or disable the primary and redundant interface and also have the capability to enable or disable the interrupt generated by the time mark hardware.

4.2.1.3 Passive Analog Interface

The EGSE software will drive the passive analog interface during the simulation of the TRMM spacecraft. The EGSE software shall be able to excite any one of 4 (redundant) thermistors, convert the analog voltage to a 12-bit digital word and also pass the data to the EGSE ADP equipment. | SCN001

The EGSE software will drive the passive analog interface during the simulation of the TRMM spacecraft. The EGSE software shall be able to excite any one of 8 (redundant) thermistors, convert the analog voltage to a 12-bit digital word and also pass the data to the EGSE ADP equipment.

4.2.1.4 Power Distribution Interface

The EGSE software will drive the power distribution simulator. The EGSE software shall activate the control lines that open and close the four distribution relays and also read the status of the contact closures.

4.2.2 GSFC TRMM Simulator Configuration

The EGSE software will provide TRMM interface simulation by the GSFC simulator hardware. The EGSE software shall control the ethernet interface to the TRMM simulator and also provide command and monitoring functions.

4.2.3 Calibration Configuration

The calibration configuration will have either the MSFC TRMM simulator configuration or the GSFC TRMM simulator configuration with the addition of an interface to the calibration facility computers.

The EGSE software shall control the interface between the calibration facility and the EGSE computers and also control the exchange of data between the two systems.

4.2.4 Post-Integration Configuration

The post integration configuration is used after the LIS instrument has been integrated to the TRMM spacecraft and also is used to interface the TRMM Spacecraft Ground Support Equipment (SGSE) for LIS checkout. The interface to the SGSE is accomplished via a thin wire (10Base 2) ethernet. | SCN001

The EGSE software shall control the interface between the EGSE and the SGSE and also provide command and monitoring functions.

4.3 Commands

EGSE commands shall be issued by the operator or sequences stored on disk. All other information supplied to the EGSE will be classified as data.

4.3.1 LIS Instrument Command Simulation

4.3.1.1 Command List

The EGSE software will simulate the FDS by issuing commands to the LIS instrument. A list of instrument commands and 1773 mode control commands are in Appendix A and Appendix F. The block data transfer protocol is described in the FDS Appendix of the TRMM Spacecraft to LIS Instrument ICD (Reference 2), section 2.2 "Telemetry Packet Descriptions." The mode control commands are given in Appendix F.

4.3.1.2 Command Constraints

In addition to constructing all valid LIS commands the EGSE software shall test the LIS response for generating invalid LIS commands.

4.3.1.3 Timing Constraints

The EGSE software shall issue commands subject to the FDS timing constraints listed in the FDS Appendix of the TRMM Spacecraft to LIS Instrument ICD (Reference 2), sections 2.2.2, 2.3.2, and 2.4. This will provide simulation of the TRMM FDS while operation in the MSFC TRMM interface simulator configuration.

4.3.2 Platform Simulation Commands

The EGSE software will support platform simulation commands in each of the hardware configurations. These commands are issued by the FDS to exercise and test the LIS hardware via the TRMM interfaces.

4.3.2.1 Command List

The EGSE software shall support insuring of the simulated FDS commands listed in Appendix B in order to fully exercise the LIS hardware.

4.3.2.2 Command Constraints

None.

4.3.2.3 Timing Constaints

None.

4.3.3 EGSE Commands

EGSE commands are defined as:

1. a command that issues to LIS and/or the interface simulator, a sequence of commands designed to perform a check of LIS response.
2. a command issued to the EGSE that performs some internal checking function, processes data, or controls i/o devices such as printers, disks, etc.
3. A command issued to control the data exchange between the EGSE and the calibration facility equipment.

4.3.3.1 Command List

The EGSE shall provide commands to perform all the functions listed in Appendix C.

4.3.3.2 Command Constraints

None

4.3.3.3 Timing Constaints

None.

4.4 Operational Modes

4.4.1 Self-Test Mode

The self-test mode shall be executed upon command, or immediately upon execution of the EGSE program, unless this feature is disabled by the user. The default operation will have a self-test performed. This default may be disabled by pressing the 'ESC' key within 1 second of program execution. Exiting the program re-enables the default. During self-test mode, there is no requirement for maintaining the TRMM simulation mode or the analysis mode.

4.4.2 TRMM Software Simulation Mode

The EGSE software shall support both the TRMM software simulation mode and the analysis mode (4.4.3) simultaneously. During the TRMM software simulation mode the EGSE software will support any one of the three hardware configurations and provide also simulation of the activity of the TRMM FDS software.

4.4.3 Analysis Mode

The EGSE software will display, store and process LIS and GSE data. Data processing will verify command responses and also data format.

4.5 Interrupts

The time update interrupt routine is only required in the MSFC TRMM Interface simulator configuration. The EGSE software shall process the time update interrupt generated by the time-mark simulator. In response to the interrupt the EGSE software updates the coarse time code to the LIS via the 1773 bus. The time of update will conform to the timing constraints of the FDS.

4.6 Data Formats

4.6.1 LIS Data Formats

The EGSE software shall be able to check LIS data for format validity and correctness and also extract the following information:

a. Row, column, intensity, and time-stamp of lightning events.

b. Approximate scene background and time generated.

c. Analog value of each DAS housekeeping channel.

d. Condition indicated by each bit of the status word(s).

4.6.2 EGSE Internal Data Formats

The EGSE software developers will define and document internal data formats for manipulation of LIS data as needed.

4.6.3 Calibration Facility Data Formats

All data exchanged between the EGSE and the calibration facility shall be compliant with the format in Appendix D.

4.6.4 SGSE/GSFC Simulator Data Formats

The EGSE software will support the exchange of commands to and data from the LIS instrument while utilizing the formats and constraints required by the TRMM IGSE/SGSE Interfaces Document (Reference 5).

4.7 Displays

The EGSE software will display all LIS data, the status of EGSE command settings and also utilize the dual display capability of the EGSE. The GSE display will provide science data and other data.

The MSFC configuration will include data collected from the 1773 bus and also data collected from discrete interfaces. Other configurations will include data passed to the EGSE by the ethernet interface.

4.7.1 EGSE Command Status

The EGSE software shall allow the user the ability to view the command status of the LIS instrument.

4.7.2 Engineering Data Display

The EGSE software shall provide monitoring capability of LIS housekeeping data, discrete telemetry and also simulated TRMM interface status.

4.7.3 Lightning Image Display

The EGSE software shall display science data with the ability to view individual frames of data (in non-real time) and during active calibration real-time science data.

4.8 Engineering Development and Analysis Software

The EGSE software will support the development and testing of the EGSE hardware and also the LIS instrument. This software will be written on an as-needed basis.

4.8.1 Focal Plane Simulator Software

The EGSE software shall control the focal plane simulator board. This software will be used as a development and test tool for the RTEP and also provide control of the output of simulated CCD patterns and simulated lightning events. The EGSE software should provide the ability to vary the number, location, and intensity of simulated lightning events against variable backgrounds.

4.8.2 1773 Test Routines

The EGSE software shall meet the developmental testing of the LIS 1773 command and control interface. The test routines to be provided are listed in Appendix E.

4.8.3 EGSE Diagnostic Mode

The EGSE software shall provide detailed diagnostic tests for the EGSE ADP and simulation equipment. This software will provide full exercise of the hardware capabilities.

4.9 Implementation

Documentation and testing of all software, including commercial software and reusable software, will be treated as if they are a new development.

4.9.1 Developed Software

The EGSE software shall be implemented in a programming language compatible with the family of computers selected as ADP equipment. The selected computer is an Intel 80486 based IBM compatible with an ISA bus structure.

4.9.2 Commercial Software

The EGSE software shall utilize commercially available software environments for developing software and as drivers for commercially purchased hardware interfaces or peripherals.

4.9.3 Reusable Software

The EGSE software will utilize software written for other NASA projects.

5.0 CALIBRATION FACILITY SOFTWARE REQUIREMENTS

Calibration Facility Software is defined as that software controlling the generation of simulated lightning events (through optical stimulation of the LIS instrument) and the software required to analyze the correlation of the input simulation to the output LIS science data.

5.1 Hardware and Exception Generated Routines

5.1.1 Initialization Software

The initialization software shall be a menu driven setup procedure to select the conditions for the different tests that will be apart of the calibration. The list of test options are listed in Table 5.1.

Table 5.1 Test Menu Options

OPTIONS	DESCRIPTIONS
1. PIXEL SCAN	A pixel by pixel scan of the LIS under different conditions CW, pulsed, with or without backgrounds.
2. FLOOD FOV	Full illumination of LIS at different intensities and wavelengths.
3. LIGHTNING SIMULATION	Providing a real time scene for LIS with various back-grounds, lightning rates, lightning intensities, in many locations at near simultaneous occurrences.

5.1.2 Exception Monitoring

TBD

5.2 Hardware Configuration

5.2.1 Optical Stimulation Equipment Interface

The acoustic optical scanner and modulator shall be controlled by a slave digital signal processor that will generate the lightning scenes. All the conditions for the scene will be transferred through the 486 PC selection initialization software.

5.2.2 TRMM Simulation Equipment Interface

The calibration software shall be capable of controlling interfaces to the ground support equipment for the purpose of passing information required to compare the LIS science data output to the input stimulus.

5.2.3 Raw LIS Pixel Data

This data shall be collected by the Matrox frame grabber boards under the control of the 486 PC. The PC will initialize the frame grabber boards which are intelligent and controlled by the PC.

5.2.4 High Speed Photometer

This data shall be collected by the 486 PC using a high A/D from National Instruments. The photometer will monitor the temporal activity of the lightning simulation.

5.3 Commands

There is one command to indicate the start of the test to all the processors.

5.4 Operational Modes

The operation modes are indicated in the top level menu selected in Table 5.1.

5.5 Interrupts

There shall be one user interrupt to stop the test and TBD software error interrupts to indicate problems.

5.6 Data Analysis

Software shall be capable of comparing the LIS science data to the input stimulus.

5.6.1 Detailed Analysis

This software shall provide the radiometric and temporal transfer functions for all the pixels in LIS. This is the results from all the data taken and reduced to a set of coefficients describing each pixels performance.

5.7 Displays

The display of scene by scene comparisons of the generated scene and the LIS scene will be compared visually in near real-time. The 500 frame/sec rate of LIS shall be shown at the standard TV rate of 30 frames/sec or less.

5.8 Engineering Development and Analysis Software

Software will be written on an as needed to support the development of the optical stimulation hardware.

5.9 Implementation

The calibration software shall be compatible with the computer system selected to control the calibration facility optical stimulus equipment. The hardware chosen for this purpose is an IBM compatible, based on the Intel 80386 family of microprocessors.

5.9.1 Commercial Software

5.9.1.1 Assemblers/Compilers

Calibration facility software may make use of commercially available software development environments.

5.9.1.2 Commercial Hardware Drivers

Calibration facility software may utilize, if required, commercially available software for driving the interfaces between the simulation computer and the TRMM simulation computer.

5.9.2 Reusable Software

N/A

5.9.3 Functional Partition

Optical Lightning Simulation software shall be resident in a computer system interfacing to the stimulation hardware. This machine is different from the computer system controlling the TRMM simulation.

6.0 ABBREVIATIONS AND ACRONYMS

ADP	-	Automatic Data Processing
BCRT	-	Bus Controller Remote Terminal
CRT	-	Cathode Ray Tube
CCSDS	-	Consultative Committee for Space Data Systems
DMA	-	Direct Memory Access
EGSE	-	Electrical Ground Support Equipment
FDS	-	Flight Data System (TRMM)
GSFC	-	Goddard Space Flight Center
Hz	-	Hertz
IBM	-	International Business Machines
ICD	-	Interface Control Document
IGSE	-	Instrument Ground Support System
ISA	-	Industry Standard Architecture
I/O	-	Input/Output
IP&CL	-	Instrument Program and Command List
LIS	-	Lightning Imaging Sensor
MIPS	-	Million Instructions Per Second
MS	-	Milliseconds
MSFC	-	Marshall Space Flight Center
NASA	-	National Aeronautics and Space Administration
NS	-	Nanosecond
RAM	-	Random Access Memory
ROM	-	Read Only Memory
RT	-	Remote Terminal
RTEP	-	Real Time Event Processor
SGSE	-	Spacecraft GSE

ABBREVIATIONS AND ACRONYMS

SRR - Software Requirements Review

TI - Texas Instrument

TBD - To Be Determined

TRMM - Tropical Rainfall Measuring Mission

7.0 VERIFICATION MATRIX

Verification Methods:	Verification Phases:
A = Analysis I = Inspection T = Test X = Information Only	DP = Design Phase IP = Implementation Phase VV = Verification and Validation Testing

Requirement Reference	Verification Phase			Remarks
	DP	IP	VV	
				Flight Software
3.0			T	
3.1	X			
3.1.1			T	
3.1.2			T	
3.2	X			
3.2.1	X			
3.2.1.1			I	
3.2.1.2	I			
3.2.1.2.1		A	I	
3.2.1.2.2		A	I	
3.2.2		A	I	
3.3			T	
3.3.1		I		
3.3.2	I			
3.3.3		A	T	
3.4	X			
3.4.1	A		T	
3.4.2	A		T	
3.4.3	A		T	
3.5	X			
3.5.1			T	
3.5.2			T	
3.5.3			T	
3.6	X			
3.6.1			T	
3.6.1.1		A	T	
3.6.1.2		T		
3.6.1.3		I		
3.6.1.4		I		
3.6.2		I		
3.7	X			
3.8	I			
3.9	I			

VERIFICATION MATRIX

Verification Methods:	Verification Phases:
A = Analysis I = Inspection T = Test X = Information Only	DP = Design Phase IP = Implementation Phase VV = Verification and Validation Testing

Requirement Reference	Verification Phase			Remarks
	DP	IP	VV	
4.0			I	EGSE Software
4.1	X			
4.1.1			T	
4.1.2	X			
4.2		I		
4.2.1		I		
4.2.1.1		I		
4.2.1.2		I		
4.2.1.3		I		
4.2.1.4			T	
4.2.2			T	
4.2.3			T	
4.2.4			T	
4.3			T	
4.3.1	X			
4.3.1.1	X			
4.3.1.2			I	
4.3.1.3			I	
4.3.2	X			
4.3.2.1			I	
4.3.2.2	X			
4.3.2.3	X			
4.3.3		A	I	
4.3.3.1			I	
4.3.3.2	X			
4.3.3.3	X			
4.4	X			
4.4.1			T	
4.4.2			I	
4.4.3			I	
4.5			I	
4.6	X			
4.6.1		A	I	
4.6.2	X			
4.6.3			I	
4.6.4	X			

VERIFICATION MATRIX

Verification Methods:	Verification Phases:
A = Analysis I = Inspection T = Test X = Information Only	DP = Design Phase IP = Implementation Phase VV = Verification and Validation Testing

Requirement Reference	Verification Phase			Remarks
	DP	IP	VV	
				EGSE Software (Continued)
4.7	X			
4.7.1			I	
4.7.2			I	
4.7.3			I	
4.8	X			
4.8.1			I	
4.8.2		A		
4.8.3		A		
4.9	X			
4.9.1		I		
4.9.2		A		
4.9.3	X			
				Calibration Facility Software
5.0	X			
5.1	X			
5.1.1			I	
5.1.2	X			
5.2	X			
5.2.1		A	I	
5.2.2		A	I	
5.2.3	X			
5.2.4			I	
5.3	X			
5.4	X			
5.5		A	I	
5.6			T	
5.6.1		A	I	
5.7		A		
5.8	X			
5.9		A	I	
5.9.1	X			
5.9.1.1	X			
5.9.1.2	X			
5.9.2	X			
5.9.3		A	I	

8.0 DATA FLOWS

The following figures make up the Flight and EGSE software functional data flows. Figure 8-1 is a flight hardware configuration chart. Figures 8-2 through 8-5 are flight software functional data flow charts. Figures 8-6 through 8-7 are EGSE software functional data flow charts. Figures 8-8 through 8-10 are ground hardware configuration charts.

Flight Software Functional Data Flow

LIS Hardware Configuration

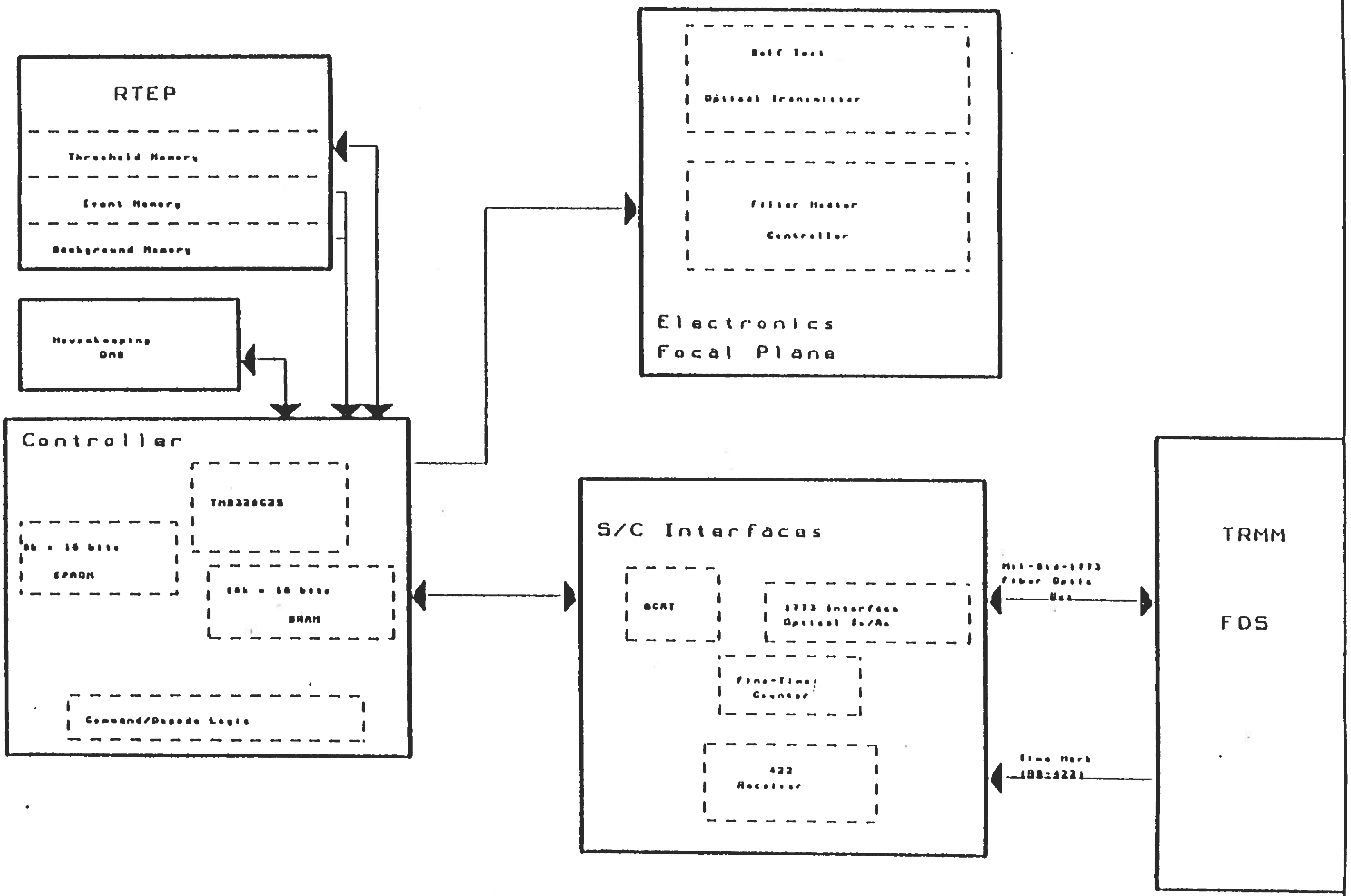

Figure A-1 LIS Hardware Configuration

Flight Software Functional Data Flow

Coarse Time Update, Packet Transmission Confirmation,

And Instrument Command

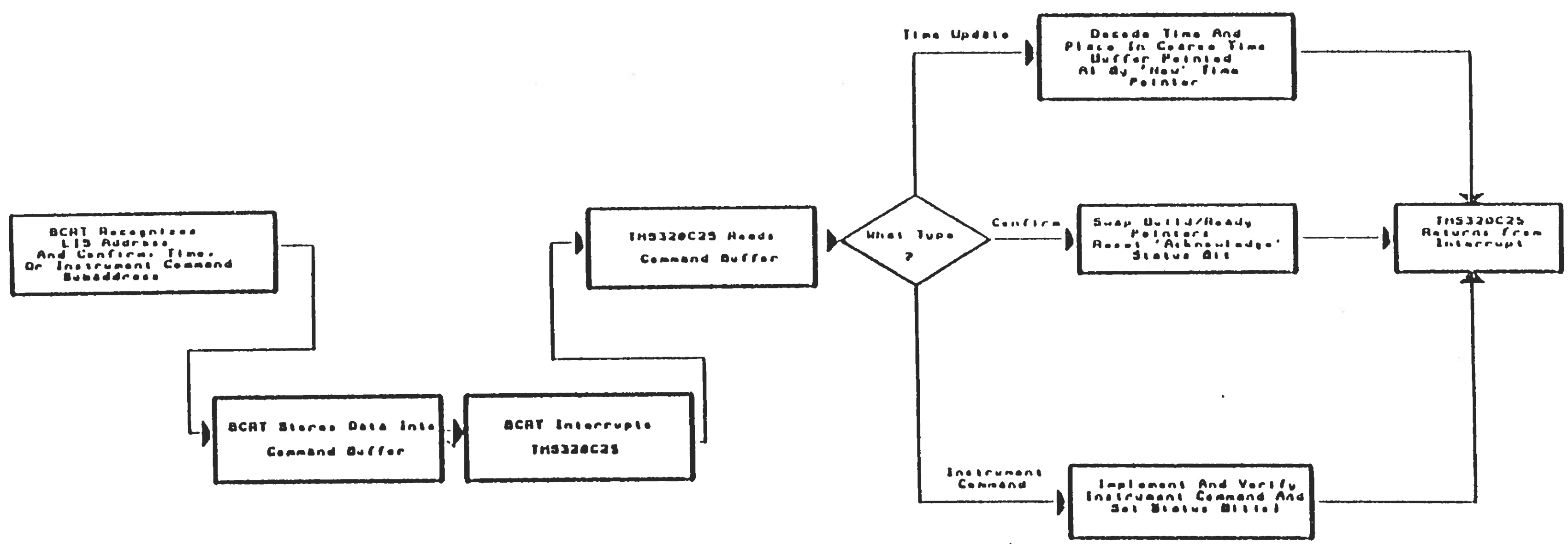

Figure 8-2 Coarse Time Update

SCN001

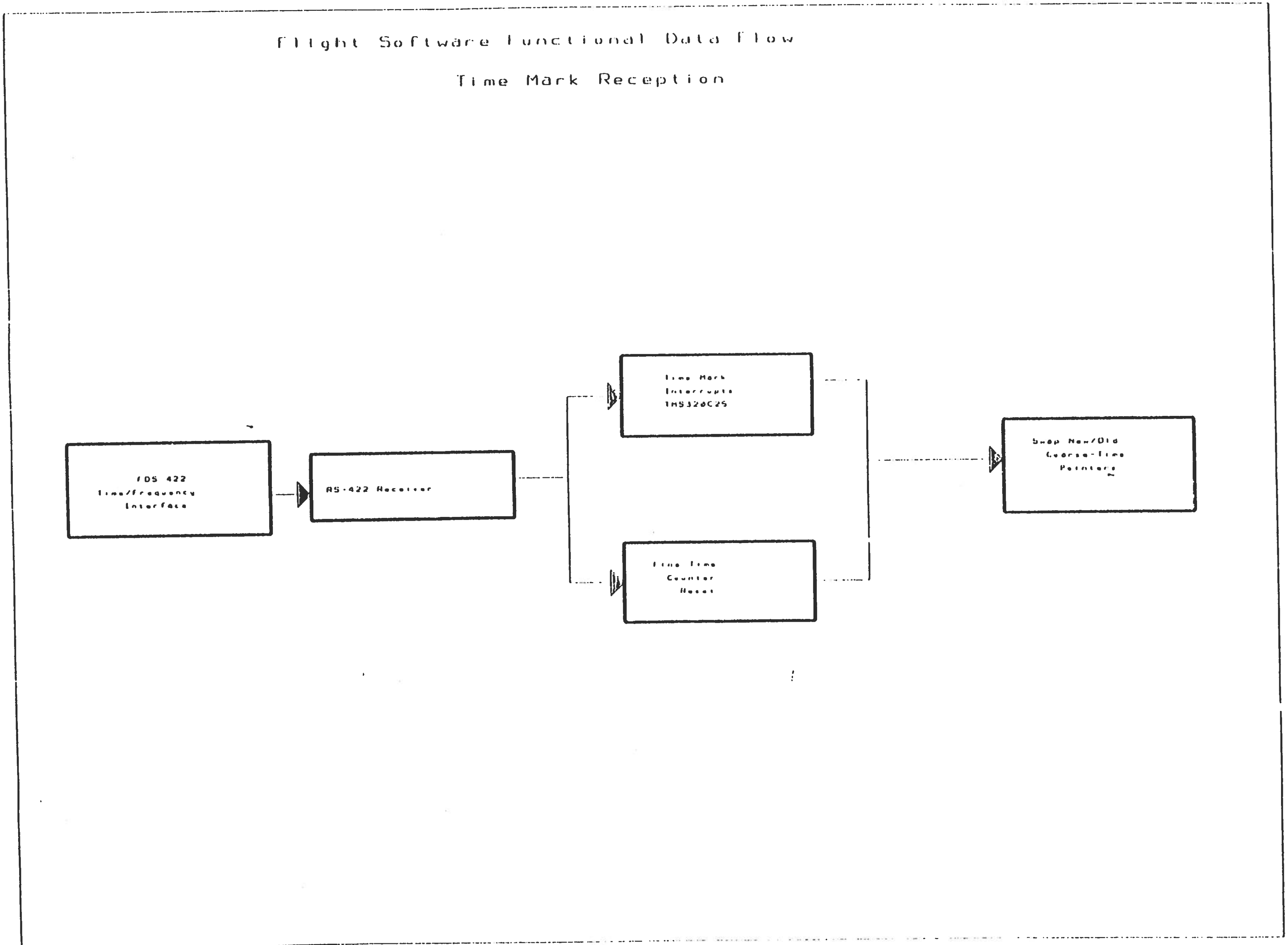

Figure 8-3 Time Mark Reception

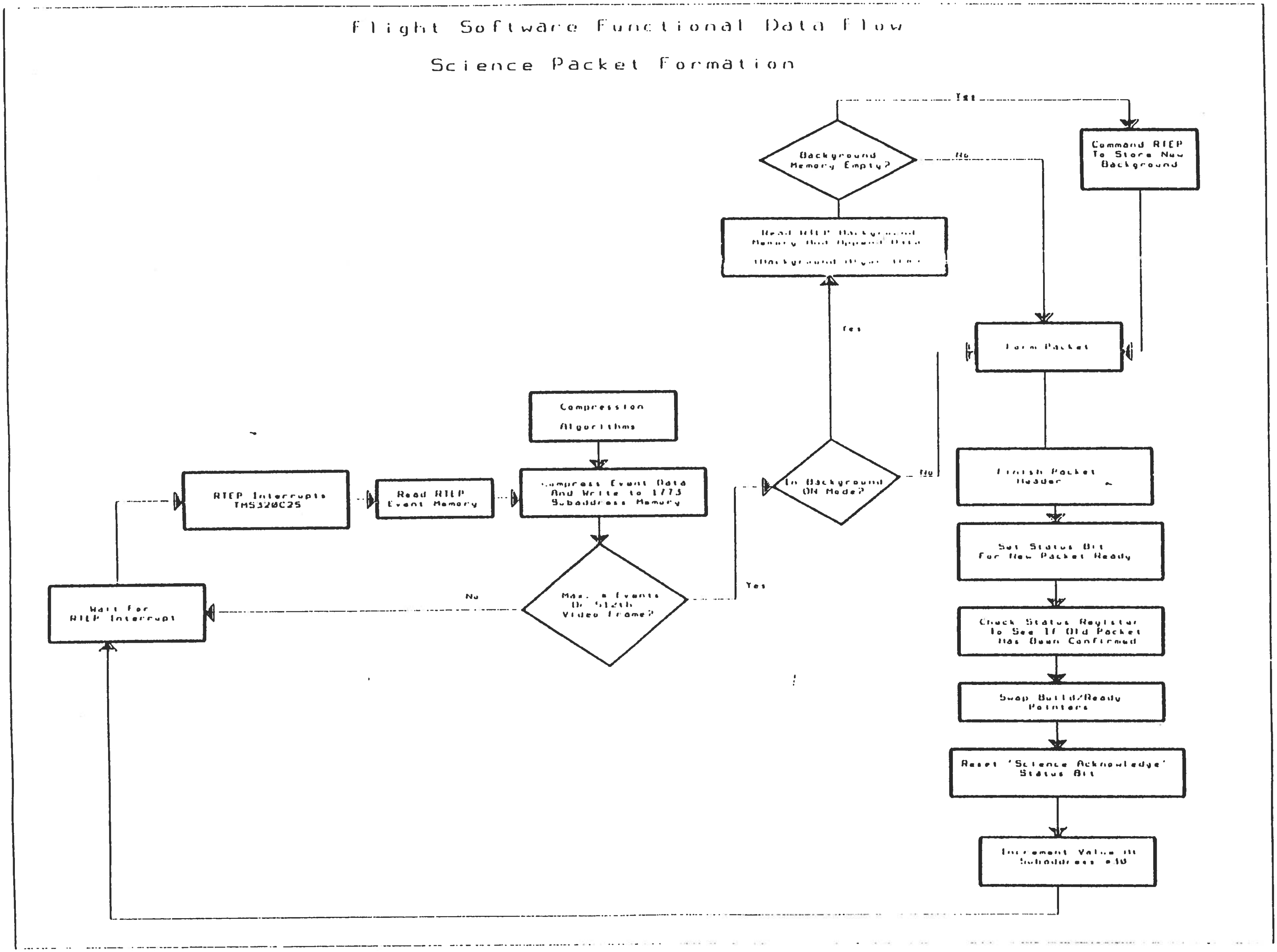

Figure 8-4 Science Packet Formation

Flight Software Functional Data Flow

Housekeeping Packet Formation

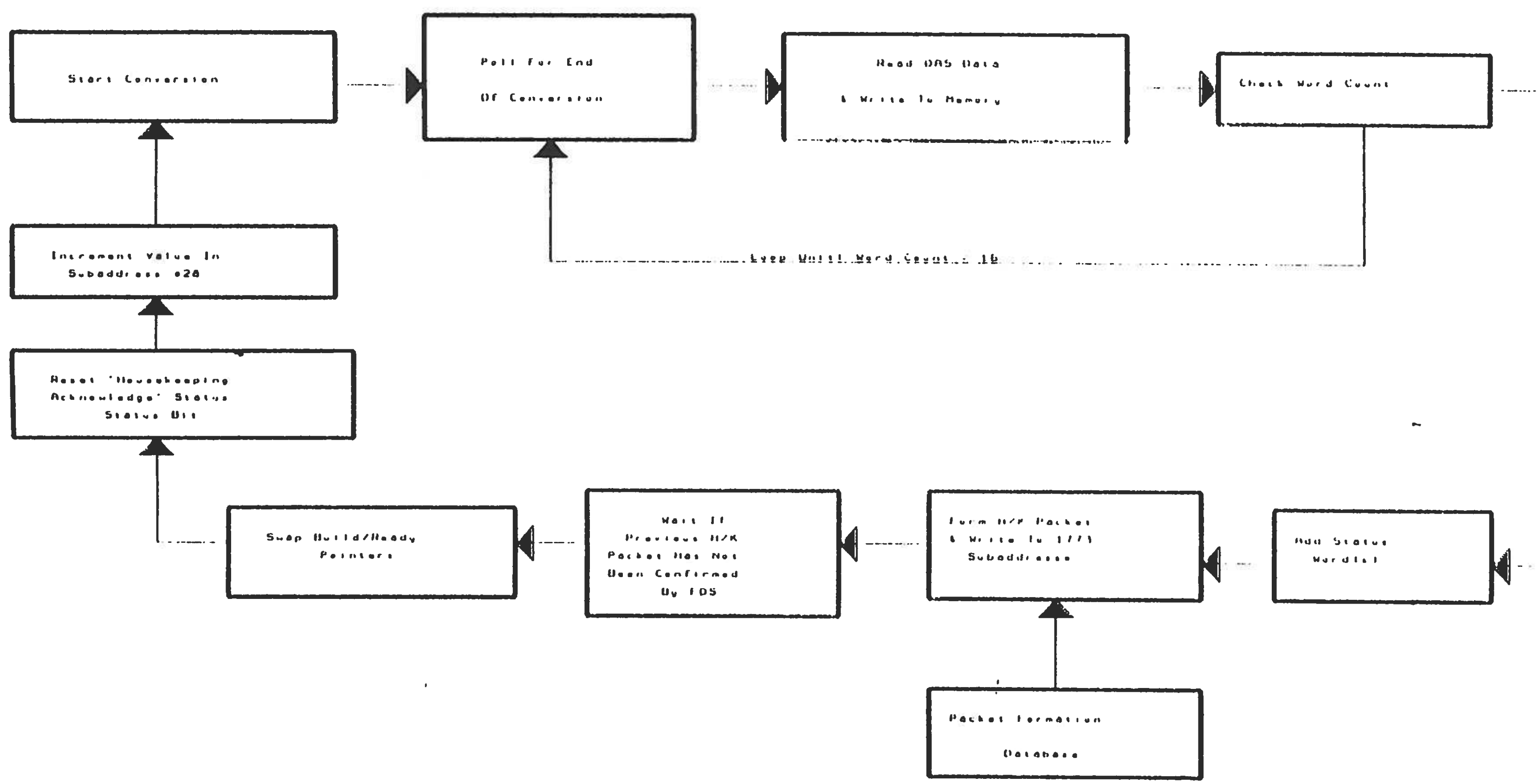

Figure 8-5 Housekeeping Packet Formation

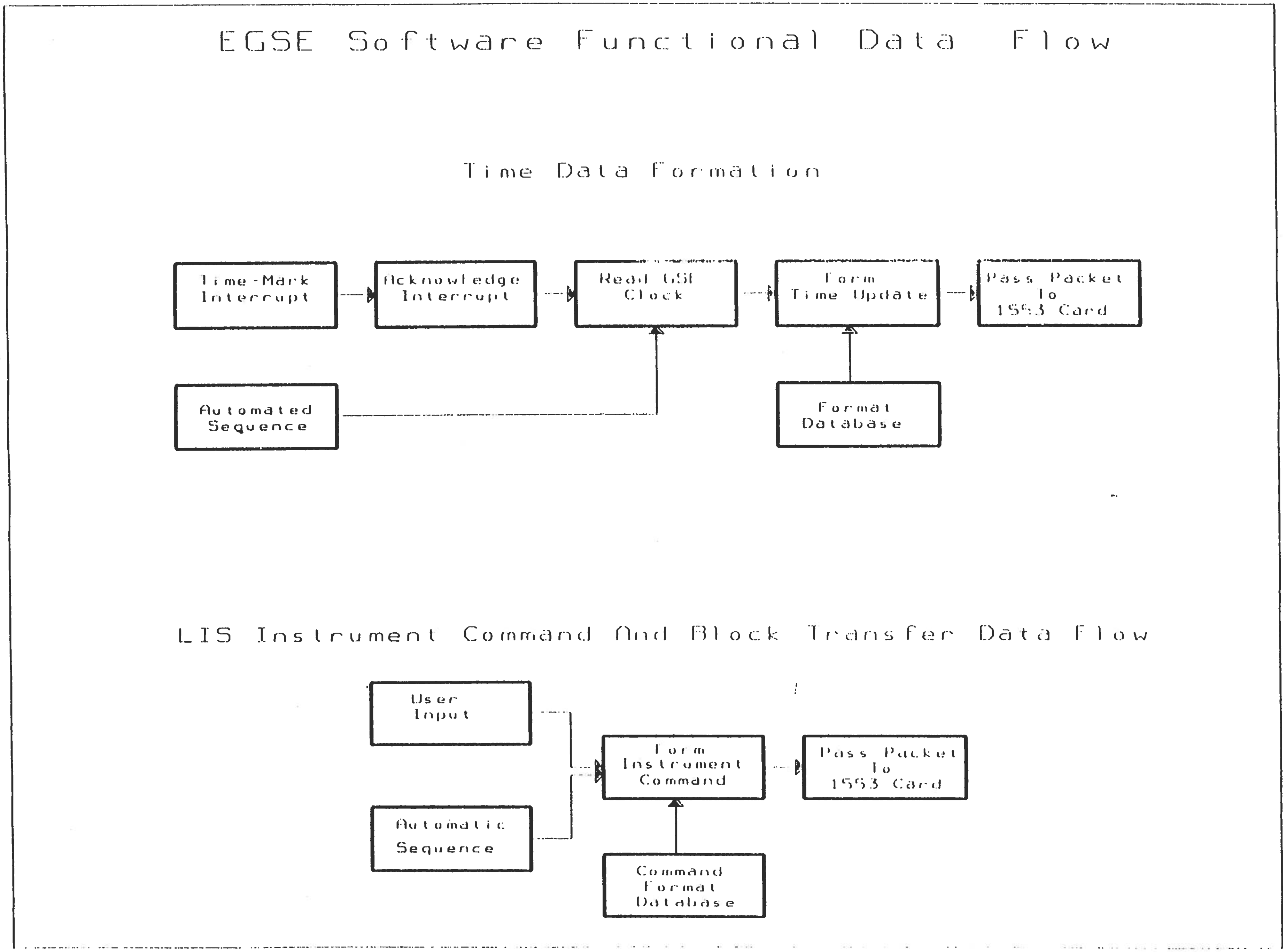

Figure 8-6 Time Data Formation

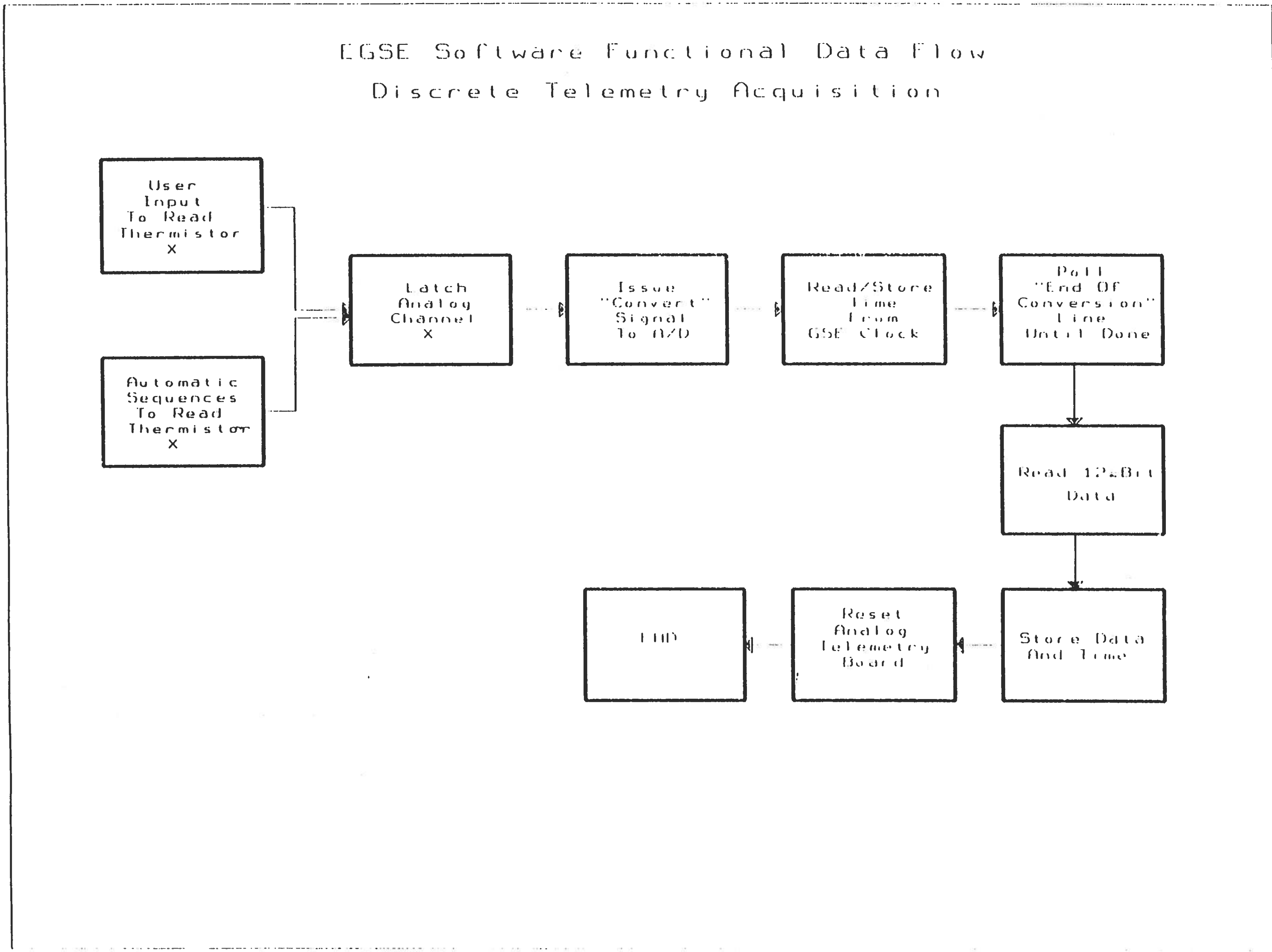

Figure 8-7 Discrete Telemetry Acquisition

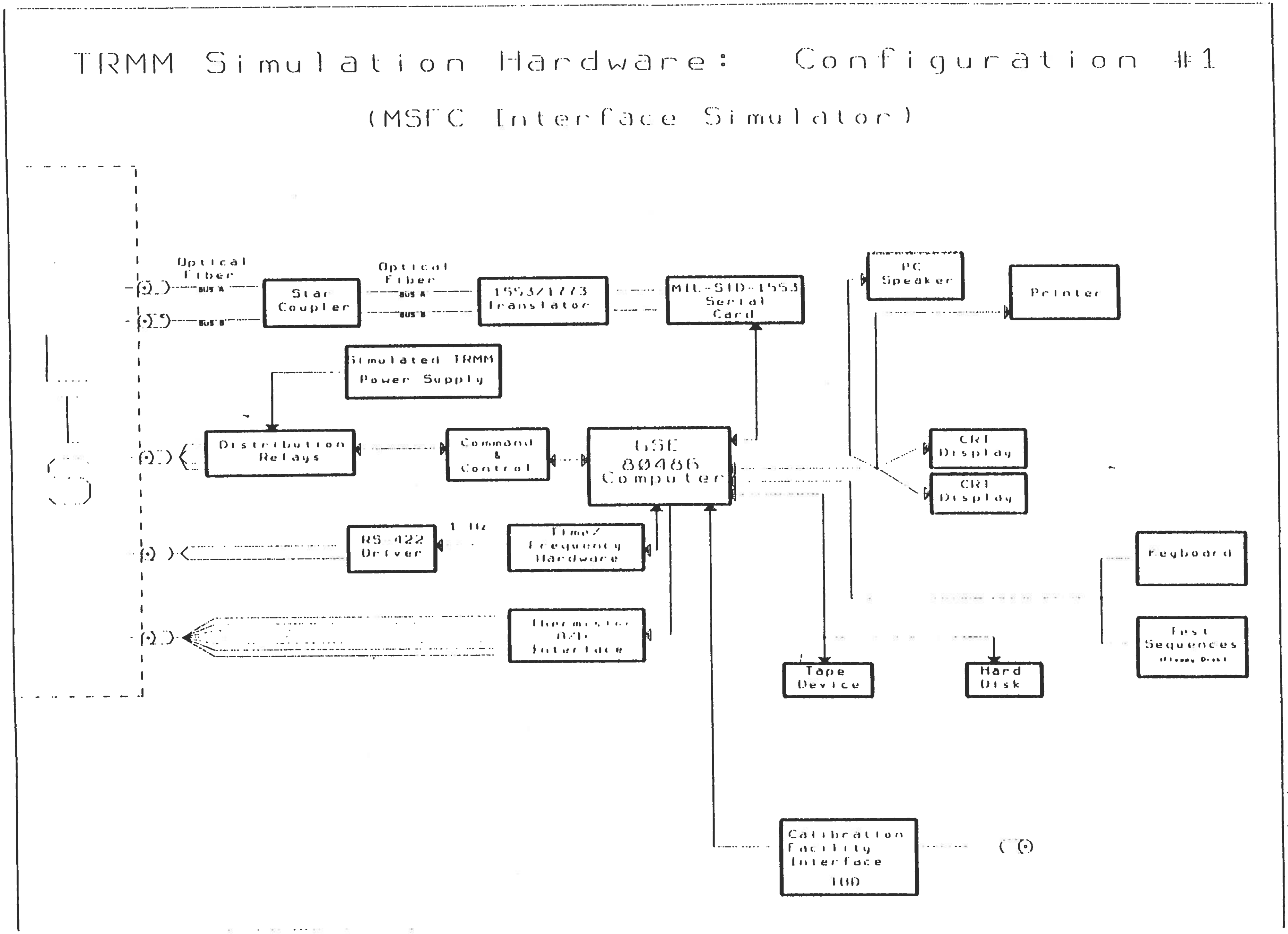

Figure 8-8 MSFC Interface Simulator

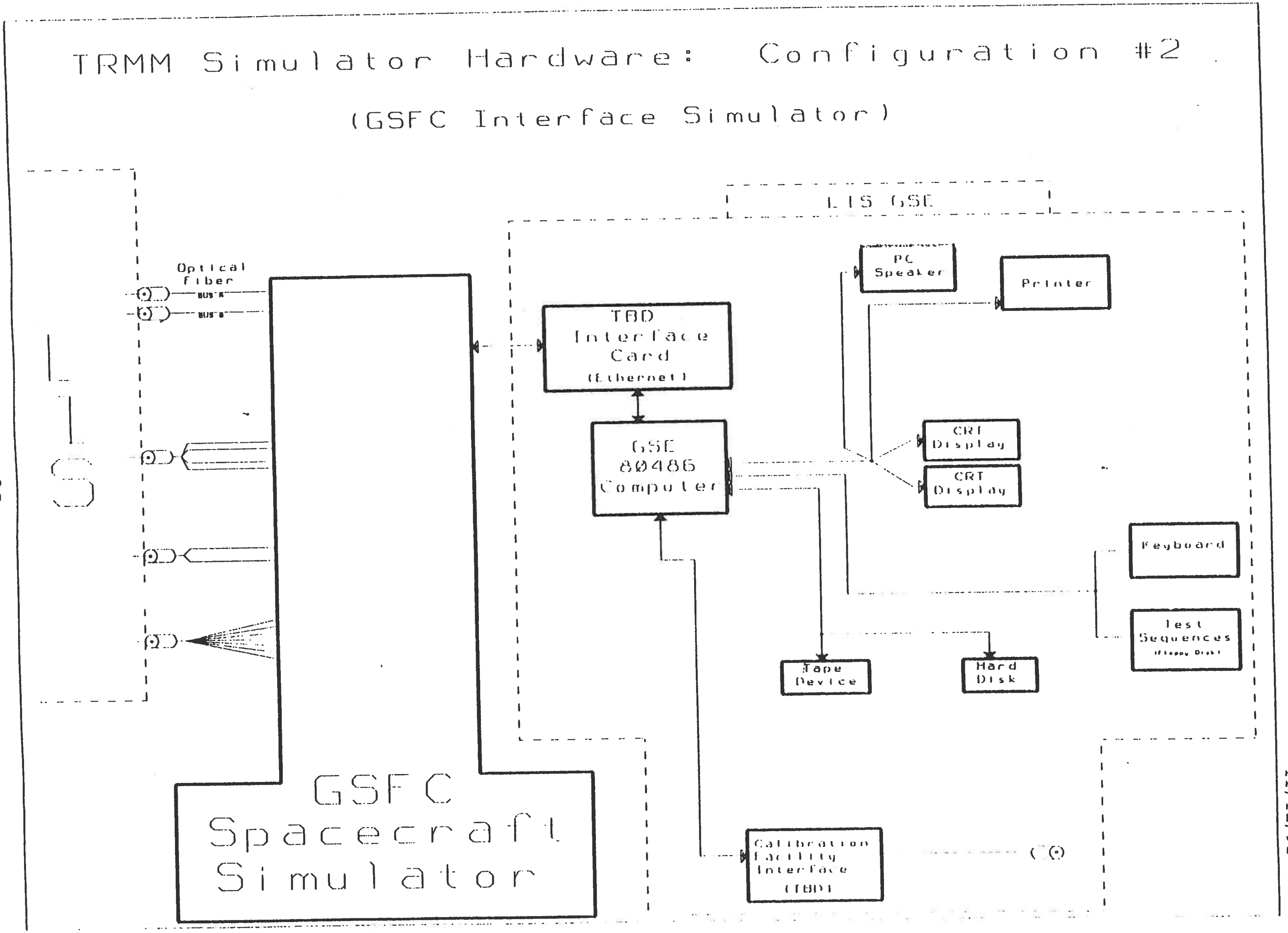

Figure 8-9 GSFC Interface Simulator

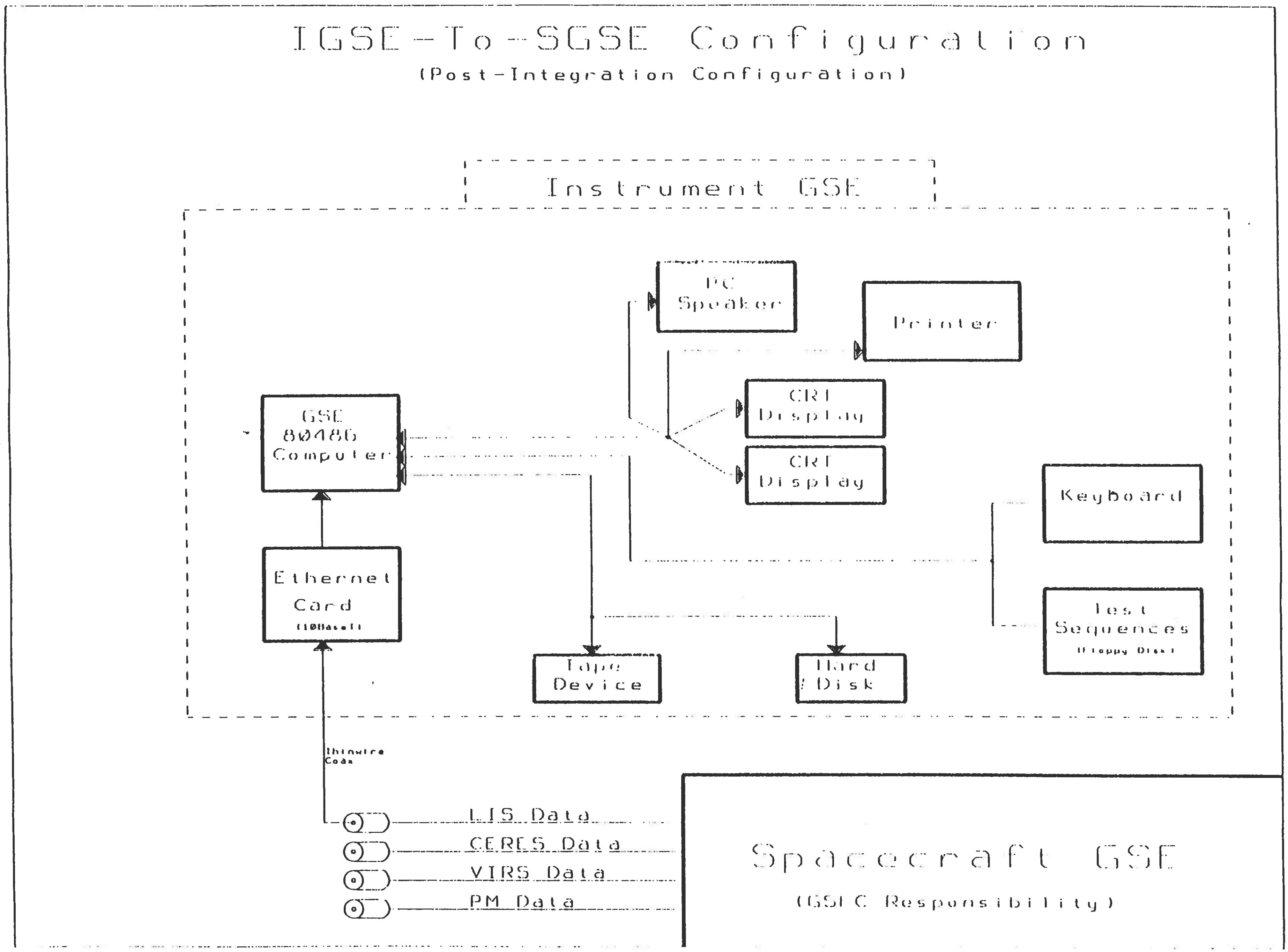

Figure 8-10 Post Integration Configuration

Appendix A

LIS Instrument Commands

1. Background Send ON

This command will cause the flight software to enter the Background Send On Mode (section 3.4.2.1).

2. Background Send OFF

This command will cause the flight software to enter the Background Send Off Mode (section 3.4.2.2).

3. Threshold Adjust

This command will include new threshold values for the RTEP. Flight software will place the new values in the RTEP threshold memory.

4. Filter Temperature Set Point

This command will include a value representing a set point for the filter temperature controller hardware. Flight software will write this value to the temperature controller board.

5. Self Test

This command will cause the flight software to perform an instrument level self-test. Software will execute the following instructions:

TBD

6. Aperture Door OPEN

This command will cause the flight software to open the LIS aperture door and also check the aperture door status.

7. Watchdog Timer Enable

This command will cause the flight software to enable the watchdog timer.

8. Watchdog Timer Disable

This command will cause the flight software to disable the watchdog timer.

9. Heater A ON

This command will cause the flight software to reset both filter heaters and then enable heater A.

10. Heater B ON

This command will cause the flight software to reset both filter heaters and then enable heater B.

11. Enable Filter Temperature Exception Monitoring

This command will enable software exception monitoring of the filter temperature and automatic switching between the A and B heaters (section 3.1.2).

12. Disable Filter Temperature Exception Monitoring

This command disables the automatic switching fuction enabled by the Enable Filter Temperature Exception Monitoring command.

Appendix B

Simulated FDS TRMM Interface Commands

1. Read Thermistor #N

This command will cause the EGSE software to read the temperature of LIS thermistor #N, where N = 1 - 8.

2. Enable Primary Time-Mark

This command will cause the EGSE software to enable the primary timemark.

3. Disable Primary Time-Mark

This command will cause the EGSE software to disable the primary time-mark.

3. Enable Redundant Time-Mark

This command will cause the EGSE software to enable the redundant time-mark.

4. Disable Redundant Time-Mark

This command will cause the EGSE software to disable the redundant time-mark.

5. Assert Relay Control Line #N

This command will cause the EGSE software to assert the relay control line, energizing the associated coil of the magnetically latching relays distributing power to the LIS instrument. This command will be labeled as the following titles:

- Primary Essential Bus ON
- Primary Essential Bus OFF
- Primary Non-Essential Bus ON
- Primary Non-Essential Bus OFF
- Redundant Essential Bus ON
- Redundant Essential Bus OFF
- Redundant Non-Essential Bus ON
- Redundant Non-Essential Bus OFF

Appendix C

EGSE Commands

TBD

Appendix D

Calibration Facility/EGSE Data Exchange Formats

The EGSE software will remove all CCSDS overhead and protocol from LIS science data. The EGSE software will also provide the calibration facility with the compressd LIS science data packet. No header, parity, or other overhead will be applied to the LIS science data by the EGSE.

The EGSE will provide to the calibration facility each LIS packet of science data received. The data will be provided within the timing constraints of the EGSE. Should multiple LIS packets be available, the latter packets will be appended to the previous.

LIS background data that has been accumulated can be sent upon command to the calibration facility as a full 128x128 frame of data. The format of this data will be as follows:

```
<time stamp>
<row1, pixel1 value>
<row1, pixel2 value>
     .
     .
     .
<row1, pixel128 value>
<row2, pixel1 value>
<row2, pixel2 value>
     .
     .
     .
<row2, pixel128 value>
```

No packet headers or flag will be applied. Hence, the calibration facility computer must be in the proper mode to receive this data prior to the EGSE command.

Appendix E

LIS Instrument Developmental Test Routines

1. Send 1773 command word to LIS, subaddress N, requesting the transmission of 32 data words. N = (1,31). Verify proper status word received from LIS.

2. Send 1773 command word to LIS, subaddress N, requesting the transmission of X data words. N = (1,31); X = (1,32). Verify proper status word received from LIS.

3. Send 1773 command word to LIS, subaddress N, indicating the transmission of 32 data words. Send LIS 32 data words. N = (1,31). Verify proper status word received from LIS.

4. Send 1773 command word to LIS, subaddress N, indicating the transmission of 32 data words. Send LIS X data words. N = (1,31); X = (1,32). Verify proper status word received from LIS.

5. Send LIS instrument comands (Appendix A) and verify proper status word received from LIS.

6. Send valid commands to non-LIS RT addresses. Verify LIS does not respond.

7. Send invalid commands to LIS and non-LIS RT addresses. Verify LIS does not respond.

8. Send mode commands (Appendix F) to LIS and/or as broadcast.

9. Broadcast time commands to LIS.

Appendix F

1773 Mode Control Commands

The following 1773 mode codes, as required by MIL-STD-1553B, Notice 2, shall be implemented by EGSE software:

Function	Mode Code	Transmit/Receive Bit
Transmit Status Word	00010	1
Transmitter Shutdown	00100	1
Override Transmitter Shutdown	00101	1
Reset Remote Terminal	01000	1

These commands shall be formed in compliance with Reference 3.